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Climate Action and Low-Carbon Economy

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Definitions

Climate change is "any change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (UNFCCC 1992). The Intergovernmental Panel on Climate Change has described climate change as "any change in climate over time, whether due to natural

W. Leal Filho et al. (eds.), *Climate Action*, Encyclopedia of the UN Sustainable Development Goals,
https://doi.org/10.1007/978-3-319-95885-9

variability or as a result of human activity" (IPCC 2014). The UNFCCC definition focuses on human-induced climate change, while the IPCC adopts a broader definition that includes both natural and human-induced climate change.

Climate change impacts are "the effects of climate change on human and natural systems" (IPCC 2018). These effects have detrimental consequences on the composition, resilience, and productivity of natural and human systems (UNFCCC 1992).

Climate action includes responses by institutions, communities, or societies to respond to climate change (IPCC 2018). The main objective is to minimize GHG emissions that aggravate global warming and address the disruptions caused by climate change impacts (UNFCCC 1992).

Climate change mitigation refers to efforts to prevent or reduce the release of greenhouse gas (GHG) emissions into the atmosphere or to enhance the absorption of GHGs already emitted, thereby reducing the magnitude of future warming. This can be achieved through measures such as deployment of renewable energies and new technologies, enhancing energy efficiency, and improved sustainable agricultural and consumer practices (IPCC 2014; IPCC 2018).

Climate intervention measures include remedial measures such as solar radiation management (SRM) and deployment of carbon dioxide removal (CDR) techniques (Royal Society 2009; IPCC 2018; Royal Society 2018). SRM measures are distinct from mitigation or adaptation as their primary aim is to temporarily reduce or offset warming through deliberate modifications to the Earth's ability to reflect sunlight and radiation (albedo). The net effect of these modifications is to increase the amount of solar radiation reflected from the Earth system therefore reducing the peak temperature from climate change. CDR is focused on reducing the concentrations of carbon dioxide or GHGs already in the atmosphere, as opposed to reducing the amount of carbon dioxide or GHG emissions entering the atmosphere (mitigation).

Means of implementation (MOI) refers to collective actions toward realizing the objectives of the UNFCCC Convention and the Paris Agreement (Paris Agreement Article 14). Means of implementation includes capacity building, finance, and technology development and transfer.

Low-carbon economy refers to the development of an economy based on a low-emission pathway. This implies a low fossil fuel-based or decarbonized economy that has minimal output of GHG emissions (GHGs) particularly carbon dioxide, into the atmosphere (Carrasco 2014). Low-carbon economies possess key elements including low energy consumption, low carbon dioxide emissions, and low levels of pollution (Dou 2015).

Introduction

In September 2015, the United Nations General Assembly adopted a resolution (Res. 70) that set out a global agenda of transforming the world toward sustainable development (UNGA 2015). The resolution set out 17 global Sustainable Development Goals (SDGs) and 169 targets that were to underpin this transformation agenda. Goal number 13 focused on climate change, with the objective to "take urgent action to combat climate change and its impacts". Similarly, the adoption of the Paris Agreement on Climate Change, in December 2015, also marked a major milestone in international efforts to mobilize action toward responding to climate change. There is broad consensus that responding to climate change would require the development of a global economy that is based on a low-emissions pathway. The entry highlights the dynamic and broad variety of climate action across diverse regions, actors, institutions, and levels of governance and the linkages to the development of low-carbon economies.

Climate action has evolved both in definition and scope over the years. Initial focus was on reducing and stabilizing human-induced GHG emissions in the atmosphere (UNFCCC 1992). It has been broadened to include other elements under the UNFCCC, such as adaptation to climate change, loss and damage, and support for means of implementation (MOI), through capacity building, climate finance, and technology development and transfer (UNFCCC 1992). Additionally, the scope of climate actors has also expanded over time from a primary focus on states and other parties to the UNFCCC and related agreements to non-state actors such as cities, private sector, civil society, and multilateral development institutions, among others (UNFCCC 2018).

While the discussion on implementing and scaling up climate action continues through various forums and at multiple scales of governance, it is becoming increasingly clear that considering scientific evidence, there is an urgent need to scale responses to climate change. This is especially considering increased intensity and frequency of adverse climate change impacts (IPCC 2018). It is also clear that ratcheting up of these responses will have to address diverse needs and circumstances of communities, countries, and regions. Adoption of the SDGs and entry into force of Paris Agreement reaffirmed countries' commitment to climate action (UNFCCC 2016; Falkner 2016; Makomere and Mbeva 2018; Pauw et al. 2018).

General discussions on low-carbon economy have focused on the broader concept of the green economy, broadly defined as "an economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP 2011, p. 1). Green economy tries to capture the broader efforts toward sustainability, with its three key components being the economy, environment, and society.

A more recent term, the blue economy, draws attention to oceans and other water resources; hence, it has a narrower focus. There are several definitions for blue economy. The most prominent is that advanced by the World Bank, whereby a blue economy "is understood here as comprising the range of economic sectors and related policies that together determine whether the use of oceanic resources is sustainable" (World Bank 2017, p. vi). Transition to a low-carbon blue economy primarily involves reducing emissions from activities involving the use of ocean resources including the maritime industry. This entry incorporates both concepts in its reference to low-carbon economy.

The rest of the entry is arranged as follows. First, it sets the context by presenting the nexus between climate action and low-carbon economy. Next, it discusses the governance arrangements, categories of climate action, and the types of climate actors. Finally, it identifies the key issues emerging from this transition and concludes by identifying future research and policy directions.

Climate Action and Low-Carbon Economy Nexus

The link between climate action and low-carbon economy involves several key elements. These include governance and economic implications of climate action on the global economy. Governance arrangements facilitate and regulate both climate action at all levels and the development of economies based on low-emission pathways. The economic implications of climate action not only drive decisions on the transition to low-carbon economies but also influence the rate of this transition at the international, national, and local level.

Governance

There are several governance arrangements linking climate action to low-carbon development at multilateral, transnational, and sub-national levels. These range from multilateral agreements such as the UNFCCC and the Paris Agreement to national climate action plans and Nationally Determined Contributions (NDCs) of various countries. These governance arrangements have been important in elaborating on the linkages between climate action and the transition to a low-carbon economy. They have also played a critical role in galvanizing actors, actions, and resources toward climate compatible development, a key component of a carbon economy.

The Agreement also opened the door for countries to identify and include other stakeholders in the implementation of their NDCs (Hale 2016).

All the NDCs had a mitigation target chosen by the parties submitting them. An analysis of the aggregate impact of the NDCs, conducted by the UNFCCC, indicated that they would lead to a 3-degree temperature increase, much higher than the 2-degree target, and 1.5-degree aspirational target, of the Paris Agreement (UNFCCC 2016).

The Paris Agreement is however designed to foster stronger action over time, using a "catalytic" approach of pledge-review-ratchet (Hale 2016). Parties are therefore expected to communicate their updated NDCs after every 5 years, with a view to strengthening them with each update. Following this logic, the aggregate impact of NDCs on mitigation should increase over time and get closer to the Paris Agreement's temperature targets.

SDGs also embrace a "catalytic" approach, by adopting specific targets and establishing a high-level forum for review of progress on implementation. Specifically, SDG 13 (climate action) has targets on adaptation and resilience to disasters: integrating climate change measures into national policies, strategies, and planning; improving education and awareness on climate change; and mobilizing resources and enhancing capacity to respond to climate change.

Twelve indicators were then developed to track progress in implementation of the targets by 2030. Taken together, the Paris Agreement on Climate Change and SDG 13 not only form the backbone of the multilateral response to climate change but also underpin actions toward the development of low-carbon economies at international, national, and even local level.

Transnational climate governance has also emerged as an important way of strengthening climate action toward a low-carbon transition (Bulkeley et al. 2014; Andonova et al. 2017). While previous efforts to address climate change at the international level have focused on states, the rise of non-state actors has transformed the climate governance landscape. Increasingly, such actors work with each other, and with states, across borders to address climate change. The Non-State Actor Zone for Climate Change (NAZCA) platform, for instance, lists numerous transnational initiatives on climate change, most of them focusing on mitigation (Chan et al. 2018, p. 139). This "regime complex for climate change" underscores the transformation from state-led to multi-actor and multilevel climate governance (Eckersley 2012; Jordan et al. 2018). Overall, the various climate governance approaches seek to broaden, catalyze, and strengthen climate action toward a low-carbon economy.

Economic Implications

The transition to a low-carbon economy, through climate action, will have significant economic impacts. These impacts include demand side, supply side, value chains, and opportunity costs. On the demand side, climate action will have an effect on global consumption patterns. This will require a shift from carbon-intensive to low-carbon consumption, such as energy-efficient technologies (Mercure et al. 2018). On the supply side, extraction of fossil fuels will have to be limited or even ultimately stopped, as the next big step in climate policy (Erickson et al. 2018; McGlade and Ekins 2015). Similarly, financial investments will have to shift from the fossil fuel sector to the support, development, and uptake of low-carbon energy (Ansar et al. 2013; Hunt and Weber 2018).

Transition to a low-carbon economy will require a reduction in the carbon intensity of global value chains. For example, transportation of goods will need to be more energy efficient, and those goods will need to have lower levels of embedded carbon (Mercure et al. 2018). Finally, a just transition to a low-carbon economy will have to take into account the related opportunity costs. The question of who will have to forego exploitation of their fossil fuel resources, to keep within the carbon budget, will have to be resolved (McGlade and Ekins 2015; Newell and Mulvaney 2013). Furthermore, there will be need to enhance access to low-carbon technologies, especially by developing countries (Ockwell and Byrne 2016).

Implementation of Climate Action and the Transition to Low-Carbon Economies

Categories of Climate Action

In the pursuit of the objectives of the Convention and the Paris Agreement, there are several categories for climate action under the UNFCCC. These include climate change mitigation, climate change adaptation and climate resilience, loss and damage, and means of implementation.

Mitigation

There is a direct link between the increase in global average temperatures and the concentration of GHG in the atmosphere. A key component of the responses to global warming therefore is to decrease the amount of GHG emissions released into the atmosphere and reduce current concentrations of carbon dioxide by enhancing sinks (e.g., increasing the land cover of forests). There are several guiding provisions in the Convention and Paris Agreement that govern global efforts toward mitigation. State and non-state actors have a role to play in global efforts toward mitigation. The Convention, for instance, requires all parties to develop and implement programs aimed at mitigating climate change.

Mitigation actions could include policies, incentivizing programs for clean activities across all sectors and involving all types of actors, initiatives, and investment programs covering all sectors. Mitigation actions could also be translated into measures such as increased use of renewable energy, application of new technologies in areas like lighting and transportation, and behavioral adjustments like lifestyle change. Mitigation actions also include the conservation of natural sinks through expanding forests, and protecting oceans, so that they remove more carbon dioxide from the atmosphere (UNFCCC).

Climate Intervention Measures

Warnings from the UNFCCC and the IPCC that current mitigation efforts fall short of the Paris Agreement's temperature targets (UNFCCC 2016; IPCC 2018) have opened and catalyzed debate on removing GHG emissions from the atmosphere through climate intervention technologies. Climate intervention, sometimes referred to geoengineering in some literature, broadly involves "...deliberate large-scale intervention in the Earth's climate system, in order to moderate global warming" (Royal Society 2009; IPCC 2018). There are two main overarching categories of climate intervention actions: GHG removal, which involves the removal of GHG from the atmosphere, and solar radiation management (SRM), which aims to reflect some of the sun's heat away from the Earth (Royal Society 2009). Carbon dioxide removal (CDR) is currently the most developed form of GHG removal. It is focused on the reduction of atmospheric carbon dioxide concentrations. Examples of CDR include ocean fertilization, ocean liming, and carbon capture and storage (Royal Society 2009; Lenton 2014; Talberg et al. 2018). SRM techniques on the other hand are focused on reducing warming through intercepting solar radiation before it reaches Earth's surface. Some of the proposed methods include injecting particles into the stratosphere to deflect sunlight or spraying aerosols into low-lying marine clouds to make them more reflective (Royal Society 2009; Vaughan and Lenton 2011; Talberg et al. 2018).

Climate intervention measures however are complex, and the science of many climate intervention methods remains uncertain. It is broadly appreciated that deployment of these methods at a scale required to have the desired impact could have negative ecological and socioeconomic effects (Talberg et al. 2018). There are several governance concerns raised by climate intervention proposals. Some of these issues are common to other transboundary environmental issues, while others are distinct to the proposed interventions. The concerns include competing political institutions, perspectives, approaches, and values in governance of common natural resources. Some of the specific concerns with these proposals include the risk of moral hazard where they may potentially undermine global efforts for mitigation and adaptation (Reynolds 2015). Consequently, discussions on climate intervention require careful consideration at all levels of governance.

Several international environmental agreements are relevant to the governance of climate intervention measures. Climate intervention measures are loosely governed by agreements that were designed for other purposes, since there is no international agreement that primarily governs climate intervention measures (Talberg et al. 2018; Brent et al. 2018). These include the United Nations Convention on Biological Diversity (CBD), the United Nations Law of Sea Convention (LOSC), the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972 London Convention), and the Protocol to the

Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter (1996 London Protocol). International customary norms that deal with risk management, such as the no harm rule, due diligence, and the precautionary principle, are also relevant to the governance of climate interventions. However, climate intervention measures remain underdeveloped and pose risks to natural and human systems. Countries have therefore taken a cautious approach to adoption of these measures, for example, through forums such as the CBD and the London Protocol (for instance, Decision X/33 of the CBD, Article 6 bis London Protocol).

Means of Implementation

Support for means of implementation has always been a critical feature of international negotiations on global responses to climate change. Means of implementation consists of several elements, including climate finance, capacity building, and technology development. Developing and least developed countries require support to realize their climate action goals due to lack of capacity and resources. Support for means of implementation is based on the notion of the Common but Differentiated Responsibilities and Respective Capabilities (CBDR&RC) (UNFCCC 1992). CBDR&RC underpins calls for particularly developed countries to support countries that have contributed the least to climate change, are most vulnerable to the impacts, and have low adaptive capacity (Rajamani 2006).

Climate finance involves local, national, or transnational financing. It takes various forms, including grants, concessional loans, and commercial loans. It can also come from various sources including public, private and alternative sources such as multilateral development banks (MDBs). Large-scale investments are required to not only significantly reduce emissions but also enhance adaptation and climate change resilience. To facilitate the flow of climate finance to developing countries, financial mechanisms exist under the UNFCCC regime. There are several funds that have been set up to facilitate climate finance. These include the Green Climate Fund (GCF), the Special Climate Change Fund (SCCF), the Least Developed Countries Fund (LDCF), and the Adaptation Fund (AF).

Technology transfer from developed to developing countries, on the other hand, focuses on fostering access to technologies that would help respond to climate change by developing countries. These include renewable energy technologies, adaptation technologies such as drought resistance crops, and early warning systems. Practices that also advance climate action such as training on the use of climate technologies could also be included within the scope of climate technology transfer. There are several key institutions and mechanisms that support technology development and transfer. These include the Technology Mechanism, Technology Executive Committee, Climate Technology Centre and Network, Technology Framework under the Paris Agreement, and the Technology Needs Assessment Mechanism.

There is significant variation in the capacities of countries to effectively deal with climate change challenges and implement climate action (Weikmans and Roberts 2017). This makes it important to focus on building the capacity of these countries to effectively respond to climate change. Capacity building can take various forms, including creating awareness, improving technical capacity to monitor GHG emissions, and developing the adaptive capacity of developing countries and vulnerable communities, among others. Capacity building occurs at three main levels: individual, institutional, and systemic level under the UNFCCC.

The UNFCCC regime contains several provisions that guide and govern capacity building actions. There are two main frameworks under the regime that underpin efforts to enhance capacity building especially in developing countries. One is primarily focused on developing countries, and the other is focused on economies in transition. The two frameworks were developed through a decision of parties to the Convention in 2001(Decisions 2/CP.7 and 3/CP.7). This support can take the form of either financial or technical assistance. Developing countries and economies in transition are required to assess and identify their capacity needs to implement the Convention and Agreement.

There are several provisions and decisions under the Convention and the Paris Agreement that guide and govern support for means of implementation (UNFCCC Article 4, Paris Agreement Articles 9, 10, 11). These provisions call for support for finance, technology transfer, and capacity building to particular countries that are less endowed and more vulnerable. Evaluating progress in provision and mobilization of support for implementation is also part of the global stock taken under the Agreement. Crucially, the Agreement also emphasizes the central role of transparency and enhanced predictability in support for implementation. Support for means of implementation has however been a contentious issue, since critics argue that its scale has not been commensurate to the climate challenge (Weikmans and Roberts 2017). Challenges such as transparency in accounting for climate finance (Weikmans and Roberts 2017), and intellectual property rights on climate technologies (Juma 2003), have further compounded this intervention (Ockwell and Byrne 2016).

Types of Climate Actors

Climate action can also be categorized by actors involved. These include states, non-state, and transnational actors. States have been at the forefront in designing multilateral efforts to address climate change. The UNFCCC has served as the key institution where states have designed norms, rules, agreements, and work programs for responding to climate change at the international level. The Kyoto Protocol, adopted in 1997 under the UNFCCC, sought to commit the highest GHG emitters to reduce their emissions and support developing and least developed countries to undertake climate action. The Kyoto Protocol proved contentious and ineffective in part due to being too rigid and imposing targets on select parties to the agreement (Prins and Rayner 2007; Prins and Rayner 2007).

The Paris Agreement of 2015, on the other hand, adopted a different, universal approach to climate obligations by welcoming all countries to submit their national contributions (NDCs) and ratcheting up their contributions over time. In other words, the Paris Agreement adopted a universal, catalytic approach (Hale 2016; Falkner 2016). This allowed countries to set their own targets and plans of action according to their priorities, national circumstances, and capacities. Parties, including regional entities such as the European Union (EU), have developed national and regional laws, policies, and programs of action that guide climate action in their respective contexts.

Non-state actors, such as sub-national governments and authorities, private sector, and civil society, among others, are also active in climate action (Hsu et al. 2015). Non-state actor-driven climate action is taking place in both developed and developing country contexts. California in the United States, for instance, has been actively involved in leading efforts to address climate change in the United States for a long time. Measures have included spearheading renewable energy initiatives at the state level and investing in clean technologies. Other sub-national governments in developing countries have also played an active role in climate action. In Kenya, for instance, Makueni County, a sub-national government, has been involved in developing climate change policies and programs of action. These include engaging farmers in climate adaptation programs, mobilizing resources to support climate action through a County Climate Fund, and promoting sustainable drought-resistant agriculture.

Cities have also emerged as crucial actors in addressing climate change, especially given the rapid global rate of urbanization (Romero-Lankao et al. 2018). Private entities such as multinational corporations have also been active in climate action. This has been mainly through voluntary schemes such as forest certification (van der Ven and Cashore 2018). Multinational Development Banks (MDBs) such as the World Bank, regional development banks, and UN agencies have also emerged as key actors, especially in financing climate action and offering technical and capacity building expertise. Overall, non-state climate actors can significantly contribute to closing the gap between countries' NDC pledges and the action required to meet the Paris Agreement's temperature targets (Chan et al. 2018).

Actors engaged in climate action do not always work in isolation, neither are they restricted within certain jurisdictions. Partnerships among and across various actors have become increasingly common. For instance, MDBs such as the World Bank often fund climate change initiatives in various countries; cities on the other hand collaborate through partnerships such as the Covenant of Mayors; and private companies coordinate their climate actions through the UN Global Compact. The significance of such initiatives was underscored in the lead up to the Paris Agreement on Climate Change, when the Lima Call for Climate Action identified them as a crucial element of addressing climate change. Recent efforts to map such initiatives have led to development of online databases and portals such as the Non-State Zone for Climate Action (NAZCA). This complex landscape of a wide variety of actors and institutions has led to what is often referred to as the "regime complex for climate change" (Keohane and Victor 2011).

Key Issues on the Transition to Low-Carbon Economy

Debates on how to transition to a low-carbon economy have centered on certain old and current key contentious issues. Some of the issues include support for means of implementation, balance between climate action and economic development, removing government support for fossil fuels, and how to manage the negative impacts of the transition. At the heart of the controversy is the nature and adequacy of the support, transparency, and accountability. While previous international negotiations focused on grant-based sources of climate finance, recent scholarship indicates that loans are dominant (Weikmans and Roberts 2017). That is, what counts as climate finance is highly contested. Transfer of climate-related technologies has also been controversial, focusing on the balance between respecting intellectual property rights (IPR) (Juma 2003) and obligations for support under CBDR&RC in the various international agreements on climate change (Ockwell and Byrne 2016).

Striking a balance between economic development and climate action has been a hotly debated issue (Najam 2005). Developing and emerging economies have often argued that since they have historically contributed less to GHG emissions, hence climate change, they should undertake less action than developed countries. When they have committed to climate action, they have done so conditional on support for means of implementation by industrialized countries. Limited agency of some of the countries in mitigation schemes has also been contentious (e.g., Atela et al. 2017). Developing countries have therefore placed climate action within the broader context of sustainable development (Najam 2005; Makomere and Mbeva 2018). Equitable Access to Sustainable Development (EASD) thus emerged as the preferred concept for these contesting countries (Winkler and Dubash 2016). This debate has been long-standing and is manifest in the Paris Agreement.

While conventional approaches to mitigation have focused on the consumer/demand side, attention has recently turned to "supply-side" efforts. Governments often provide subsidies to fossil fuel companies in the form of tax breaks and other fiscal instruments. Some estimates indicate that the value of annual fossil fuel subsidies is between US$ 600 billion and US$ 1 trillion (Coady et al. 2015; OECD 2015). Phasing out fossil fuel subsidies therefore presents a potent climate mitigation policy because it focuses on the production of fossil fuels (van Asselt 2018; Erickson et al. 2018). Some governments, especially high-income countries, have begun addressing the issue. The G20, for instance, pledged to phase out inefficient fossil fuel subsidies in 2020 and conduct peer review of each other's progress (G20 2016, p. 6).

Management of the negative effects of the transition to a low-carbon economy has led to a normative debate on how to realize a just transition (Klinsky et al. 2017). That is, how would a just transition to a low-carbon economy look like? The most significant issue at the global level is the allocation of the remaining carbon budget. Since there is more carbon in fossil fuel reserves than can be burned in keeping within global temperature rise limits, a significant amount will have to remain in the ground (McGlade and Ekins 2015).

Scholars have come up with several suggestions on how to allocate the scarce carbon budget (Pont et al. 2017; Kartha et al. 2018). These debates revolve around the notion of equity, which tries to adjudicate between historical responsibility, vulnerability, and capability. Related discussions have also explored, for instance, how coal mine workers in the fossil fuel industry can be retrained after closure of the mines (Newell and Mulvaney 2013; Mayer 2018).

Divestment from fossil fuel assets has emerged as an important climate policy to spur the transformation toward low-carbon economies (Ayling and Gunningham 2017). The goal of divestment is to shift financial investments from fossil fuel assets toward supporting transition to an economy based on low emissions. Efforts by investors to divest from fossil fuels have led to concerns over stranded assets, since some of those fossil fuel assets will lose their value (to the tune of US$ 4 trillion) (Ansar et al. 2013; Mercure et al. 2018). Stranded assets due to climate action are therefore becoming a major component of financial risk assessment. Shareholder activism based on ethical concerns for investing in fossil fuels has become a significant factor influencing major investment decisions (Reid and Toffel 2009; Hunt and Weber 2018).

Future Directions

There is broad consensus on the need to strengthen climate action toward a low-carbon economy. Several themes, challenges, and opportunities are emerging in efforts to enhance climate action and the transition to a low-carbon economy. Some of these are discussed below.

While multilateral climate governance has been widely studied, some national, regional transnational climate governance and other non-state-led climate action remain less studied. Recent scholarship has begun addressing this gap, but it has mostly focused on the Global North. Transnational and non-state climate action and governance in the Global South however are still underexplored (Hale 2016, p. 20). Addressing this crucial gap will contribute to greater understanding of how such actions and governance arrangements can enhance the transition toward low-carbon development.

Understanding how states and their constituents particularly in less developed and emerging countries are striking a balance between economic development and climate action will also be critical. These countries will be the biggest future source of GHG emissions; hence it is important to understand their climate policy implementation. Issues of equity and fairness are becoming more acute. Examining the global transition to a low-carbon economy from this perspective could require a constant evaluation of the implementation of principles underpinning climate action such as Common but Differentiated Responsibilities and Respective Capabilities (CBDR&RC), in light of the global stock take on responses to the impacts of climate change (Rajamani 2006).

C

Cross-References

▶ Climate Change Adaptation (CCA)
▶ Financial Market Services: Finance Flows for Climate Change Adaptation

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Climate Change

► Climate-Resilient Cities in Latin America

Climate Change Adaptation (CCA)

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Definition

The concept of adaptation originated from evolutionary biology in the 1970s and 1980s. It is often categorized as planned or autonomous, reactive, or anticipatory. It also involves process with goals to reduce vulnerability (Naess 2013). Since then it has been widely applied in both social and ecological systems to prepare for disasters and minimize risks. Below are some of the definitions that are widely used by various groups:

The IPCC Third Assessment Report defines adaptation as, "*adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli, and their effects or impacts. This term refers to changes in processes, practices or structures to moderate or offset potential damages or to take advantages of opportunities associated with changes in climate*" (McCarthy et al. 2001).

Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC TAR 2001).

Adaptation solutions take many shapes and forms, depending on the unique context of a community, business, organization, country or region. There is no 'one-size-fits-all-solution'—adaptation can range from building flood defenses, setting up early warning systems for cyclones and *switching to drought-resistant crops, to redesigning communication systems, business operations and government policies... It is a key component of the long-term global response to climate change to protect people, livelihoods and ecosystems* (UNFCCC 2018).

Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects. (Zimmerman and Faris 2011:15)

The UN-Habitat (2011) defines adaptation as initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. On the other hand, the World Bank (2011) defines adaptation as the process of adjustment to actual or expected climate change and its effects in human systems. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate change and its effects.

The 2009 Copenhagen Accord recognized the need to cut global emissions and how it is indispensable to sustainable development. It declared adaptation as a key measure to tackle climate change related impacts (UNFCCC 2010):

> Adaptation to the adverse effects of climate change and the potential impacts of response measures is a challenge faced by all countries. Enhanced action and international cooperation on adaptation is urgently required to ensure the implementation of the Convention by enabling and supporting the implementation of adaptation actions aimed at reducing vulnerability and building resilience in developing countries, especially in those that are particularly vulnerable, especially least developed countries, small island developing States and Africa. We agree that developed countries shall provide adequate, predictable and sustainable financial resources, technology and capacity-building to support the implementation of adaptation action in developing countries. (p.6)

According to the Government of Japan (2010), adaptation measures are developed to achieve the following:

(a) Risk avoidance: As preventive measures against predicted impacts (disaster prevention facilities, and regulation of development in vulnerable areas).
(b) Reduction of negative impacts: It is designed to reduce the damage that may occur, especially in areas like disaster prevent to reduce the damages and assist in recovery.
(c) Risk sharing: These measures avoid the concentration of impacts by spreading their burden across a larger population and over time.
(d) Risk acceptance: It is okay to accept the potential of an event that has low likelihood to occur today by delaying the implementation of measures while monitoring the situation.

Introduction

Climate change is the biggest challenge facing humanity today. It will affect the biophysical systems, human health, agriculture, and socioeconomic well-being. These impacts are not distributed equally; the poor, primarily, in the developing nations, will be disproportionately affected (Parry et al. 2005). As the temperature rises, sea level rises, ocean acidifies, and the entire environment changes from climate change, adaptation therefore becomes part of planning and development process (O'Brien 2017). Adaptation is the adjustment to actual or expected climate and its effects. Adaptation demands coordinated and complementary responses across all levels – individuals, policy-makers, nongovernmental organizations (NGOs), and the private sector. Adaptation approaches are linked to understand the causes of vulnerability. From the perspective of biophysical drivers of vulnerability, adaptations should be designed to minimize the impacts from climate change. Such adaptation is sectoral that focuses on water, agriculture, energy, health, or buildings. Most of these approaches are technical in nature, which could lead to a piecemeal solution that address only the symptoms without considering the systemic factors of vulnerability (O'Brien 2017). In addition, they could ignore cultural factors such as values, identities, and sense of place. The social approach to adaptation focuses on some of the underlying causes of vulnerability such as poor social services, education, and safety net. From this perspective, adaptation's goal is to change social relations and address historical injustices which might be making poor people vulnerable to climate change. On the other hand, the resilience approach to adaptation looks at the complexity, feedbacks, linkages, flexibility, and adaptive capacity of socio-ecological systems. This approach looks at the incremental and transformative systems of change. One related approach is transformational adaption which goes beyond incremental adjustments or approaches and may include changes in form or structure through novel, large-scale actions (Park et al. 2012). Examples include shifting new types of agriculture or relocation people in response to sea level rise.

Adaptation to impacts of climate change consists of the actions that people take in response to or in anticipation of, anticipated or occurring change in climate, to reduce adverse impacts of climate change (Parry et al. 2005). Importantly, adaptation is not a "science" with a narrow view as a finite and technical-rational process with a beginning and a clearly identified milestones and endpoints. It is more interdisciplinary with multiple ongoing processes across time and scale (Palutikof et al. 2015). No adaptation is not an option anymore. Rather adaptation is essentially a pragmatic response to a perceived present or future imbalance between climate and the societies and environments that it affects.

> Adaptation needs vary across geographical scales (local, national, regional global), temporal scales (coping with current impacts versus preparing for long-term change) and must be addressed in complex and uncertain circumstances. Responding to this process requires interdisciplinary and multiple expertise at the local and international level. Researchers and practitioners in climatology, ecology, economics, and the management of natural resources, including agriculture, forestry, watersheds, and fisheries, will have to join forces with those from public health, engineering, business, disaster risk reduction, community development and social services. (Parry et al. 2005:4)

Adaptation-Related Terms

Adaptation Assessment – *The practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency, and feasibility* (IPCC TAR 2001)

Adaptive Capacity – *The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences* (IPCC TAR 2001)

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Types of Adaptation

Adaptation can be categorized along three dimensions (Bosello et al. 2012):

1. Based on the subject of adaption like who or what adapts
2. From the object of adaptation such as what they adapt to
3. The way in which adaptation takes place such as how they adapt (process)

Most common types of adaptation include anticipatory, autonomous, community-based, ecosystem-based, evolutionary, incremental, mal (adaptive), physiological, planned, private, public, reactive, and transformational (Palutikof et al. 2015).

There are two kinds of adaptation based on who implements it – autonomous or market-driven and planned or policy-driven. Autonomous adaption can be defined as "adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems" and planned adaptation as "adaptation that is the result of a deliberate policy decision based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state" (McCarthy et al. 2001). In addition, adaptation can be differentiated based on the timing of adaptation actions, anticipatory or proactive adaption, and reactive or responsive adaptation.

On the other hand, adaptation can be private or public. The Intergovernmental Panel on Climate Change (IPCC) defines private adaptation as "adaptation that is initiated and implemented by individuals, households or private companies. Private adaptation is usually in the actors' rational self-interest" (IPCC 2001) and public adaptation that is "adaptation that is initiated and implemented by governments at all levels. Public adaptation is usually directed at collective needs" (McCarthy et al. 2001).

Depending on how adaptation programs are implemented, they could be top-down or bottom-up. The top-down adaptation is a scenario-driven approach where policy-makers provide the information about the likelihood of impacts of climate in different region and work to raise awareness across levels. However, they do not share the information with local decision-makers to make localized decisions. On the other hand, the bottom-up or vulnerability-driven approach to adaptation involves assessment of past and current climate vulnerability, existing coping strategies and how to modify them to the changing climate. This approach overcomes uncertainties associated with the top-down approach by increasing the capacity of communities and government to cope and adapt to the local changes. In a real world, both approaches complement each other for the best results (Parry et al. 2005).

Park et al. (2012) identified two types of adaptation based on the end goals.

1. Incremental adaptation – maintaining the essence and integrity of an incumbent system or process at a given scale.
2. Transformational adaptation – a discrete process that fundamentally (but not necessarily irreversibly) results in change in the biophysical, social, or economic components of a system from one form, function, or location (state) to another, thereby enhancing the capacity for desired values to be achieved given perceived or real changes in the present or future environment.

Sometimes adaptation could be specific to a single component or service sector of the society. For example, in many cities in the United States (USA), adaptation initiatives include the following localized actions (Zimmerman and Faris 2011):

1. Infrastructure service adaptations – Protection against sea level rise because of the low elevation, heavy use, and overuse of infrastructure. In New York City (NYC), transit system improvement is of priority to the city.
2. Stormwater management – Since stormwater is related to sea level rise, and/or extreme storms or precipitation, adaptation strategies aim at increasing water storage capacity, promoting drainage, controlling land and soil movement, and building more infrastructure.
3. Urban trees – Cities in the United States have adopted planting trees for many adaptive benefits like absorbing CO2, increasing the absorptive capacity of soil for water and reducing heat through shading.
4. Land use planning and policy – Climate change adaptation is widely included in cities' land use policies. For example, King County aggressively included climate as a fundamental consideration in all land use planning and policy discussions.

Finally, based on the timing of the programs, adaptive responses can be categorized into three types: anticipatory adaptation, reactive adaptation, and adaptation research and development (Bosello et al. 2012).

- Anticipatory adaptation – Here the society builds a stock of defensive capital, which it can use when the damage materializes. The stock depends on economic inertia to invest in defensive program that can protect capital after some years. It is usually undertaken before the damage occurs.
- Reactive adaptation – This includes all actions undertaken in response to climate change damages that were not addressed by anticipatory adaptation.
- Adaptation research and development – It deals with investing in R&D and knowledge to build adaptation system that is effective. It is widely applied in agriculture and health sectors in trying to discover new crops and vaccines to reduce vulnerability to climate change.

Overall, adaptation can be broadly categorized into four types: reaction, planned, public, and private (Table 1).

Climate Change Adaptation (CCA), Table 1 Types of adaptation measures to respond to climate change (IISD 2018)

Type of adaptation	Definition	Examples
Reactive	Actions taken by farmers and communities using existing technology and management options under the current climate	Crop calendar shifts (planting, input schedules, harvesting) Cultivar changes Crop mix changes Wetland migration
Planned (nonreactive)	Actions that require concerted action from local, regional, and/or national policy. It is like establishing an early warning system	Land use incentives Pollution control form inputs Water costing Building codes
Public planned adaptation	Designed and implemented by national and provincial governments	Subsidies/compensation payments Changes in insurance payments Changing standards, such as construction codes, limits per unit of production
Private planned adaptation	These are initiatives undertaken by companies and/or households to respond to climate change impacts	Water metering to support water conservation Implementation of standards Purchasing insurance Small-scale water storage Expanding drainage infrastructure as a major way to accommodate heavy precipitation events

Approaches to Adaptation

Basically, there are two approaches to adaptation: short-term and medium- to long-term adaptation (Gov. of Japan 2010). Governments can use one or both approaches based on their policy goals, resource availability, and in response to the disaster.

1. *Short-term adaptation*: Initiatives that encourage urgent response to prevent or mitigate short-term impacts that are happening or likely to occur from climate change. Examples include:
   (a) Crisis management arrangements and improvements in early warning systems, to deal with sea-level rise and with rising damage in confined areas and from intense rainfall events.
   (b) Installation and augmentation of independent electrical generation equipment for water purification plants to respond to power outages caused by the increase of natural disasters.
   (c) The introduction of heat-resistant crop varieties and promotion of appropriate cultivation methods, to address the declining crop quality and yields.
2. *Medium- and long-term adaptation*: Response measures to enhance adaptive capacity to prevent and mitigate possible impacts, by assessing the risks of impacts that may occur in the medium and long term and by controlling the impacts, reducing vulnerability, and strengthening resilience. Examples include:
   (a) Adaptation measures in individual sectors: These are measures implemented with the intention of adapting to estimated impacts in specific sectors. New construction and functional improvements of embankments to cope with sea level rise and storm surges, "soft" (non-structural) measures such as improvements in tsunami and storm surge hazard maps and strengthening of measures to prevent outbreaks of infectious diseases such as dengue fever).
      (i) Improvements of river and sea embankments, functional improvements of existing facilities, etc. Land use regulations and incentives in affected areas. Construction (nesting) of ecosystem networks. Strengthening of measures to prevent outbreaks of infectious diseases. Development of

global food supply-and-demand systems that consider climate change impacts (30- to 50-year time frame) based on existing projection methods. Systematic water supply development to cope with recent frequent droughts.

(b) Integrated adaptation and basic capacity enhancement: These approaches include integration of measures planned on a sectoral basis to a unified and effective adaptation plan and enhancement of basic capacities of localities and sectors such as technologies and human resources. These should be implemented with a systematic and long-term perspective.
  (i) Acting to clarify issues that require cooperation and cross-sectoral initiatives among multiple departments and sections within an organization, for more efficient implementation of measures. Reviewing the collection and organization of basic data and information relating to impact assessments and adaptation measures, and where found to be inadequate, identifying issues that require priority attention and implementing systematic improvements. Prioritizing climate change adaptation measures within the comprehensive plans of local governments. Establishing organizations that cooperate with local research institutions, non-profit organizations, and various other types of organization.

(c) Awareness raising (improvement of enabling conditions): It is of fundamental importance to raise the awareness and understanding of the people and government agencies responsible for adaptation. It is also important to identify the responsibilities, roles, and collaborations among organizations both at national and local levels. These efforts should be initiated and promoted as quickly as possible.
  (i) Improving and promoting the use of basic information about research data and future projections. Developing and providing information about examples of risk assessments and assessment tools. Setting up Internet portal sites for impacts and adaptation information that will be useful for governments. Promoting information exchanges and collaborative research with local research institutes.

(d) Information consolidation (improvement of enabling conditions): Institutional arrangements and methodology development for gathering, managing, and utilizing basic information on the target areas and sectors are the basis for planning and implementation of adaptation measures. These efforts should be initiated and promoted as quickly as possible.
  (i) Risk-related information provision, communication about risk, and awareness-raising activities (combined with mitigation efforts) targeting citizens and businesses. Sharing of information among relevant government departments; establishing supportive institutional arrangements; and creating collaborative arrangements among governments, research institutes, and NGOs.

(e) Research and technology development: Research and technology development should be promoted in such areas as monitoring and projections of climate change, measures for the short-term, and the medium- and long-term adaptation effective to improve the resilience of local societies.

Adaptation Planning

The Council on Environmental Quality (CEQ) Task Force during the Obama administration outlined eight guiding principles for adaption in its 2010 progress report for governments, communities, the private sector, and others in designing and implementing adaptation strategies. These include:

1. Adopt Integrated Approaches: Adaptation should be incorporated into core policies,

planning, practices, and programs whenever possible.

2. Prioritize the Most Vulnerable: Adaptation plans should prioritize helping people, places, and infrastructure that are most vulnerable to climate impacts and be designed and implemented with meaningful involvement from all parts of society.
3. Use Best Available Science: Adaptation should be grounded in the best-available scientific understanding of climate change risks, impacts, and vulnerabilities.
4. Build Strong Partnerships: Adaptation requires coordination across multiple sectors and scales and should build on the existing efforts and knowledge of a wide range of public and private stakeholders.
5. Apply Risk Management Methods and Tools: Adaptation planning should incorporate risk management methods and tools to help identify, assess, and prioritize options to reduce vulnerability to potential environmental, social, and economic implications of climate change.
6. Apply Ecosystem-Based Approaches: Adaptation should, where relevant, consider strategies to increase ecosystem resilience and protect critical ecosystem services on which humans depend to reduce vulnerability of human and natural systems to climate change.
7. Maximize Mutual Benefits: Adaptation should, where possible, use strategies that complement or directly support other related climate or environmental initiatives, such as efforts to improve disaster preparedness, promote sustainable resource management, and reduce greenhouse gas emissions including the development of cost-effective technologies.
8. Continuously Evaluate Performance: Adaptation plans should include measurable goals and performance metrics to continuously assess whether adaptive actions are achieving desired outcomes.

On the other hand, the Government of Japan recommends the necessary five steps for adaptation planning and implementation:

Step 1: Share knowledge and approaches to adaptation and examine existing measures.

- Share knowledge and approaches about the need for, the importance of, and concepts relating to adaptation.
- Compile information about adaptation-related aspects of existing policies and measures and identify areas where gaps exist.

Step 2: Assess the risks associated with climate change impacts.

- Collect and analyze existing, readily available monitoring results information, etc.
- Assess risks of climate change impacts using existing information (identify high-risk events and areas).

Step 3: Promote communication and decide adaptation plans, programs, and measures.

- Share risk assessment results with the public and stakeholders.
- Determine the necessity of adaptation measures, consider their levels of importance, and prioritize adaptation planning and implementation in the policies.

Step 4: Start with the most feasible initiatives.

- First, initiate urgent response measures to prevent and/or mitigate short-term impacts.
- Next, consider adaptation measures where socioeconomic benefits are clearly higher than costs.
- Track and assess progress and effectiveness of adaptation measures (overall assessment of progress).

Step 5: Consolidate risk assessments and adaptation measures based on monitoring and the latest knowledge.

- Identify areas and items requiring priority monitoring and consider and improve methodologies and arrangements for them.
- Improve future projections using the latest research results and local monitoring data.

- Reassess risks, review, and integrate adaptation measures.

Regardless of which approach the government, or a city applies, it is very crucial to have the following questions answered before implementing any adaptation programs (Palutikof et al. 2013:22). Since climate change impacts are not equally distributed, there will be winners and losers in the process of adaptation. To minimize the risks of inequality, every adaptation plan should address these types of questions specific to the place and risk.

- *From whose perspective is the adaptation activity evaluated?*
- *Whose needs should be paramount?*
- *Are they those of government or of community?*
- *If you improve the resilience of a village, will central government care?*
- *If central government builds a dam to improve water supplies and displaces ten villages, is that a successful adaptation?*
- *If market forces rule, and water availability is managed through pricing, who looks after the interests of the poor and disadvantaged?*
- *Who maintains environmental flows?*

Challenges to Adaptation

Limits of adaptation is a condition where despite adaptive action, an actor can no longer secure valued objective from intolerable risk. Some sources for such limits are perception, values, processes, and power structures with the society that impose barriers. Limits can be categorized as ecological and physical, economic, and technological. In the ecological and physical limitation, it is likely human action cannot avoid repeated and severe coral bleaching. Economical limit would be when the costs of adaptation exceed the costs of impacts averted. Finally, technological limitation is when the available technology cannot avoid climate impacts (Barnett and Palutikof 2015). Sometimes, adaptation becomes an alibi for business as usual if it is delinked from climate change mitigation policies (O'Brien 2017). As a result, it can be seen as promoting passive responses to climate change; diverting attention from other possibilities; including responses that minimize risk and vulnerability by changing existing systems, structures, and power relations; or promoting a technical solution to a complex problem such as climate change. The biggest challenges to adaptation are (Palutikof et al. 2013):

1. Knowledge barriers – It is one of the biggest barriers when people lack sufficient knowledge about future climate, socioeconomic trends, and technological developments. Even though scholars and decision-makers use scenarios to predict future changes, scenarios are limited and cannot control for the unexpected changes across variables. Related to this is the lack of skills to act upon existing knowledge and the gap between rich and poor nations on knowledge exchange.
2. Financial barriers – Money is an impediment at all levels from individuals to national governments to international organizations. The United Nations Framework Convention on Climate Change (UNFCCC) estimates by 2020 100 billion dollars a year for adaptation, and mitigation programs will be needed in least developed countries alone. In response, the international bodies have set up the Green Climate Fund, which will continue to support actions in poor countries. However, many nations have not fulfilled their commitment to the fund, making it a small pool of money. At national, community, and individual levels, perception of the problems makes it hard to allocate funds to address an issue that might happen in the future.
3. Legislative and regulatory barriers – Legislations are key to enforce policies and even bring changes in social behavior (fines for food waste) and provide incentive for change. In addition, legislation will play a role in assigning agency responsibilities, establishing and empowering institutions, providing legal authority in decision-making, and identifying process and actors of decision-making. Sometimes, existing legislation and regulation would be in conflict with the proposed

adaptation goals and, therefore, need new legislation to support adaptation. Incremental changes to the legislation process will help in establishing adaptation programs for the long run.

4. Failures of communication – Failure to communicate relevant information on time and in an appropriate manner and ineffective communication can lead to misunderstanding or misinterpretation of the information. Failures of communication to support adaptation have included failure to adequately set communication goals, identify and understand target audiences, appropriately frame messages and use appropriate language, make use of "messengers" most likely to effectively communicate and influence particular audiences, and provide adequate resources (time, funding, expertise) to support communication efforts (p. 14).
5. Cognitive and psychological barriers – It is true even if all the above barriers are addressed, adaptation is likely to fail if perception of vulnerability, risk, and urgency is missing. "Human cognition is the basis for all other barriers to adaptation, and it presents arguably one of the most vexatious challenges to address in adapting to climate change" (p.14). In the political process, the lack of ability or willingness to combat the complexity of climate change reduces the ability of decision-makers to enact effective adaptation policies. For individuals, the long time lags between prediction of future change and the occurrence of those changes affects their perception of risks in the future. One of the ways to address cognitive barriers is to build adaptive capacity by dealing with current adaptation deficits such as preparation for extreme events and management of water resources.
6. Barriers to adaptation and lack of adaptive capacity – The presence of all these barriers creates a deficit of adaptive capacity. Because of this deficit, communities may fail to adapt to current climate conditions and engage in misdirected adaptation or maladaptation. Some of the sources for the deficit would be lack of resource (financial constraints), poor understanding (knowledge constraints), or a rapidly changing set of social, economic, and demographic variables (instability constraints).

On the other hand, climate change presents its own challenges to building an effective adaptation system (Schneider 2013). These include:

1. Uncertainty – The biggest uncertainty with climate change is the uncertainty about how much future emissions will decrease globally. In addition, there are other non-climatic sources of uncertainties such as demographic change, technological change, markets and economic change, and social and political change that will affect adaptation.
2. Rates of change and feedbacks – The rates of change in both climate system and other drivers of change (population growth) can affect the rates of temperature change. Furthermore, most feedbacks in the climate system will be positive (increase of plant productivity in colder regions), creating special challenges for adaptation.
3. Equity in adaptation – Impacts of climate are unevenly distributed; the poor in every society are the most vulnerable. Developing nations that contribute little to the problem are most affected. Therefore, adaptation assistance to the most vulnerable population is critical. There are also concerns that the current practice of inserting adaptation in the broader development agenda might increase the risk of reducing resilience and adaptative and lead to maladaptation.

Addressing the above challenges requires adaptation to become more inclusive of different groups of people and increase cooperation and coordination among different stakeholders. Community based adaptation (CBA) is one of the ways to overcome the barriers. Involving local people in the decision-making process means those decisions will better reflect citizens' needs and result in more widely accepted interventions. If adaptation is to address social vulnerability, then the best source of information is vulnerable people themselves, who can say why they are vulnerable, how they experience vulnerability, and what can help them adapt to stresses. In this framework, adaptation can become an intervention done to the community, to protect the community, and be determined by the types and scales of climate impacts (Ayers and Forsyth 2009). Importantly, local governments are close to constituencies and can influence behaviors of people in their choice of energy consumption and transportation options and can influence the daily use of energy, transportation, and other sources of greenhouse emissions (Zimmerman and Faris 2011). At higher levels, there are two ways to tackle the challenges to adaptation (Palutikof et al. 2013):

1. Market-based and regulatory instruments – Economists believe climate is the greatest market failure; therefore, a strong and flexile economy can help successful adaptation. They see an active role of markets to deliver successfully adapted societies where industry, business, communities, and individuals are incentivized to adapt. Here, the role of governments is to create frameworks for these markets to operate. One example of this idea is carbon pricing, which would be available in the markets for maintenance of healthy ecosystems and biodiversity and for disadvantaged groups. However, this will happen only in an ideal world, and in many cases, market will be unable to drive successful adaptation. In these cases, governments still can play a role to build adaptive capacity and to ensure that the right actions are taken at the right time, that the necessary regulatory frameworks are in place, that ecosystem services are properly recognized, and that vulnerable communities are protected (p. 16).
2. Role of engagement and communication – Engagement and communication can play a role in ensuring that robust and informed adaptation decisions and actions by audiences who have access to and the ability to consider and use the information to achieve adaptation goals. There is a need to make the communication of information about climate change adaptation to be participatory, integrated, iterative, outcomes focused, and accounts the scale at which such adaptation measures need to be undertaken (individual, local, regional, or global). This is crucial for local communities where adaptation action is happening on the ground and the success of the program depends on the inclusion of local knowledge and expertise.

Adaptation in the Agriculture Sector

Agriculture sector is one of the biggest contributors to climate change, and it is also the most vulnerable sector that could affect billions of people. This will have severe consequences to the biodiversity (new areas exploited for farming) and society (displacement, social unrest, and conflict). Therefore, adaptation and mitigation strategies can be used to limit the damage and to develop a sustainable agriculture sector. This can be done through specific cultural, technical, system, and policy options that are embedded within, but also informing, socioeconomic development strategies (e.g., diversification of income, rural energy planning) (Tubiello 2012:9). Some ways adaptation and mitigation can enhance resilience of vulnerable people is by implementing win-win strategies such as developing more diverse crop strains tolerant of a variety of different conditions (heat, drought, salt, etc.), bolstering social capital and resilience, creating early warning systems and preparedness plans, improving public health infrastructure, and bolstering disease surveillance (El-Ashry 2009:60).

The Food and Agriculture Organization (FAO), United Nations, contends, the sooner the mitigation activities begin, the lesser the impacts and less adaptation. On the other hand, adaptation measures should protect livelihoods and food security in many developing countries, which are more vulnerable. These measures can be implemented locally to safeguard food availability and minimize impact on access, stability, and utilization of food resources. Some of the available adaptation strategies for the agriculture sector include (Howden et al. 2007):

- Altering inputs, varieties, and species for increased resistance to heat shock and drought, flooding, and salinization; altering fertilizer rates to maintain grain or fruit quality; altering amounts and timing of irrigation and other water management; and altering the timing or location of cropping activities.

- Managing river basins for more efficient delivery of irrigation services and prevent water logging, erosion, and nutrient leaching; making wider use of technologies to "harvest" water and conserve soil moisture; and using and transporting water more effectively.
- Diversifying income through the integration of activities such as livestock raising, fish production in rice paddies, etc.
- Making wider use of integrated pest and pathogen management, developing and using varieties and species resistant to pests and diseases; improving quarantine capabilities and monitoring programs.
- Matching livestock stocking rates with pasture production, altered pasture rotation, modification of grazing times, alteration of forage and animal species/breeds, integration within livestock/crop systems including the use of adapted forage crops, reassessing fertilizer applications, and the use of supplementary feeds and concentrates.
- Undertaking changes in forest management, including hardwood/softwood species mix, timber growth and harvesting patterns, rotation periods; shifting to species or areas more productive under new climatic conditions, planning landscapes to minimize fire and insect damage, and adjusting fire management systems; initiating prescribed burning that reduces forest vulnerability to increased insect outbreaks as a nonchemical insect control; and adjusting harvesting schedules.
- Introducing forest conservation, agroforestry, and forest-based enterprises for diversification of rural incomes.

Other long-term adaptation programs that nations can include in their policies are long-term investments in plant and animal breeding programs (including of underutilized crops), building capacity in the science and user communities, developing quarantine systems, establishing perennial crops and forest plantations, making land purchases or sales, and building (or decommissioning) major infrastructure such as dams and water distribution systems, flood mitigation works, and storage and transport facilities, as well as shorter-term investments, to ensure access to food and safety nets (Howden et al. 2007:12).

Conclusion

It is believed that for effective implementation of adaptation programs, it requires an understanding of current and future climate risks. This information can be used to develop new measures, policies, programs, and projects to minimize the risks. This process is known as "climate proofing" – the development of actions to protect infrastructure, systems, and processes against climate impacts. This integration of adaptation in policies is key to providing protection from climate change (Parry et al. 2005). Adaptation against climate change requires rethinking the current model of development that is harmful to the natural and social systems. To balance development and adapt to climate change nations must adopt a development paradigm that is based on a low-carbon economy and re-examine the role of global public policy and institutions to deal with crises in the financial, food, water, and energy sectors (El-Ashry 2009:60). In addition, where possible adaptation programs should apply win-win strategies that can bring multiple benefits to the people and the ecosystem. Some of the priorities national and local governments can use to make adaptation successful are (Parry et al. 2005):

a. Integrate adaptation across local, sectoral, national, and international levels; it is crucial to engage diverse stakeholders and include non-climate experts to develop anticipatory strategies.
b. Disseminate and implement the knowledge, tools, and technologies to assist communities reduce vulnerability to climate change.
c. Finance vulnerability reduction activities in poor countries that are inclusive and accessible to these nations.
d. International financial institutions and the private sector must be effectively engaged as well to support adaptation efforts, particularly in poor countries.

Furthermore, adaptation strategies can be designed for short-term coping to longer-term, deeper transformations, aiming to meet more than climate change goals. Three approaches can be conceptualized that can assist nations reach their goals (Roy et al. 2016:23):

1. First, adaptation should not be just about climate change alone and should include non-climate factors.
2. Second, adaptation programs should prepare for mixed outcomes. The chances of success of such programs in moderating harm and exploiting beneficial opportunities depend on many factors, not just on the adaptive action itself.
3. Third, local adaptations of a community and its members can be supported, constrained, or undermined by external interventions. Therefore, examining who acts is critical to understand effective adaptation.

Cross-References

- ▶ Climate Change Impacts and Resilience: An Arctic Case Study
- ▶ Climate Change Planning: Understanding Policy Frameworks and Financial Mechanisms for Disaster Relief
- ▶ Making Communities Resilient to Global Climate Change
- ▶ Maladaptation to Resource Scarcity: The Jevons Paradox

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Climate Change Agreement

► Kyoto Protocol (KP)

Climate Change and Education

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Definition

Climate Change Education (CCE) is a specific area of Environmental Education aiming at designing and developing educational responses based on informed decisions intended to be effective in the context of the climate crisis. This means such decisions must be coherent with the objectives of mitigating greenhouse gasses and with the need to adapt to the inevitable consequences of a changing climate. CCE must incorporate a sense of social and environmental urgency and emergency stemming from the temporal inertia of human-induced climate change and of its long-term systemic, complex and unpredictable consequences on the biosphere and sociosphere. In this respect, CCE must include Climate Literacy among its tools, but it must go beyond that, given that there is no time for the best available scientific knowledge on climate to imbue the entire society and all societies as a precondition for avoiding the worst future climate scenarios foreshadowed by science in the absence of a significant civilizing change.

Based on these premises, CCE must adopt perspectives related to civic education and to a pedagogy that is critical towards the current model of production, distribution and consumption of energy, goods and services. The objective is to ease the transition towards sustainable societies and communities, with a fairer and more equitable distribution of environmental burdens and resources. The main CCE short- and medium-term challenges are: turning this threat into a socially relevant and significant problem; involving people and social groups in actions aimed at decarbonizing daily life, especially in more developed societies; fostering citizen participation in the policies to combat climate change; and facilitating social adaptation and resilience to the inevitable consequences, especially in the societies that are most vulnerable due to their geographic location or socio-economic weakness.

Introduction

Climate change is the main social and environmental challenge faced by humanity in the twenty-first century (UNESCO 2010). The latest IPCC Report (2014a) finds that it is real and indeed happening. The report also establishes that the main causes for the abnormal alteration of the climate are the emissions of Greenhouse Gases (GHG) associated with the intensive burning of fossil fuels since the beginning of the Industrial Revolution. The scientific community warns that we are in a critical moment to avoid the worse climate scenarios projected for the end of the century (IPCC 2014a; Rockström et al. 2017; Figueres et al. 2017). If humanity continues down the same path, the biosphere will be an increasingly hostile place for our species.

Especially in more developed societies, it will be no easy task to inform and raise awareness among the population of the fact that this reality will increasingly condition human life, and of the need to implement technological, socio-cultural and economic transformations on par with its threat potential. The change in the global climate is no longer avoidable, the inertia of the climate system prevents it. But it is possible to reduce GHG emissions to a threshold that allows a safe and decent human life. Similarly, it will be necessary to adopt strategies for adapting to the alterations that will inevitably occur, as well as for reducing the vulnerability of human communities in the face of the biophysical and social impact of the ongoing changes.

The Paris Agreement (UNFCCC 2015) set this threshold at limiting the temperature rise to +1.5 °C or +2 °C by the end of the century. To achieve this goal, the signatory countries had to develop mitigation and adaptation policies taking into account their differentiated responsibilities in the causes of this issue, their socio-economic circumstances and their specific vulnerabilities in the face of climate change, conditioned by factors such as their development level, cultural identity, or geographic location.

In this situation, making the transition towards low-carbon societies is not an option, but rather an ecological, ethical, and social imperative for survival. The transition requires a structural change in energy patterns, which implies abandoning our dependence on fossil fuels. It also calls for a redefinition of the current forms of exploitation, transformation and distribution of natural resources and environmental burdens in order to adjust human civilization to the ecologic limits of the biosphere, and to do so according to criteria of equity and justice.

The ecologic transition will involve profound changes, especially in the more developed societies, which will force us to deconstruct and redefine the dominant modes of production and consumption. It is apparent that such an objective cannot be reached solely through technological and economic innovations. It will be necessary to foster a cultural change where the citizens assume a protagonist, active role: as the driving force behind the transition, aware of the threat potential of the climate crisis, demanding and supporting adaptation and mitigation policies on different levels (local, community, regional, global); on the other hand, as an agent of change, by adopting consumption habits and lifestyles that are consistent with the reduction of the individual and global carbon footprint. Education, both formal and informal, must play an essential role in this process of change, a role it has still to begin to play.

The Urgent Need for Climate Change Education

Objective number 13 of *The 2030 Agenda for Sustainable Development* (UN 2015) explicitly states this challenge: "Take urgent action to combat climate change and its impacts." Of the 17 objectives of the Agenda, this is the only one that explicitly calls for an "urgency" to act. This is no minor detail. The demand for an urgent response to the climate challenge has to do with the structural and systemic nature of the threats it entails and the physical inertias that project it further into the future if effective responses are delayed. Acting in the present will determine our ability to meet the other 16 objectives of the Agenda on a medium and long-term basis. An increasingly warmer climate would make it difficult, if not impossible, to appropriately meet basic human needs (food, water, health, freedom, equality, safety, etc.), especially in the case of more vulnerable groups. On the contrary, a controlled climate would increase the likelihood that the biosphere be a welcoming and safe place for all humankind. The inertia of the climate system, together with the inertia of a humanity that is unable to modify its course, would sentence us to the worse scenarios that institutions such as the IPCC (2014a) project for the future.

Among the goals that constitute Objective 13 of *The 2030 Agenda*, goal number 13.3 points out the necessity to "Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning" (UN 2015, p. 23). From an educational point of view, goal no. 13.2 is of no less importance, given that it stresses the necessity to "Integrate climate change measures into national policies, strategies and planning," a proposal that must set the ground for the cross-cutting integration of the climate crisis in all areas of political action, including educational and communicative policies. Education must contribute to mitigate the problem and reduce the vulnerability of people and communities faced with the consequences of climate change (UNESCO 2010, 2016).

The 2030 Agenda associates Objective 13 to the development of the *United Nations Framework Convention on Climate Change* (UN 1992) as the main international and intergovernmental frame in order to achieve a consensual response to the climate crisis. Article 6 of this convention expresses the necessity to include, in the policies of response to climate change, programs of "education, training and public awareness," with two specific lines of action: one aimed at creating "public awareness" on the climate threat – at a time when this was irrelevant in the public agenda – and another recommending the integration of climate change into every country's educational and formative system.

Despite appearing in the text of the UNFCCC (UN 1992), the educational responses to the climate challenge have been limited, poorly structured, and devoid of a solid political, theoretical and methodological underlying frame. Their presence has been marginal both in climate policies, and in educational policies. This shortfall can be linked with a similar difficulty in reaching a consensus about an effective global agreement on reducing GHG emissions. The *Kyoto Protocol,* for instance, left out any reference to including educational activities. The omission of the educational dimension from international climate policies is officially corrected in the Paris Agreement, which states in Article 12: "Parties shall cooperate in taking measures, as appropriate, to enhance climate change education, training, public awareness, public participation and public access to information, recognizing the importance of these steps with respect to enhancing actions under this Agreement" (UNFCCC 2015, p. 10). As it can be observed, its text sums up Article 6 of the UNFCCC (UN 1992), except for calling for education as a tool for fostering public participation in the national plans designed for the enforcement of the agreement. A great part of the practical implications of this article remain to be defined. Each signatory country is to design their own adaptation and mitigation policies in order to align the evolution of their GHG emissions to global goals that might allow maintaining the Earth's average temperature below 2 °C by the end of the century. Given that the Agreement will not enter into force until 2023, it is to be expected that each country, according to their circumstances and vulnerabilities, will integrate the educational dimension in the adaptation and mitigation policies they design, as well as integrate the climate crisis among the priority goals of the national educational policy.

Contrary to other socio-environmental problems that call for an institutional educational response, the urgent need to begin reducing emissions must turn the climate crisis into a priority educational topic, up to the point of thinking about implementing an "emergency curriculum," both nationally and internationally, in order to raise awareness about the severity of the threat and to contribute to a massive and quick response. (Miléřa and Sládek 2011; Heras 2014; Henderson et al. 2017; Allen and Crowley 2017). "The climate emergency," states Whitehouse (2017, p. 64), "is more than a socio-scientific topic to be investigated, however effectively (. . .). The climate emergency is a real condition that has current and direct impact on babies', children's, and young people's lives. This means climate education, in its many forms will, by necessity, shortly move towards the centre of curriculum practice." Not only do we need to place climate change at the center of the curriculum, but also, we need to reinforce educational resources that do not belong to the formal education system, by activating social learning systems, as suggested by Heras (2014), and by creating peer-to-peer knowledge networks in order to involve all kinds of public to take action against climate change.

Response time is, now more than ever, a main educational variable in the manner in which societies are to react to the imbalances between human systems and the biosphere. We cannot go on repeating naïve speeches that attribute to education in general, and to environmental education in particular, the mission to pro-environmentally socialize the new generations in the hope that they will not commit the same mistakes that have caused the present crisis. The transition towards a climatically viable future will not be possible unless it is initiated now, in a socially cross-cutting manner, and by involving all generations. The strategies, programs and educational resources aligned with climate policies must address all population groups, but must priorities groups of adults who, through their activity as producers and/or consumers, as well as through their role as citizens or decision-makers, can be crucial for fomenting or hampering climate policies. As suggested by Henderson et al. (2017, p. 4), "What ought we, as educators and researchers, do? The first thing is to see clearly that employing education as a social change lever, and educational settings as sites of socialization toward alternative futures, is our strongest suit."

Climate Change Education or Climate Literacy?

Climate change education must go beyond climate science literacy. Climate literacy is a branch of scientific literacy that has become prominent in the last decade, as climate change started to become substantial in the scientific and public scene. In a meta-study on the use of this concept in educational research, Azevedo and Marques (2017) examine 22 documents published between 2007 and 2013 that attempt to clarify what climate literacy is, and conclude that it is an open concept, subject to debate. For Dupigny-Giroux (2008, 2010, 2017), "Climate literacy involves a deep appreciation of the complexity and interconnectedness of the climate system over space and time; the role that humans exert in modifying and interacting with the climate system; the ability to 'act accordingly' having understood the above; and the recognition of bias or the change in behavior due to insights gained about an issue or concept" (Dupigny-Giroux 2017, p. 1). As can be noted, the author links the area of scientific knowledge about the "climate system" – not specifically about climate change – with the acquisition of competencies to act in coherence with that knowledge. This nuance separates it from the simpler literacy approaches linked to theinformation deficit model, although it continues to assume that scientific knowledge is necessary for responsible action to be possible.

Another widely used definition is the one proposed by the *US Global Change Research Program* (USGCRP 2009, p. 4): "Climate Science Literacy is an understanding of your influence on climate and climate's influence on you and society," also stating that "A climate-literate person: understands the essential principles of Earth's climate system, knows how to assess scientifically credible information about climate, communicates about climate and climate change in a meaningful way, and is able to make informed and responsible decisions with regard to actions that may affect climate." This conceptualization reflects more clearly the widely held belief, also among the scientific community, that access to scientific knowledge, in this case about climate change, entails a pro-environmental response on the part of literate people. This belief is based on the assumption that environmental problems are attributable to a deficit in the scientific culture of the population, leading to the belief that one way to address these problems is to extend scientific education so that people can analyze and rationally evaluate their behavior and, therefore, avoid contributing to the causes of such problems. Azevedo and Marques (2017, p. 414), for example, highlight that "In most developed countries, there is a substantial consensus about the importance of a scientifically literate population for democratic processes in a society that is more and more technologically demanding."

This approach to climate literacy is limited for two reasons. The first is that psychological and educational research shows that, in general, there is no direct relationship between a higher level of scientific knowledge and the development of pro-environmental attitudes and behaviors (Kollmuss and Agyeman 2002; Wibeck 2014; Hemple 2014; Arto et al. 2017). Without questioning the fact that in democratic societies there may be a positive correlation between the level of scientific literacy of the population and their civic commitment (Azevedo and Marques 2017; Stevenson et al. 2014; Carvalho 2011), research such as that of Drummond and Fischhoff (2017) stresses that personal stance towards socially controversial scientific questions, such as climate change, far from being clarified, is even more polarized among people who have a higher level of studies. Azevedo and Marques (2017, p. 416) admit that it is necessary "to be cautious as a high climate literacy may not directly translate into adaptation to climate change's unavoidable effects or mitigation of its causes." As other research shows, more than the level of climate literacy or level of education, the main conditioning factor of personal and collective judgements, attitudes and behavior in the face of the climate crisis are variables such as cultural or religious identity, experiences with weather phenomena, ideology or party militancy (Stern 2016; Hornsey et al. 2016). This observation is even more relevant if we take into account that most of the climate literacy programs focus on contents related to the biophysical dimensions of climate and the climate system, ignoring or marginalizing social (psychological, sociological, anthropological, ethical, etc.) dimensions, which tend to be, moreover, the most relevant to understand how people connect their lives with significant aspects of climate change. In other words, a high level of scientific literacy does not necessarily translate into an awareness of the threats associated with climate change, and even less in individual or collective behaviors consistent with mitigation and adaptation goals.

The second reason is a pragmatic one. Given the urgency needed to make the transition towards decarbonized societies, there is not enough time to reach climatic literacy levels among the population that could guarantee, if this were the case, the awareness and change of behaviors and lifestyles that are dominant nowadays. The climatic emergency demands immediate changes in which all societies and all people must be involved, regardless of the greater or lesser knowledge of climate sciences they possess. Climate literacy is necessary and will have to be fostered, especially in higher education and in forming social agents (technicians, professionals, decision-makers) whose leadership will be strategic in making the ecological transition; and also within the framework of primary and secondary education, by expanding the presence that the climate crisis has in curricula and educational materials (national curricular designs, textbooks, complementary teaching resources, etc.), and by incorporating it into the initial and ongoing training of teaching staff. But climate literacy will not be enough.

Climate Change Education must go beyond climate literacy understood as the mere educational transposition of the science available on the climate and its anthropic alteration. The educational response to the climate crisis must be oriented towards action for transition and social change. To paraphrase McKeown and Hopkins (2010), from the whole "climate change" equation, education (especially within the framework of formal educational systems) has so far paid more attention to the "climate," as a representation constructed in the field of natural and physical sciences, than to the "change," seen as a concept that refers to the social and economic trajectory that has led humanity to this crossroads. A critical and global understanding of the "change" necessarily involves other fields of knowledge, from the social sciences (economics, sociology, anthropology, geography, etc.), to the humanities (philosophy, ethics, etc.). Shwom et al. (2017, p. 377) call to overcome this decompensation: "Climate literacy programs have traditionally promoted education on the biophysical science of the climate system but have largely failed to integrate relevant knowledge from the social sciences. We argue that understanding human behavior and the social drivers of climate change are essential for the public to fully appreciate the climate system, and that this knowledge can inform decision making related to climate-change mitigation and adaptation."

The imbalance between the biophysical and the social dimensions in the construction of the scientific representation of climate change does not only affect the educational field. The very trajectory of the IPCC shows this decompensation. The first four reports of this organization focused on analyzing and assessing the best science available in order to answer two essential questions: whether climate change is real and whether it is being caused by human activity.

In their affirmative answer to these questions, the IPCC has essentially resorted to the natural and physical sciences. The only social science with obvious weight in the first reports of the IPCC was economy. There is a simple reason for this: apart from delimiting the problem from a bio-physical point of view, it is necessary to assess the economic costs of climate change, as well as of the mitigation and adaptation alternatives. Only the latest IPCC report (2014a), the most conclusive on the severity of the climate crisis, takes into account the role that other social sciences should play in assessing the dangers that threaten humanity and, mainly, in the design of possible alternatives; that is, it takes into consideration the question of social change and the alternatives that can guide it (IPCC 2014b). Chapter 3 of the IPCC Group 3 Report is an obligated reading in order to understand the relevance of social sciences in the construction of a complex representation of climate change as a challenge for humanity. It is in this precise chapter where we can find a very clear and operative prescription of the role that education must play regarding the climate crisis: "The task of an educational programme in mitigating and adapting to climate change is to represent a collective global problem in individual and social terms. This will require the strategies for disseminating scientific information to be reinforced and the practical implications advertised in ways that are understandable to diverse populations" (Kolstad et al. 2014, p. 256). This statement fails to allude to the processes of ecologic transition and decarburization that the educational activity should foster, according to the responsibilities and vulnerabilities of each society regarding climate change, as well as the theoretical, ethical and methodological foundations that might help to cement this action pedagogically (González-Gaudiano and Meira 2010). In the following section we offer some observations regarding this issue.

Climate Change Education: Basic Principles

Henderson et al. (2017) speak of a "climate silence" in research and in educational theory, which they interpret as a subtle form of denial, which does not question the existence of the problem, but also does not give it the social relevance it really has. For these authors, the educational response to climate change requires a pedagogical project that transcends the limited areas of environmental education and scientific education, to which it has been confined until now. To this end, they call for the creation of an agenda with a view to placing climate change in the front line of research in all educational subdisciplines: the design of spaces, curricular studies, civic education, educational policy, didactics, research on the teaching-learning processes, etc. The role that the education sciences must play in responding to the climate crisis will also have to observe an inescapable ethical commitment: "Doing nothing, as we as educational professionals have mostly done about climate change, will at minimum make us complicit accomplices, and at worst, servants to environmental oppression and ultimately death. What is needed is a renewed commitment to the form of educational justice appropriately scaled to the size of the challenge we face" (Henderson et al. 2017, p. 417).

Even recognizing this deficit, there is sufficient literature in the field of education sciences and social sciences to outline a minimal theoretical-methodological foundation that might allow articulating increasingly effective educational programs and resources to respond to the climate challenge. Given the limitations of space, the issues considered here are the management of uncertainty and the social relevance of climate change, the management of the emotions it generates and the curricular integration of climate change.

Managing Uncertainty and Relevance of Climate Change

One of the most surprising patterns detected by the studies on the social perception of climate change is the persistence among the population of high levels of uncertainty regarding the image that science projects of said issue. Climate change deniers make up important percentages of the population in few societies, although the presence of climate change denial is important in key countries from the climate point of view, such as the United States or China (Capstick et al. 2015; European Commission 2017). The belief that climate change is real and is due to human activity is a majority view in practically all societies, and tendencies show a general increase (Capstick et al. 2015). But this acceptance is accompanied by a perception of high levels of uncertainty with regard to the level of consensus among the scientific community on this matter, a doubt that is unfounded (Cook et al. 2016). It is also accompanied by a low relevance of the climate change among the issues that people consider as most important. The Spanish society is a good example of this paradox: 9 out of 10 people believe that climate change is real and caused by human activity; however, 5 out of 10 do not see a consensus on these matters among the scientific community, and only 1 out of 10 considers climate change to be an important global problem, while being completely absent from the agenda of the most important local or national issues (Meira et al. 2013). How can these paradoxes be explained? What are the challenges that they represent for education? Social research points to some answers which, combined, outline a complex socio-cultural scenario that educational practice must consider:

– Climate change denial acts insidiously, taking advantage of the counterintuitive nature of climate change and its scientific complexity, in order to cast doubt among the public perception with respect to its existence and threat potential. The excellent study by Oreskes and Conway (2010) reveals the strategies that climate change denial has been using in order to maximize its social influence.
– Epistemological uncertainty is inherent to the scientific method. The construction of a "scientific truth," particularly in the case of extremely complex objects such as climate change, is subject to uncertainty levels that stem from possible information gaps, unpredicted interactions between the elements that compose it, limitations in interpretation, etc. A "scientific truth" is always provisional. The latest IPCC report (2014a) quantifies the level of certainly that climate change is real and caused by human activity as 95%; the remaining 5% represents uncertainty. When epistemological uncertainty is projected upon society, it may cause insecurity and foster the belief that science questions the nature or severity of the problem. Such socially perceived doubts justify inaction (we will have to wait until these issues are clarified in order to act...), reinforces messages of climate denial and relegates climate change to a secondary place, far from socially urgent issues. Faced with the language of uncertainty, education must use the language of risk and prevention, stressing the urgency to act in order to avoid the worst consequences of a phenomenon that is real and gradual (Heras and Meira 2014; Heras 2014).
– Research on the social perception of climate change also shows that people tend to perceive it as a problem that is remote both when it comes to time (it is believed to affect future generations), and when it comes to space (it is believed that it affects or will affect others). This psychological distance has an unmotivating effect and justifies postponing response actions. One of the great challenges of Climate Change Education is bringing the problem nearer to areas that are significant to people, both from the point of view of theirvulnerability to its impact, and

from the point of view of their responsibility for its causes and, as a result, of their responsibility for the search for answers in the way of mitigation and adaptation. Didactic instrumentalisation of the relations between climate change and vital areas such as health, food, safety, justice, equality, housing, etc., may help reduce this psychological breach.

Managing Emotions Within Climate Change

Another variable to be considered in the educational treatment of climate change is the role of emotions in its social representations and judgements (Smith and Leiserowitz 2014; Heras et al. 2018). Conventional approaches to climate literacy tend to ignore this dimension and focus educational action on the scientific contents and cognitive processes related to learning.

Nevertheless, the emotional burden of the issue, shaped by its threat potential and by people's self-perceived effectiveness with regards to their ability of doing something as a response to this threat, is the key to their readiness to take on an active part within the framework of adaptation and mitigation policies. Climate change is usually presented as a global and complex problem, whose causes and consequences evade to a great extent the space in which people or communities can take action. Faced with a threat that is presented as severe, but, at the same time, as unmanageable and distant, the feelings that tend to emerge are a fatalistic combination of fear and impotence: as an "I" (or "us"), anchored in a specific time and place, people may feel that their action is irrelevant faced with the magnitude of the problem and with the possible solutions which, indeed, must reach a global scale in order to be effective. Studies on the social representations of climate change speak of a state of "over-determination," a mixed emotion that combines fear, guilt -or a feeling of accountability- and impotence, which usually has a paralyzing and demobilizing effect (Höijer 2010; Smith and Joffe 2012; Heras et al. 2018). Henderson et al. (2017) warn that when an educational action generates a fatalistic emotional climate, most of the people involved, both learners and educators, feel overwhelmed and tend to adopt escapist attitudes and behaviors, selectively ignoring the threat and taking refuge in everyday routines. Much of the difficulty in placing climate change at the center of personal and collective agendas has to do with the weight of these negative emotions. As stated by Kelsey and Armstrong (2012, p. 190), "an educational movement that leaves its participants in despair, hopeless, [and] immobilized by dread (. . .) is neither morally defensible nor likely to lead to sustainability outcomes" (quoted in Henderson et al. 2017, p. 417).

To avoid demobilizing pessimism, research suggests that it is necessary to stimulate self-sufficiency and empowerment at an individual and collective level, showing and putting in practice adaptation and mitigation alternatives in the school and community contexts in which the educational action is contextualized (Wibeck 2014; Allen and Crowley 2017). As Heras (2014, p. 59) expresses, "knowing the solutions (and putting them in practice at different possible levels: personal, school, community) makes it possible for us to stop seeing climate change as a depressing issue with no way out and begin to conceive it as a formidable social challenge faced with which it is possible to intervene" (our parenthesis). Educational centers and programs must become alternative public spheres where to test and experiment with alternative practices that facilitate the transition to a low-carbon society, without ignoring the cumulative effect that these changes may have at the macro-social level. It is important not to forget that global GHG emissions are, ultimately, a consequence of the sum of multiple specific actions, so billions of alternative actions also have a positive cumulative effect on the global GHG balance.

Climate Change Education in Inter- and National Curricula

Educational policies must be aligned with the strategies of transition towards decarbonized societies, resilient in the face of the consequences of climate change. In this regard, national curricula, at all educational levels, must incorporate climate change in all its dimensions, from the biophysical to the social and the political. The universalization of education makes the path through the education system an opportunity, often unique, to connect people with the threat of climate change and with the alternatives to address it. The school experience can and should be transformed into a context in which to transpose the best available science on the climate crisis so that the population understand and better value the threats that we face, the responsibilities that we have, and the alternatives that we can use to build socially in order to avoid an infernal climate (UNESCO 2010, 2016).

The international curricular panorama, however, does not reflect the environmental and social importance of the climate challenge. A study carried out by the International Bureau of Education on the presence of climate change in the national curricular framework of 78 countries reflects that only 35% of the total includes the topic "climate change" in the text (IBI 2016, p. 19). Another issue is the treatment that climate change receives when included as educational content. Curriculum research on this issue is not abundant. In general, it is possible to point out that climate change is usually linked in curricula to the natural and physical sciences, which pay close attention to its processes, causes and biophysical consequences. The human, ethical and social dimensions of the climate crisis receive little attention, nor are mitigation or adaptation actions usually contemplated (Kagawa and Selby 2012; Serantes and Meira 2016; Colliver 2017; Chang and Pascua 2017; Monroe et al.). Issues such as ecological transition or decarburization are absent from official curricula. Faced with this situation, Whitehouse (2017, p. 64) argues that it is necessary to shift climate change "to the center of curricular practice."

How to advance along these lines? The timing of the crisis forces us to act diligently and without delay. The available literature offers some clues. Monroe et al. (2017) perform a meta-analysis of educational experiences in order to identify replicable aspects that might allow designing more effective actions. This study formulates six main recommendations: focus the educational practice on contents that are relevant and meaningful for the target population; use attractive and active teaching-learning methods; generate dynamics that facilitate debate and argumentation in order to explore the controversies surrounding the climate crisis; design activities that allow interaction with scientists linked to climate science; take into account students' misconceptions and beliefs about climate change and use them as a foundation to build the learning experience; and develop at the community level projects and school experiences on climate change.

To these recommendations, two complementary curricular development lines could be added: the first is the incorporation of the climate crisis and the ecological transition as fundamental contents in the processes of initial and ongoing teacher training; the second is the incorporation of the environmental and social complexity of climate change into standardized didactic materials, mainly school textbooks, given that they continue to be the most commonly used didactic resources for content mediation in education systems.

Future Perspectives

On November 4, 2016, once the requirements established in the previous year in the French capital had been fulfilled, the UN declared the entry into force of the Paris Agreement. Nevertheless, until 2023 the main part addressing the assessment of national agreements for its implementation will not be applied, including, as can be supposed, the parts addressing the enforcement of Article 12 of said Agreement regarding the activation of measures with respect to climate change education and public awareness. It might be expected that, in less than 2 years' time from that date, most States, especially most developed ones, would already have established, on the one hand, ambitious programs in order to place climate change mitigation and adaptation on the list of priority curricular objectives of their respective educational systems, and, on the other hand, a "nonformal" agenda of civic and environmental education that might allow efficiently and universally reaching sectors of population situated outside the school setting.

This does not seem to be the case, though. Educational actions related to climate change remain on the sidelines of educational agendas, through secondary programs, unambitious if we are to consider the scope of the socio-ecologic transition that must be urgently undertaken. At the same time, there is no social research agenda, in general, nor an education research agenda, in particular, that might foment this process of urgent educational action; at least, there isno such agenda with the scope and ambition of the research agenda in the field of natural s ciences and technology (Meira et al. 2018). It might be said that it is expected that the scientific objectivation of the issue and the implementation of low carbon technologies will have a positive social effect. Nevertheless, this will not simply happen, especially if the messages on climate change reaching the population are dampened by problems perceived as more urgent, both on an individual and on a collective level, although the very consequences of the human-induced climate change (poverty, desertification, migratory processes, conflicts over the control of natural resources, etc.) are precisely the cause of their becoming more severe.

It is expected that by 2023, when the Paris Agreement enters into full force, educational strategies on different levels should be implemented in order to align the educational responses with adaptation and especially with mitigation policies. It is in this matter that the responsibility of the countries that produce the most historical and current GHG emissions becomes particularly relevant, both in terms of their objective responsibility in causing the problem, and in their ability to finance and foment international educational agendas that might seriously address the ecological transition process and the contradictions this causes with respect to the objectives of the market economy. This will be the main political and social challenge and, thus, the main educational challenge in order to attempt limiting global temperature rises to 2 °C by the end of the century.

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Climate Change and Human Migration as Adaptation: Conceptual and Practical Challenges and Opportunities

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Definition

Climate change-related human migration is an area of growing interest and policy concern. Although climate change is not easily isolated as the predominant cause of human movement, it is increasingly impossible to dismiss its role as a key contributing migration push factor. Moreover, there is agreement among experts that its contribution to migration, relative to other causes, will increase significantly as the effects of climate change impacts are progressively borne out in the future. This makes anticipatory migration-as-adaptation an important emergent priority (Brown 2007, 2008; Laczko and Aghazarm 2009; Hugo 2011; Luetz 2017; Ahmed 2018; Jha et al. 2018; Luetz and Havea 2018; Salerno 2018).

Synonyms

Climate change-induced mobility; Climate migrants; Climate refugees; Climate-related human displacement; Environmentally displaced people; Migration-as-adaptation

Preamble

This chapter should be read in conjunction with the chapter entitled ▶ "Climate Refugees: Why Measuring the Immeasurable Makes Sense Beyond Measure".

Introduction

This chapter explores the topic of climate change and human migration (CCHM) within the broader framework of the United Nations Sustainable Development Goal (SDG) 13 Climate Action: Take urgent action to combat climate change and its impacts (UN 2019). More specifically, Targets 1 and 3 explicitly emphasize the need for anticipatory adaptation to climate change, envisaging progress as follows:

- "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries" (Target 1)
- "Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning" (Target 3)

Situated within this context, discourses about CCHM typically comprise theoretical, conceptual, legal, and practical considerations, among others. Importantly, adaptation to climate change in the migration arena is a human development and policy concern, which typically envisages a forward-thinking posture of preparedness. This makes the proactive engagement of human development actors in the CCHM space a fertile undertaking (EC 2019).

In terms of content arrangement, this chapter is divided into three sections and organized as follows. Section "Conceptualizing Climate Change-Related Human Migration" introduces both definitional and conceptual challenges, discusses "Etymological Perspectives," and canvasses "Agency, Inclusivity, Empowerment: "Nothing About Us, Without Us!"" Thereafter the following section discusses "Legal and Practical Considerations," including selected instruments and migration frameworks that have been proposed to manage CCHM: the "Geneva Convention Relating to the Status of Refugees," "The Guiding Principles on Internal Displacement," the "United Nations Framework Convention on Climate Change (UNFCCC)," and "Global Compact for Migration (GCM) Global Compact on Refugees (GCR)." Critical analysis of today's global framework architecture around migration and displacement is offered in section "Synthesis." Finally, section "Concluding Synthesis: Migration as Adaptation to Climate Change" synthesizes the state of the art in the context of adaptation to climate change.

Conceptualizing Climate Change-3Related Human Migration

Available literature on climate change-induced migration abounds with contentious issues, but perhaps none more so than the question how those driven to move from their homes in response to climate change-related problems should be labelled or conceptualized. The question of nomenclature or definition is delicate and laden with implications (Luetz and Havea 2018). The list of suggested labels is long and growing, and examples in the shortlist below are necessarily incomplete:

> "climate refugees" (e.g., Biermann and Boas 2010), "climate change refugees" (e.g., Docherty and Giannini 2009, p. 361), "refugees" (Hansen 2008, p. 2), "environmental refugees" (e.g., Ehrlich and Ehrlich 2013, p. 4), "eco-refugees" (Cournil 2011, p. 359), "environmental and climate change refugees" (Dupont and Pearman 2006, p. 55), "sea-level refugees" (WBGU 2006, p. 61), "rising-sea refugees" (Brown 2011, p. 73), "desert refugees" (Brown 2011, p. 77), "water refugees" (Brown 2011, p. 79), "displaced persons (refugees)" (Westing 1992, p. 201), " 'climate refugees' " (e.g., McAdam 2012; Bettini 2012) [N.-B. various authors "perpetuate variations of the term "climate refugees" in inverted commas, apparently recognising the widespread comprehension that this construct enjoys among readerships, and yet without conceding personal assent." (Luetz and Havea 2018, p. 21)], "environmentally-displaced persons" (Lopez 2007), "climate migrants" (e.g., Gibb and Ford 2012), "climate change migrants" (Shamsuddoha and Chowdhury 2010, pp. 3–7), "climate exiles" (e.g., Wei 2011, p. 1), "climate change exiles" (Byravan and Rajan 2006), "environmentally-induced [displaced] populations" (e.g., UNHCR 1996, p. 14), "environmental migrants" (e.g., IOM 2011, p. 33), "climate evacuees" (Cournil 2011, p. 359), "environmental migrants/refugees" (Renaud et al. 2007, pp. 14–17), "climate-change victims" (Popovski 2011; Popovski and Mundy 2012), "ecomigrants" (Wood 2001, p. 43), "ecological migrants" (ADB 2012, p. 9), "environmentally displaced persons" (e.g., Cournil 2011, p. 359), "[climate] displaced people" (e.g., Kolmannskog 2009), "climate change-induced displaced people" (McAdam 2011, p. 18), "forced migrants" (Brown 2007, p. 8), "persons displaced by climate change" (Kälin 2010, p. 97), "[people] forced to leave their homes due to sudden-onset climate-related natural disasters" (UN-OCHA 2009, p. 15), "survival migrants" (Betts 2010), "climigrants." (Bronen 2010, p. 89)

As shown, the list of proponents of varied terms and terminologies is considerable, and the arguments put forth in favor of some disambiguations over others plentiful. In a widely cited paper migration scholar, Richard Black (2001) aptly synthesizes that there could be "perhaps as many typologies as there are papers on the subject" (p. 1). Definitions and typologies discussed below are therefore limited to the most prominent studies, organizations, think tanks, and schools of thought.

Campaigners and humanitarian NGOs have frequently used the terms "environmental refugee" or "climate refugee" to highlight the plight of climate displaced populations as a matter of urgency (e.g., Trent 2009; Shamsuddoha and Chowdhury 2010; Bauer 2010; Environmental Justice Foundation 2012), and even Australian politicians have not shied away from labelling such groups of people "refugees" (e.g., Sercombe and Albanese 2006). Proponents of the refugee label generally justify its use on the grounds that those displaced literally seek "refuge" from the impacts of climate change and are therefore rightly to be identified as "climate refugees" (Brown 2008, p. 13; cf. Ahmed 2018). Moreover, it is generally maintained that "[t]he word 'refugee' resonates with the general public who can sympathize with the implied sense of duress" (Brown 2007, p. 7) experienced by forcibly dislocated populations and that this term also carries "strong moral connotations of societal protection in most world cultures" (Biermann and Boas 2010, p. 67).

Since the terms "evacuee" and "exile" imply temporary displacement and would therefore seem inapplicable in cases of permanent displacement (e.g., sea-level rise induced submergence of small islands), they have been less frequently proposed as suitable nomenclature (for the most notable exceptions, see Byravan and Rajan 2005a, b, 2006, 2008, 2009, 2010; Wei 2011).

The term "migrant", on the other hand, connotes a degree of "choice" and "free will" and may "imply a voluntary move towards a more attractive lifestyle" (Brown 2008, p. 13). As a result, perpetuating the term "migrant" could consequently imply a reduced responsibility on the part of the international community for the welfare of this category of people and also lower any sense of liability for their forced fate (Brown 2008, pp. 13–15; cf. Ahmed 2018). Put simply, refugees may be seen to "run from" – migrants "run towards"; refugees are "pushed" by pandemonium – migrants are "pulled" by promise; refugees are "reactive" – migrants are "proactive"; and refugees enjoy public "empathy" – migrants public "mistrust" (or vice versa). Moreover, there are suggestions that the classification "refugee" heightens a sense of "victimization," whereas "migrant" insinuates "opportunism" (e.g., Brown 2007, 2008). Expressed in simple language, the words "refugees" and "migrants" conjure up vastly different mental images and associations which seem to be, more often than not, indicative of the writers' normative preferences, institutional or ideological allegiances, or underlying agendas (Zetter 2007; Cournil 2011, pp. 359–360).

Debates surrounding the definitional or associational appropriateness of different terminologies appear to have broadly divided academics into two camps (Brown 2008, pp. 13–15), namely, those favoring the term "refugee" (e.g., Docherty and Giannini 2009) and those favoring the term "migrant" (e.g., IOM 2018). While environmentalists have tended to portray migration as a form of failed climate change mitigation, migration researchers have traditionally treated it as one of numerous potentially positive means of adaptation (Castles 2010). With academics arguing both sides of this terminological divide, consensus has remained notoriously elusive (e.g., Zetter 2007; Laczko and Aghazarm 2009, p. 397). Furthermore, by perpetuating terms like "climate refugees" and "environmental refugees," the media have also played a role in propagating, popularizing, and lodging such terminology firmly in the public domain (Lawton 2009; MacFarquhar 2009; Schmidle 2009; Vidal 2009; Lam 2012; Luetz and Havea 2018).

Etymological Perspectives

According to Black (2001, p. 1), the term "environmental refugee" was first popularized by Lester Brown of the Worldwatch Institute in the 1970s but failed to gain traction until a publication by the United Nations Environment Programme (UNEP) defined "environmental refugees" as:

> [. . .] people who have been forced to leave their traditional habitat, temporarily or permanently, because of a marked environmental disruption (natural and/or triggered by people) that jeopardized their existence and/or seriously affected the quality of their life. (El-Hinnawi 1985, p. 4)

Myers and Kent (1995) subsequently volunteered the following definition of "environmental refugees" as:

> [. . .] persons who can no longer gain a secure livelihood in their traditional homelands because of environmental factors of unusual scope, notably drought, desertification, deforestation, soil erosion, water shortages and climate change, also natural disasters such as cyclones, storm surges and floods. In face of these environmental threats, people feel

> they have no alternative but to seek sustenance elsewhere, whether within their own countries or beyond and whether on a semi-permanent or permanent basis. (pp. 18–19)

Their study firmly anchored the term "environmental refugees" both in academic literature and public policy discourse. It appears that given the progressively growing public awareness of climate change, recent years have seen a gradual popularization of the term "climate refugee," which more directly reflects the climatic "cause" of the environmental "effect" leading to forced migration.

While the two terms "environmental refugees" and "climate refugees" have at times been used almost interchangeably, there is no unified view about the appropriateness of one term over another. Stavropoulou (2008), for example, condones the term "environmental refugee" (though conceding its legal inaccuracy) as "more compelling than 'environmental migrant' because it evokes a sense of global responsibility and accountability, as well as a sense of urgency" (p. 12). Nevertheless, she stops short of endorsing the term "climate change refugee" which she views as "going too far [given that] it will generally be impossible to say whether a degradation in ecosystems leading to displacement has climate change as a major causative factor" (Stavropoulou 2008). Similarly, the Climate Change, Environment and Migration Alliance (CCEMA 2010) made the point that "it is difficult to clearly identify the relative role of environmental factors in a decision to migrate [and] isolating the role of climate change is even more difficult. Therefore, *terms containing a reference to the environment are preferable to those referring to climate change*" (p. 5; emphasis original). Notwithstanding ongoing debate, if environmentalists like Myers (1993, 1996, 2002, 2005; Myers and Kent 1995) have been largely successful at coining the concept of "environmental refugees" and disseminating it in the public domain, migration scholars have repeatedly and resolutely rejected its assimilation (Black 2001; Laczko and Aghazarm 2009; IOM 2018).

In 1996, the United Nations High Commissioner for Refugees created the less controversial concept of "environmentally displaced persons," defining this group of people as:

> Persons who are displaced within their country of habitual residence or who have crossed an international border and for whom environmental degradation, deterioration or destruction is a major cause of their displacement, although not necessarily the sole one. (UNHCR 1996, p. 9)

Notwithstanding, the strongest attempt at blocking the term "refugee" from gaining currency in public policy discourse appears to have been the counterproposal of a new terminology and typology advanced by the International Organization for Migration (IOM). At its 94th Council Session, the organization floated a definition which uses the word "migrant" instead of "refugee":

> Environmental migrants are persons or groups of persons who, predominantly for reasons of sudden or progressive change in the environment that adversely affects their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their country or abroad. (IOM 2011, p. 33)

Additionally, the IOM openly discourages the use of the terms "environmental refugees" and "climate change refugees" (Laczko and Aghazarm 2009, p. 397), urging emphatically that such terms are "to be avoided" (IOM 2018, para 5). Furthermore, the mention of a "growing consensus among concerned agencies, including UNHCR" (IOM 2018, para 5), appears to be an attempt on the part of the IOM to entrench its proposed typology and build momentum around this definitional approach (IOM 2018). However, despite the impression that the pragmatic focus on "forced migration" already appears to resonate well with some scholars as a suitable common denominator consensus (e.g., Brown 2007, 2008; ADB 2009; Warner et al. 2009), it seems unlikely to settle the refugee-versus-migrant debate once and for all. Highlighting the plight of islanders made homeless by rising sea levels (e.g., Schmidle 2009; cf. Luetz 2017; Luetz and Havea 2018), the German Advisory Council on Global Change (WBGU 2006) offered the following definition of "sea-level refugees":

> If a state is submerged, its citizens become stateless. 'Refugees from sea-level rise' will probably seek refuge in neighbouring countries, perhaps greatly exceeding these countries' absorption capacities.

> WBGU therefore considers that formal provisions are required to regulate the legal status of these people. [. . .] In line with the non-refoulement principle, . . . states should undertake not to return sea-level refugees to their country of origin if climate change has rendered these countries unsustainable. (WBGU 2006, p. 61)

More recently, Harvard scholars Docherty and Giannini (2009) conceptually defined a "climate change refugee" as:

> [. . .] an individual who is forced to flee his or her home and to relocate temporarily or permanently across a national boundary as the result of sudden or gradual environmental disruption that is consistent with climate change and to which humans more likely than not contributed. (p. 361)

Furthermore, research spearheaded by Biermann and Boas (2010) also came up in support of the "climate refugee" classification, which the authors have enduringly upheld (Biermann and Boas 2007, 2008, 2010). According to their conceptual classification, "climate refugees" are:

> [. . .] people who have to leave their habitats, immediately or in the near future, because of sudden or gradual alterations in their natural environment related to at least one of three impacts of climate change: sea-level rise, extreme weather events, and drought and water scarcity. (p. 67)

Finally, Reeves and Jouzel (2010) have also unapologetically lent support to the "climate refugee" conceptualization in their book entitled *Climate Refugees*, as has Nash (2009) in his documentary by the same name, and Hack (2015, para 1) through his public displays of "world climate change refugee camps" artwork.

In summary, there is no consensus definition on people who are displaced (in full or in part) by the adverse environmental effects brought on by progressive climate change (ADB 2012), leaving a situation that has been described as "confusing" and "unhelpful" (Dun and Gemenne 2008, p. 10). Instead, different normative approaches and agendas have led scholars to propose a vast array of competing conceptualizations and dissimilar definitions.

Agency, Inclusivity, Empowerment: "Nothing About Us, Without Us!"

Importantly, diversity in respect of nomenclature reaches beyond simple semantic preferences as Brown (2008) has emphasized: "which definition becomes generally accepted will have very real implications for the obligations of the international community under international law" (p. 13). Further, given that the word "refugee" is a legal term of entitlement, which bestows privileges of protection that are not claimable by "migrants," IOM and UNHCR have expressly discouraged any extraneous or expansive uses of the term "refugee" so as not to risk undermining the Refugee Convention (UNHCR 1951; Laczko and Aghazarm 2009; CCEMA 2010, p. 5). At the same time, the situation is not remedied simply by using the term "migrant" instead, which appears to be inept in situations where human movement is induced by environmental factors:

> There is no definition of 'migrant' in international law. The only definition that can be found in a universal treaty is that of a 'migrant worker', meaning 'a person who is to be engaged, is engaged or has been engaged in a remunerated activity in a State of which he or she is not a national.' [UNTC 2004] [. . .] At the same time, [. . .] the notion of 'migrant workers' as defined by international law does not really fit, since even if such people find a job abroad, they are primarily in search of protection and assistance and their decision to leave is not just triggered by economic considerations. (Kälin 2010, pp. 89–90)

To synthesize, pilot research (Luetz and Havea 2018) has proposed a shift away from treating climate migrants (however they are to be conceptually classified) as passive consignees of "scholarly labels", to placing them more firmly at the center of the definitional debate. There also seems to be a sense that some islanders may resist the categorization of "climate refugees" (McNamara and Gibson 2009; Luetz and Havea 2018). Furthermore, there are suggestions that "local contexts, dialects and expressions (e.g., "Turangu") have much to contribute terminologically with respect to more appropriately informing the definitional and conceptual constructs of policy and research discourses" (Luetz and Havea 2018, p. 23). Inclusivity in coining conceptualizations has already made advances in discourses about disability, and there is the hope that "inclusion" may be similarly normalized in the climate migration domain: "The 'nothing about us, without us' (Charlton 2000) cry within the disability discourse, calling for representation in a bureaucratic system of oppression and disempowerment, is hauntingly relevant" (Luetz et al. 2019, p. 120).

To conclude, this discourse does not feel comfortable to advance a self-consistent and universally applicable typological nomenclature and rather prefers to advocate conceptual representations that are inclusive, nuanced, and contextually grounded and which involve or even defer to the perspectives and contributions of individuals and communities who migrate for reasons that may implicate climate change. Such a posture of mutuality, inclusion, and cooperation seems to be most conducive to the kind of anticipatory adaptation to climate change envisaged by SDG 13 (UN 2019), especially via Targets 1 and 3 (see section "Introduction"). Such inclusivity seems to be all the more pivotal as "consulting the unconsulted" is increasingly identified in the international development arena as a key concern and success factor for global poverty reduction, social justice, and environmental sustainability education (Chambers 1997; Luetz et al. 2018, 2019; Luetz and Walid 2019).

Legal and Practical Considerations

Leading change in change-resistant institutional environments can be a formidable challenge (Nelson and Luetz 2019). This section will introduce selected legal instruments and frameworks that may apply to people who migrate for reasons related to climate change, including the sections "Geneva Convention Relating to the Status of Refugees," "The Guiding Principles on Internal Displacement," the "United Nations Framework Convention on Climate Change (UNFCCC)," and the two twin global compacts on migration and refugees (section "Global Compact for Migration (GCM); Global Compact on Refugees (GCR)"). The section concludes with a brief synthesis (section "Synthesis").

Geneva Convention Relating to the Status of Refugees

According to the 1951 Refugee Convention (UNHCR 1951), under international law a "refugee" is:

> A person who owing to a well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion, is outside the country of his nationality and is unable or, owing to such fear, is unwilling to avail himself of the protection of that country, or who, not having a nationality and being outside of the country of his former habitual residence as a result of such events, is unable or, owing to such fear, is unwilling to return to it. (1951 Convention relating to the Status of Refugees, Art. 1A(2), 28 July 1951, as modified by the 1967 Protocol)

Accordingly, the Refugee Convention does not offer protection to "climate refugees." Although people who migrate on account of climate change-related causes may very well meet the "well-founded fear" requirement (e.g., Luetz 2018), they are evidently not "persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion" and may also not find themselves "outside the country of [their] nationality" (e.g., Luetz and Havea 2018), to mention only some of the impediments to the legal fit of the term "refugee" in many geopolitical or socioenvironmental contexts. Expressed in simple language, under international law climate migrants do not enjoy the rights and privileges of convention refugees (Myers and Kent 1995; McAdam 2010, 2012). In short, the Convention does not include "any of the myriad factors, including climate change and environmental degradation, that might plausibly be motivating flight" (Stapleton et al. 2017, p. 27).

The Guiding Principles on Internal Displacement

Internally displaced persons (IDPs) are defined as:

> [. . .] persons or groups of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters, and who have not crossed an internationally recognized State border. (Guiding Principles on Internal Displacement, E/CN.4/1998/53/Add.2.)

While acknowledging that the Guiding Principles on Internal Displacement apply relevant aspects of humanitarian law, refugee law, and international human rights law to situations of internal displacement, Stapleton et al. (2017) point out that "this deliberately does not constitute a binding legal norm" (p. 27). Moreover, research by Zetter (2017) supports the synthesis that "in practice, few countries have incorporated these principles into their national legislation or constitutions, and those that have done so rarely implement these principles systematically or with conviction" (Stapleton et al. 2017, p. 27).

United Nations Framework Convention on Climate Change (UNFCCC)

Given the comprehensive role of the UNFCCC in coordinating multilateral international action on climate change mitigation and adaptation [e.g., in 1997 the Kyoto Protocol established legally binding obligations for developed countries to reduce greenhouse gas emissions], some scholars have seen this global convention as aptly suited to provide an appropriate framework architecture for the protection of "climate refugees" or "climate migrants" (e.g., Biermann and Boas 2007, 2008, 2010; Gibb and Ford 2012). Even so, the UNFCCC did not initially include or even envisage "any provisions concerning specific assistance or protection for those who will be directly affected by the effects of climate change" (UNFCCC 2008, p. 1). Recent years have seen limited progress in respect of "Loss and Damage," albeit the Convention pledged in 2015 to "develop recommendations for integrated approaches to avert, minimize, and address displacement related to the adverse impacts of climate change" (UNFCCC 2015, p. 8, para 50). The IOM has summarized progress as follows:

> The United Nations Framework Convention for Climate Change (UNFCCC) first recognized the growing importance of human mobility with the adaptation of the 2010 Cancun Adaptation Framework. When the 2015 Paris Agreement was adopted during the twenty-first Conference of Parties in Paris (COP21), climate migrants were finally rendered visible within the wider international policy arena. IOM has been actively engaged in the UNFCCC process since COP14 in Poznan in 2008, advocating for the recognition of migration and displacement dimensions in policy discussions on climate change. (EMP n.d., para 2; cf. UNFCCC 2015)

Stapleton et al. (2017) have synthesized that the Conference of the Parties in Paris (COP21) has resulted in the establishment of a Task Force on Displacement (TFD), which the authors consider "a significant step forward [... given that it] includes representatives from UNHCR, UNDP, the International Organization for Migration (IOM), the International Federation of the Red Cross and Red Crescent Societies (IFRC), the Platform on Disaster Displacement and the UN Advisory Group of Climate Change and Human Mobility" (p. 25). Other UNFCCC-linked initiatives include the Agenda for the Protection of Cross-Border Displaced Persons in the Context of Disasters and Climate Change (Nansen Initiative 2015), the Sendai Framework for Disaster Risk and Reduction 2015–2030 (UNISDR 2015), and the United Nations Convention to Combat Desertification (UNCCD n.d.).

In summary, it appears questionable, at best, that the UNFCCC will emerge as the predominant international framework of choice to govern climate change-related human migration.

Global Compact for Migration (GCM); Global Compact on Refugees (GCR)

The 2016 UN Summit for Refugees and Migrants in New York resulted in a pledge by states "to work towards two Global Compacts, one on migration, the other on refugees" (Stapleton et al. 2017, p. 27). The Global Compact for Migration (GCM 2018) was finalized in July 2018 and is considered to be "the first, intergovernmentally negotiated agreement, prepared under the auspices of the United Nations, to cover all dimensions of international migration in a holistic and comprehensive manner" (UN 2018a, para 1). The Global Compact on Refugees (GCR 2018) was finalized in June 2018 (UN 2018b) and recognizes that "[w]hile not in themselves causes of refugee movements, climate, environmental degradation and natural disasters increasingly interact with the drivers of refugee movements" (GCR 2018, p. 3, (iv) para 8). Although the GCR considers countries of origin primarily responsible for addressing the root causes of refugee movements, it concedes that "averting and resolving large refugee situations are also matters of serious concern to the international community as a whole, requiring early efforts to address their drivers and triggers, as well as improved cooperation among political, humanitarian, development and peace actors" (GCR 2018, p. 3, (iv) para 8).

Despite hopes that these twin compacts may result in more practical support for climate migrants, Stapleton et al. (2017) have cautioned that the GCM "is not binding and does not as yet include a framework for implementation. It remains to be seen what impact it will have on individual state policies" (p. 27). Contrastingly, the authors note that the GCR:

> is pointedly not tasked with opening up debate on the scope of the 1951 Convention or the mandate of UNHCR. Moreover, the decision to establish two separate compacts on refugees and migrants risks perpetuating a conceptual and organisational distinction between 'forced' and 'voluntary' flight that fails to reflect the fluid and complex reality of contemporary population movements, both within countries and across borders, incorporating 'voluntary migrants, putative refugees, former IDPs, other forcibly displaced people and trafficked and smuggled persons', often using the same routes and heading for the same destinations. (Stapleton et al. 2017, p. 27; attributed to Zetter 2017, pp. 23–28)

Synthesis

Given that there is no one-size-fits-all applicable legal framework and migration regime, people who migrate for climate change-related reasons are not uniformly and equitably assisted by the international community (Biermann and Boas 2010; Ahmed 2018). Stapleton et al. (2017) have aptly summarized the situation as follows:

> The conceptual framework and organisational architecture around migration and displacement are embedded within an international response machinery developed over seven decades, and any efforts to produce an approach more reflective of the complexity of contemporary displacement will face probably intractable political and institutional opposition. (p. 27)

There is also a sense that climate migrants may be most clearly classified as being in need of protection primarily *after* a desperate environmental situation spirals into violent chaos, given that such conditions are most conducive to fostering and sustaining the kind of clear-cut "persecution" identified in the Refugee Convention (UNHCR 1951). There may thus be a perverse incentive to wait for a situation to worsen (because there are initially no adequate legal instruments to address the situation preemptively) and deal with it chiefly after it has erupted into full-blown violence, armed conflict, and "persecution" (because legal instruments are now in place that squarely fit the bill). The "climate change-collective violence" nexus is well-established in the literature, and there are indications that recent humanitarian-scale refugee movements have been, at least in part, fuelled by climate change-related causality (Breisinger et al. 2013; Wendle 2016; Levy et al. 2017; cf. Ahmed 2018). Hence the case to assist early, proactively, and preemptively remains clear and compelling.

In summary, although recent notable progress has been made to recognize climate migration in international legal frameworks, there is still a lingering sense that "forced climate migrants fall through the cracks of international refugee and immigration policy. There is no 'home' for forced climate migrants, either literally or figuratively" (Brown 2008, p. 36).

Concluding Synthesis: Migration as Adaptation to Climate Change

Discourses about climate change and human migration (CCHM) are typically characterized by theoretical, conceptual, legal, and practical considerations, among others. In respect of theoretical and conceptual issues, this chapter canvassed both definitional and terminological challenges and opportunities (section "Conceptualizing Climate Change-Related Human Migration"). Zetter (2007) argues that the concept of labelling reflects a "political discourse of alienation and resistance to refugee claims [where] legitimate and objective processes are in fact pernicious tools which fraction the claim to a fundamental human right" (p. 188) and that labelling creates "convenient images, while keeping the refugees and other dispossessed people at a distance" (p. 190). While the absence of a universally agreed nomenclature is noted by scholars as a well-known challenge, pilot research (Luetz and Havea 2018) has suggested a shift away from treating climate migrants (however they are to be classified) as passive consignees of "scholarly labels," to placing them more firmly at the center of definitional discourses and deliberations. Inclusivity in respect of coining conceptualizations has already made inroads in discourses about disability, and there is now the opportunity that this may be similarly normalized in the scholarly climate migration space (Luetz et al. 2019). Furthermore, there are suggestions that "local contexts, dialects and expressions (e.g., 'Turangu') have much to contribute terminologically with respect to more appropriately informing the definitional and conceptual constructs of policy and research discourses" (Luetz and Havea 2018, p. 23).

In respect of legal and practical issues (section "Legal and Practical Considerations"), the multiplicity of diffuse frameworks and migration regimes seems to frustrate the attempts by diverse stakeholders who seek to straightforwardly assist climate migrants with clear-cut systems, mechanisms, and approaches (Ahmed 2018). Even so, studies and publications point to promising new perspectives and initiatives. For instance, there are indications that the preparedness paradigm long embraced by the disaster management community, which values proaction over reaction and preparing over repairing (Luetz 2008, 2013; UNISDR 2011, 2015; IPCC 2012), is also increasingly gaining currency in CCHM discourse, as evidenced by case study research in the Maldives (Luetz 2017) and Bangladesh (Luetz 2018; Luetz and Sultana 2019) and a "Toolbox" for planned relocations (UNHCR 2017). Given that Targets 1 and 3 of SDG 13 explicitly envisage anticipatory adaptation to climate change (UN 2019, cf. Section 1) makes the proactive engagement of human development actors in the CCHM space a fertile climate change adaptation objective (EC 2019). This offers clear benefits in respect of supporting climate change-related migration as a favorable form of adaptation to climate change (IOM 2010; Luetz 2013; Jha et al. 2018). To conclude, "migration should not be treated as a failure to adapt locally; rather, it should be well accepted as a survival strategy" (Ahmed 2018, p. 15; attributed to Siddiqui et al. 2014).

Cross-References

► Climate Refugees: Why Measuring the Immeasurable Makes Sense Beyond Measure

Acknowledgments Grateful acknowledgment for essential support is made to the University of New South Wales (UNSW) and the development organization World Vision International (WVI).

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Climate Change and Migration in Coastal Areas in South Asia

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Definitions

Climate Change and Migration

Confusion and contention has surrounded the debate about defining the terms that describe migration caused by climate change. The reason might be attributed to global politics, because it is impossible to address this issue without political considerations; to intellectual conflict, that is, whether the discourse takes place within natural, social, or political science; or to the scarcity of significant empirical evidence (Piguet et al. 2011; McCarthy et al. 2001). Therefore, the two most relevant and widely cited institutions – the Intergovernmental Panel on Climate Change (IPCC) and the International Organization for Migration (IOM) – have used the term "environmental migration" to describe migration that has been triggered either directly or indirectly by climate change and label it as one of the subsets of human mobility behavior. The IPCC (2018) identifies migration as environmental "where environmental risks or changes plays a significant role in . . . the migration decision and destination." Such migration may occur due to transformations in the environment that negatively impact the lives and livelihood of a population (IOM 2014). This migration could be of any form: temporary or permanent, planned or forced, local or international. In any case, it is neither meaningful nor possible to isolate environmental factors from other factors of migration, as all migration decisions are inevitably multicausal (IPCC 2014). Therefore, in this entry, the terms "climate migrant(s)" and "climate change migration" are used to denote any kind of human mobility caused by climate change or its direct or indirect effects.

South Asia (Fig. 1)

According to the World Bank, South Asia comprises eight countries. The region is bounded by Afghanistan and Pakistan in the west, Bangladesh in the east, Bhutan and Nepal in the north, and the islands of the Maldives and Sri Lanka in the south, including India. Of them, Afghanistan, Bhutan, and Nepal are landlocked countries. This region is limited by the Himalayas in the north and by the Bay of Bengal and the Indian Ocean in the south. South Asia is well known for the three major rivers that have shaped human civilization there: the Ganges, the Indus, and the Brahmaputra. This region is one of the most highly populated and fastest-growing economies in the world and exhibits rapid urbanization and industrialization (World Bank Group 2019).

Introduction

South Asia is considered one of the most environmentally vulnerable regions due to its geographical and socioeconomic characteristics. Its geographical location and physiographic characteristics may exacerbate the effects of climate change: low elevations and increased glacier melting in the Himalayas could result in more severe river flooding, and the rising sea level could cause salinity intrusion in the coastal areas and islands (Nicholls et al. 2016). Moreover, in the midlands, dry-season water crises could substantially increase in severity due to fewer rainy days coupled with higher temperatures (Ahmed and Suphachalasai 2014). Several studies have noted that while South Asia has limited climatic differences compared with other international regions, the area is most vulnerable because of its socioeconomic conditions (Haque 2005; Hugo 2010; DECCMA 2018; Rigaud et al. 2018). High poverty rates, a high dependence on agriculture, and insufficient infrastructure together with poor governance foster climate change vulnerability in the region. In addition, climate change could affect food security, impacting agricultural capacity and the individuals who rely on agriculture for their livelihood. All these factors, directly and indirectly, influence human migration, especially to cities and safer locations. Yet the people of this region are often hailed as the global leader in climate action; for example, Bangladesh is often praised as a global leader for its practices of climate change adaptation, and Bhutan is the only carbon-negative country in the world, leading the climate mitigation movement (Huq et al. 2003; National Geographic Society 2017).

The coastal areas of South Asia have extraordinary significance because of their ecological richness (e.g., the largest continuous stretch of mangrove, the largest sea beach, densely populated islands), their role in the economy (both production and trade), the livelihoods they support (especially through agriculture, fisheries, and tourism), and their recreational value (Neumann et al. 2015). The coastal areas of South Asia comprise less than 2% of the global coastline, yet they supports a population of 1.9 billion, which is projected to increase to 2.3 billion by 2050 (Rigaud et al. 2018). Geographically, the South Asian coastal region is vulnerable to climate change because of rising sea levels, extreme climatic events, and its high population density.

Climate Change and Migration in Coastal Areas in South Asia, Fig. 1 Map of South Asia. (Source: United Nations 2011)

Several studies have argued that climate change impacts may cause displacement of a large percentage of this coastal population (Siddiqui 2014; Martin et al. 2014; Nicholls et al. 2016; Chen and Mueller 2018).

This entry addresses the factors affecting migration induced by climate change among the coastal population of South Asia, as well as the consequences of migration. We begin by analyzing recent literature to address how the region is experiencing changes in climate parameters and then outline and predict its multidimensional impacts. Then, we focus on both the biophysical and socioeconomic vulnerabilities of the region. Finally, we conclude with a discussion on the role of climate change in the migration of the coastal population and suggest potential implications of such migrations at the local and regional scale.

Present and Future Climate Change Scenarios in South Asia

Here, we will outline the regional climate change scenario in South Asia, as well as the vulnerabilities, as the basis for further discussion about the migration that might occur as a result. The study by Ahmed and Suphachalasai (2014) found that the observed warming trend of the South Asian region is consistent with the global trend of rising atmospheric temperature. The average temperature in this region increased in the past at a rate of about 0.75 °C per century. The study also argues that the warming rate has been relatively higher in the winter (0.91 °C per 100 years) and pre-monsoon season (0.77 °C per 100 years). The regions of western Afghanistan and southwestern Pakistan have experienced the largest increase in temperature (1.0–3.0 °C); however, in the coastal areas the change was slightly lower (1.0–1.5 °C) (Mani 2018). Unlike other regions around the world, the South Asian region did not show any clear trend in the change of annual rainfall in the last century. However, there was significant variation in rainfall for the monsoon season, especially the duration and number of rainy days (Ahmed and Suphachalasai 2014). Additionally, the sea level has been rising at a rate of 3.1 mm per year over the past decade, compared with the 1.7–2.4 mm per year rise of the twentieth century in Asia (Rigaud et al. 2018).

A significant number of studies have warned that future climate change will be more pronounced in the South Asian region in the twenty-first century than it was in the twentieth (Piguet et al. 2011; Asian Development Bank 2012). The temperature will increase at a faster rate, and the rainfall anomalies may be more frequent. Table 1 shows the predicted change in climatic conditions (temperature change and precipitation departure) in South Asian countries for 2080 from a 2000 baseline under the IPCC A1B emission scenario (Fig. 2).

The study estimates a steady increase in the atmospheric temperature in South Asia, nearly 4–5 °C, with more anomalies at the end of the twenty-first century for high-emission scenarios (Ahmed and Suphachalasai 2014). By that time, the mean surface temperature will also rise about 3–5 °C, which may be more pronounced over western and central India. Unlike the temperature, the changes in rainfall may not be consistent across periods or seasons (Ahmed and Suphachalasai 2014). Bangladesh, the Maldives, and Sri Lanka are predicted to experience increased annual rainfall. However, Preston et al. (2006) and Hugo et al. (2009) have predicted there might be greater variability in rainfall during the summer and monsoon seasons and a declining trend in winter rainfall. Rainfall variability both within the rainy season and between years is projected to rise in the future (Rigaud et al. 2018). Below, we will discuss how these changes in climatic parameters will play a crucial role in upsetting the life and livelihood of the population living in the coastal areas of South Asia.

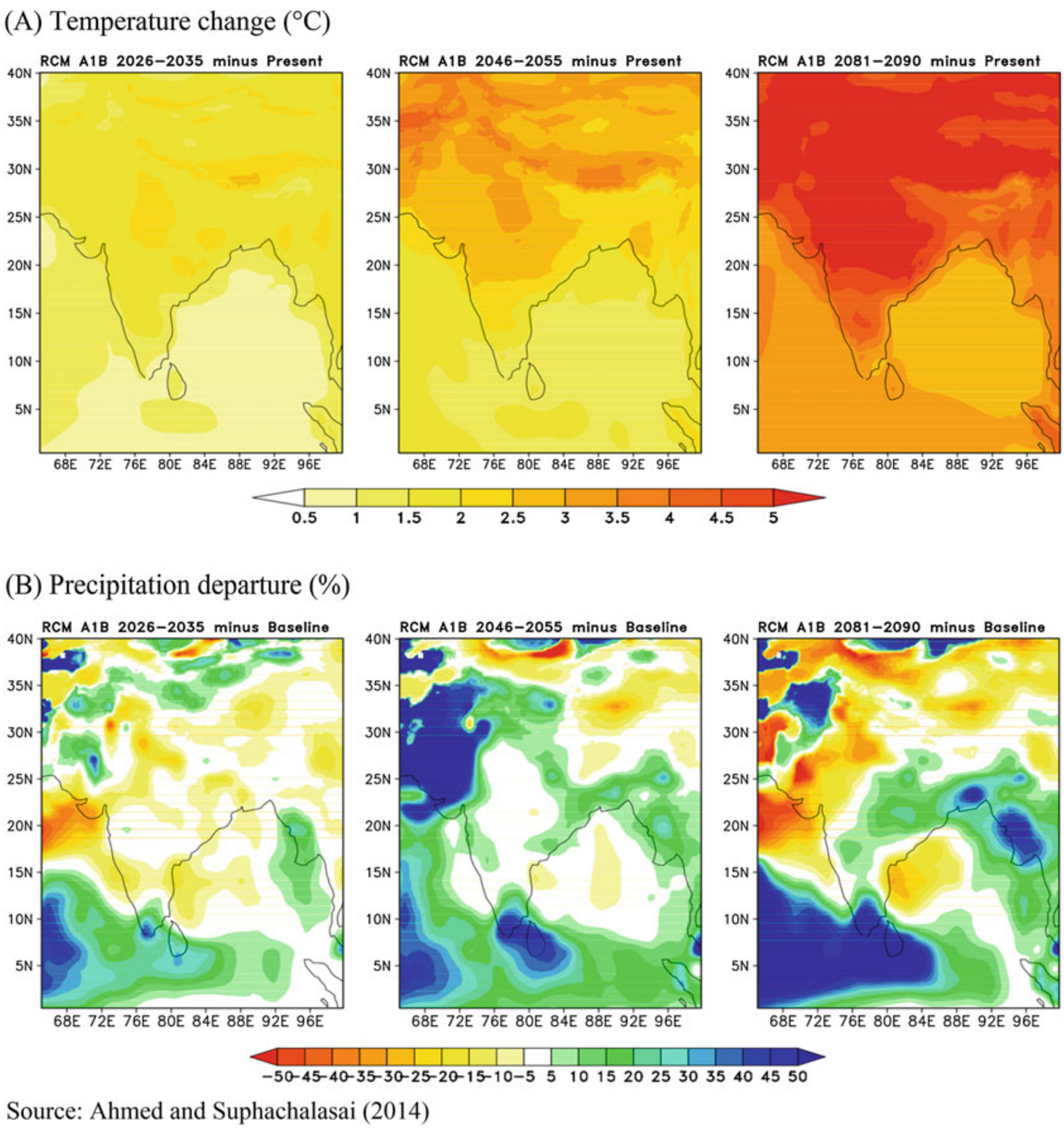
Climate Change and Migration in Coastal Areas in South Asia, Table 1 Temperature change and precipitation departure in South Asian countries for 2080 from 2000 baseline, under IPCC A1B scenario emission scenario

Country	Temperature change (°C)	Precipitation departure (%)
	A1B	A1B
Bangladesh	4.2	15.4
Bhutan	4.4	0.1
India	2.8–6.2	−42.5 to 28.7
Maldives	3.2	30.5
Nepal	5.0	0.0
Sri Lanka	3.3	35.5

Source: Ahmed and Suphachalasai (2014)

Climate Change Impact and Vulnerability of the Coastal Areas of South Asia

South Asia is regarded as one of the global climate change “hotspots” because of its high exposure to climatic stresses along with its high level of vulnerability. The uncertainty and increasing trends in temperature and extreme weather events, along with floods and cyclones, are creating a growing number of climate-vulnerable areas in this region (Rigaud et al. 2018). The climate change vulnerability can be divided into two categories – biophysical vulnerability and socioeconomic vulnerability. Biophysical vulnerability is caused by changes in climatic parameters and the resulting extreme weather events. Socioeconomic vulnerability results from the poor condition of socioeconomic parameters like income level, poverty, educational level, social capital, and social networks. Thus, climate change vulnerability is the net outcome of both – the former related to risk and the latter related to adaptive capacity. Therefore, the overall climate change vulnerability and its results cannot be singled out as functions of changes in climate; rather, it depends on the socioeconomic situation and the resources, the sociocultural context, and the quality of governance and security (Hugo 2010). Further discussion below elaborates on how biophysical and socioeconomic vulnerabilities influence migration.



Climate Change and Migration in Coastal Areas in South Asia, Fig. 2 Spatiotemporal change in temperature (**a**) and precipitation departure (**b**) in South Asia from 2000 baseline, under the IPCC A1B scenario emission scenario (The A1B is one of several future greenhouse-gas-emission scenarios. It describes a future world of very rapid economic growth, global population that peaks in the mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income and a balanced use of technology in the energy system across all sources (A1B) (Nakicenovic et al. 2000).). (**a**) Temperature change (°C). (**b**) Precipitation departure (%). (Source: Ahmed and Suphachalasai 2014)

The Biophysical Vulnerability of South Asia

There are several dimensions to the already-experienced and anticipated biophysical vulnerabilities from climate change in South Asia. The most critical and complex threat from climate change is its impact on the region's water ecosystem. Increased temperatures in the winter and pre-monsoon season could potentially create severe water stress, especially in India and Pakistan. The declining flow of water from the mountain glaciers could also result in the scarcity of fresh water, especially in India, Bhutan, and Nepal. The annual runoff from the Indus River could decrease by 14% and 27% in the Indus and Brahmaputra (region) by 2050 (McCarthy et al. 2001). There is also increasing concern about the availability of fresh water in the islands. Water for streams (especially those of islands) is highly dependent on a sufficient supply of highland precipitation, and thus rainfall variability could modify the current supply of fresh water.

Contrary to the early model-based claims of climate scientists, recent analyses have found that saltwater intrusion could be the biggest threat for this region in the near future (Nicholls et al. 2016; Chen and Mueller 2018). The climate change basis of this coastal hazard originates from the reduced water and sediment supplies from the Himalayan mountain range. Dasgupta et al. (2015) estimated that changes in salinity may reduce the freshwater supply from 40.8% to 17.1% in the rivers of coastal Bangladesh and that the percentage of suitable space for agricultural irrigation may decrease by 29.7% by 2050. Furthermore, the Maldives and Sri Lanka are also at risk for saltwater intrusion (Kelkar and Bhadwal 2007). This slow-onset process could modify the coastal ecosystem, decrease soil fertility and therefore crop production, cause human health hazards, and threaten livelihoods. The evidence for such vulnerability is already evident in the mangrove forests of India and Bangladesh.

The region is also prone to a number of coastal natural hazards, especially riverine and tidal flooding, cyclones, storm surges, erosion, waterlogging, and drought. Sea level rise (SLR) poses a significant threat for this region, especially the deltaic areas of the Ganges–Brahmaputra, the Mahanadi, the Godavari, the Krishna, and the Indus Rivers (Hugo 2010). Low-lying islands of the Bay of Bengal and the Indian Ocean are also regarded as vulnerable to SLR, high-intensity cyclones, and storm surges (Siddiqui 2014). Climate change is expected to increase both the number and intensity of floods and storms (Asian Development Bank 2012). The coastal areas of Bangladesh (Barisal, Khulna, and Chittagong), India (such as West Bengal and coastal areas, including Chennai and Mumbai), and southern Pakistan (coastal Karachi) have already proven to be prone to significant coastal flooding. In contrast, the landlocked northern regions of South Asia suffer from the uncertainty of precipitation, glacial melts, floods, and landslides.

In the coastal areas of South Asia, mangroves and coral reefs are the two of the most vital components of the coastal ecosystem, and they are already suffering the consequences of climate change. Climate change will affect the vegetation, productivity, and biodiversity of these ecosystems. Therefore, based on the biophysical vulnerability, several climate change hotspots can be identified within this densely populated region of South Asia:

1. Riverine deltas of Bangladesh, India, and Pakistan
2. Highlands of Bhutan, India, Nepal, and Pakistan
3. Arid and semiarid regions of India and Pakistan
4. Islands and coral reefs of Sri Lanka, Maldives, India, and Bangladesh
5. Low-lying coastal regions of Bangladesh, India, and Pakistan

The Socioeconomic Vulnerability of South Asia

South Asia, one of the most vulnerable regions to climate change in the world, is home to one-fourth of the world's population (Eckstein et al. 2017). Its vulnerability is the result of not only the geographical location and characteristics of the region but also its social, economic, institutional, and political conditions. The socioeconomic vulnerability of this region can be attributed mainly to the high population density, dependency on a subsistence economy, and poor governance. However, natural disasters are historically considered responsible for the poor economic growth of this region. From the earlier discussion, we note that South Asia has experienced climate change patterns and impacts similar to or worse than the global scenario.

South Asia is one of the most underdeveloped regions in the world, with an average per capita GDP of US$1,840 (2017), much lower than the global GDP of US$10,714 (World Bank Group 2018a). The poverty rate is also very high in this region (16.2% of the total population). Similarly, its poor position on the Human Development Index (HDI) can be used as a proxy to understand the magnitude of the region's very low resilience to climate change impacts (Table 2).

According to the World Bank Group (2018a), about 26.5% of the global employment is in the agricultural sector, while in South Asia, the proportion is approximately 43.1%, although this rate differs significantly from country to country: in the Maldives, 7.65% of the country relies on agriculture, whereas in Nepal, 72.28% does (World Bank Group 2018a). Because climate change could directly affect agricultural productivity, the population that relies on agriculture could experience loss of income and employment.

A recent study shows that climate change may reduce food production in India by 20% by 2030 and 30% by 2050 (Édes et al. 2012). With a 1 °C increase in temperature, wheat yields will decrease by 6–9% in the arid, semiarid, and subhumid regions of Pakistan (Sultana and Ali 2006). In Sri Lanka, rice production is predicted to drop 6% with only a 0.5 °C increase in temperature; increased temperatures will also adversely affect the production of tea, rubber, and cotton, which are the most important products of the Sri Lankan economy (MENR 2000; Hirji et al. 2017). All these risks of lower agricultural production could make it difficult for a vast amount of the population to have an adequate supply of food.

Climate Change and Migration in Coastal Areas in South Asia, Table 2 GDP from and employment in agriculture and HDI of South Asian countries

Region	% of GDP from agriculture (2016)[a]	% of employment in agriculture (2016)[b]	HDI (2017)[c]
World	3.55	26.76	
South Asia	16.71	43.88	
Afghanistan	20.97	61.35	168
Bangladesh	14.05	41.14	136
Bhutan	16.52	56.78	134
India	16.29	43.44	130
Maldives	5.88	7.65	101
Nepal	29.17	72.28	149
Pakistan	23.22	42.27	150
Sri Lanka	7.48	27.52	76

Source:
[a]World Bank Group (2018b)
[b]World Bank Group (2018c)
[c]Neumann et al. (2015)
[d]UNDP (2017)

Human Migration in South Asia

Human migration usually results from a complex, multi-criterion decision-making process that operates across different spatial and temporal scales and domains. Although the main driver of migration in South Asia is uneven economic development across the region, environmental factors are important and can influence the scale and pattern of the migration process (Seto 2011). Migration, over both long and short distances, has always been a part of peoples' lives in South Asia, originating from efforts to reduce the risk from reoccurring natural disasters and agrarian crises (Van Schendel 2009). Additionally, both voluntary and involuntary migration has taken place here in response to political changes (e.g., colonization and decolonization, wars, riots) and for religious and ethical reasons (Van Schendel 2009). The largest migration took place during the decolonization period of 1947–1948 in the Indian subcontinent. However, during recent times, migration in this delta has been predominantly shaped by economic effects. Recently, conflict and political migration have become a major source of concern in this region. Climate change and environmental stresses are also shaping migration, mainly by affecting peoples' livelihoods (DECCMA 2018). In 2016, about 3.6 million new internal displacements occurred in South Asia due to disasters (IDMC 2017). Moreover, India, Bangladesh, and Sri Lanka were among the top ten countries in the world for disaster-related displacements in 2017 (IDMC 2017).

Internal migration in the South Asian countries can be characterized mainly as rural-to-urban in nature. In recent times, this type of migration has been the center of policy discourse, because of its high visibility and impact on urbanization and industrialization. Rural poverty, landlessness, and the crises in livelihood and employment opportunities push rural people to move from their homeland. Urban areas, especially the large centers, offer diversified economic opportunities as hubs of economic growth and prosperity for their countries. South Asian countries are experiencing rapid urbanization along with industrialization, and manufacturing sectors have a significant number of jobs, especially for the unskilled poor; thus, the urban areas have become a common destination for poor rural migrants. Migration statistics show that about one in every five persons has moved away from their birth district in South Asia.

Climate Change and Migration in Coastal South Asia

Almost three decades ago, in 1990, the IPCC suggested that the most significant effect of climate change will be migration, which will displace millions of people worldwide. Climate change is expected to trigger human mobility through both sudden and slow-onset atmospheric and hydrological events and mechanisms. Therefore, it is likely to reduce the security of people's livelihoods in certain environments, and that process may encourage people to migrate. Migration on a permanent and temporary basis has always been one of the most critical survival strategies adopted by people in the face of natural or anthropogenic disasters Smith P (2007). However, there is a debate about whether such migration is a successful adaptation option or not (Bhagat 2017; DECCMA 2018).

First of all, we need to accept that climate change cannot be the prime cause, nor even one of the top causes, of migration in the South Asian region. Migration behavior is predominantly driven by economic reasons here, and climate change factors usually act in conjunction with a range of other socioeconomic elements (DECCMA 2018; Hugo 2010). For example, climate change could contribute to migration by undermining livelihoods and security, primarily by exacerbating economic inequalities (UNHCR 2008; Piguet et al. 2011). For this reason, the vast amount of modern migration literature finds it difficult to separate environmentally caused and non-environmentally caused migration (Seto 2011).

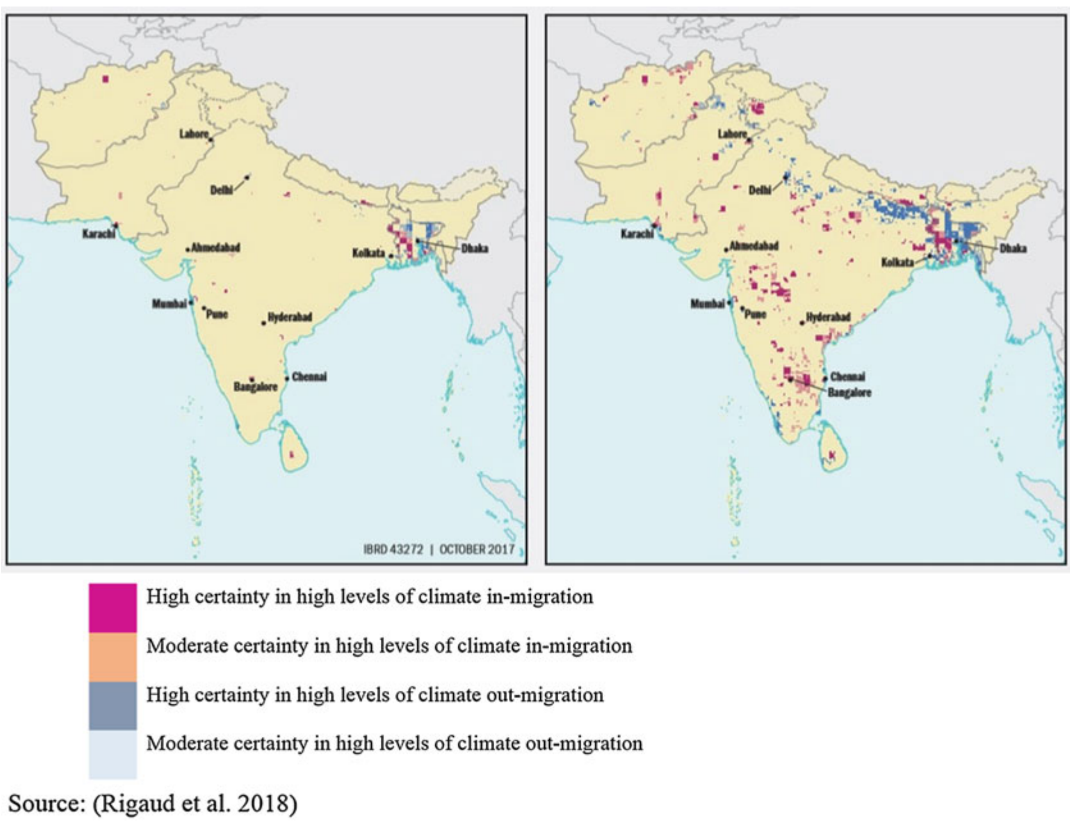
It is also challenging to find direct links between migration and rapid-onset phenomena like tropical cyclones, storms, torrential rains, and floods. And for the cases of permanent and long-range migration, determining the links is next to impossible (Nicholls et al. 2016). Drought and desertification play an unpredictable and contextual role in triggering migration because of their effects on agricultural productivity through water stress. In contrast, sea level rise (SLR) and its secondary effects (higher tides, salinization, coastal erosion) have a clear connection with and a strong potential to cause migration (Piguet et al. 2011). Salinity and its impacts on agricultural production, along with catastrophic disasters like cyclones, storms, and floods, are driving human migration (Nicholls et al. 2016).

Keeping in mind recent statistics, we would like to know how the coastal population is affected by climate change. For example, a significant portion of the rural coastal population of South Asia is dependent on marine fisheries for their livelihood, and climate change is threatening this sector (World Bank 2009). In the Maldives, the coral reefs and the baitfish stocks in the reefs are threatened by ocean acidification and increased temperature effect of climate change, which in turn has reduced marine fish production (World Bank 2009). These events could easily create a cascading effect on the lives and livelihood of the dependent population, forcing them to change occupations or migrate.

Studies have also found that migration in South Asia is generally directed from rural to urban areas and that these migrants frequently move to neighboring districts rather than undertake long-distance relocation (Haque 2005; Siddiqui 2014; Davis et al. 2018). Instead of large metropolitan areas, migration toward nearby small-to-medium-size urban areas is an increasingly common trend, predominantly for individuals seeking to maintain their livelihoods (DECCMA 2018). A recent study by the Nazrul

Islam Urban Studio at the University of Dhaka (2018, unpublished) on the Dhaka Metropolitan Region of Bangladesh found that approximately one-fifth of migrations are climate induced (both directly and indirectly). Among them, more than half of the migrants come from 10 coastal districts (out of the 18 costal districts) of Bangladesh. Most of the migrants were previously involved in subsistence activities for their livelihoods. The study found that 40% of the climate migrants were involved in agriculture and fisheries before leaving their place of origin. Additionally, more than 80% of migrants say that poor resilience to climate change coupled with their poor economic condition forced them to leave their birthplace. DECCMA (2018), in contrast, found that only 2.87% of coastal migrations are solely environmentally induced (Fig. 3).

The largest number of people affected by climate change will be mainly in South Asia due to its high population density and underdeveloped economy (Fang et al. 2014). Under different scenarios, by 2050 in South Asia the projected internal climate migration could be as high as 40.5 million, with the lowest estimate at 16.9 million (Rigaud et al. 2018). This will constitute 0.75–1.56% of the total population, up to 25% of all migrants in this region (Rigaud et al. 2018). The highest portion of this migration will occur from the coastal areas of Bangladesh. Davis et al. (2018) predict that 0.9–2.1 million people could be displaced in Bangladesh just by direct inundation caused by SLR. By 2050, the coastal population of South Asia is predicted to grow 3–66% compared to the population in 2000 under different demographic scenarios (Merkens et al. 2016). During the second part of the century, this growth is predicted to slow down, whereas coastal land area will increase from the accretion of the sediment (Merkens et al. 2016),



Climate Change and Migration in Coastal Areas in South Asia, Fig. 3 Climate migration hotspots that are expected to have high levels of migration in South Asia by 2030 and 2050. (Source: Rigaud et al. 2018) to which more people will relocate. Thus, the population growth pattern indicates that in the future more people will be vulnerable to the climate change, and the migration rate could increase substantially.

Impact of Climate Change Migration in South Asia

Climate change migration in South Asia could have substantial implications for economic and human development. However, the effects of this migration depend largely on whether it is voluntary or not. Unfortunately, a large portion of environmental migration is involuntary and thus found to be less beneficial for the migrants themselves (DECCMA 2018).

Debate is growing about the impact of migration on both the origins and destinations of the migration. Additionally, in developing regions like South Asia, the migrants do not always sever their attachment from their birthplace. In most cases, they leave their family members behind and send back money to support them. There is also some evidence that when living and working in another place, especially in the cities, temporary migrants invest in their homeland to build assets (World Bank Group 2019). Thus, migration can be considered as a way of reducing poverty or improving economic conditions. In the long run, such migration could reduce the pressure on resources in the home districts and bring economic benefit to them; therefore, migration may offer support for community members who stay behind (Hugo 2010).

Large cities could benefit from the migration process because these migrants meet the demand for cheap labor for industrial development and urbanization. Moreover, because the informal economy predominates in South Asian cities, city dwellers receive those services from the migrants at a cheap price. Rapid urbanization due to migration is also creating severe pressure on city infrastructures and services, which can have an adverse effect on the quality of life (Hossain 2018). In the rural areas, however, the economy faces a severe labor crisis as the working-age population moves out. The lack of labor in the high-demand seasons there increases production costs for both the agricultural and non-agricultural sectors.

In addition, lending labor to other cities or other countries via temporary migration primarily in response to the slow-onset environmental deterioration is one of the common coping strategies practiced in rural South Asia. For example, as a result of SLR, the destination locations in Bangladesh can anticipate additional demands for 594,000 jobs and 197,000 housing units by 2050 (Davis et al. 2018). However, because the labor force is the first to migrate to accommodate changing environmental or economic difficulties, migration can influence the local labor supply, particularly in agriculture. Therefore, the subsistence economy of the location of origin is influenced by this labor shift toward urban areas, which subsequently encourages stagnation at the origin.

Conclusion

It would be wise to incorporate the implications of climate change migration in all economic and human development policies. Following the philosophy of transformative development, the emphasis should be on assisting the community to make proper migration decisions, further streamlining the migration process and helping both migrants and nonmigrants. Any attempt to forcibly stop this migration may not turn out to be good for the growing economy of this region. Therefore, the real challenge is to maintain and, where possible, increase the productivity and resilience of the biophysical systems and community, both at the destination and origin of migration. Additionally, properly addressing climate change regionally and locally is of the utmost importance to minimize the growing tension in South Asia over migration. Last but most important, priority should still be given to climate mitigation, because adherence to the UN's Paris Agreement to substantially cut the greenhouse gas emissions could reduce up to 72% of the climate migration in this region.

Cross-References

- ▶ Climate Change Adaptation (CCA)
- ▶ Climate Change and Human Migration as Adaptation: Conceptual and Practical Challenges and Opportunities
- ▶ Climate Change Effects on People's Livelihood
- ▶ Climate Change Impacts and Resilience: An Arctic Case Study
- ▶ Climate Change Mitigation and Adaptation: Role of Mangroves in Southeast Asia
- ▶ Climate-Induced Displacement and the Developing Law
- ▶ Community Planning Opportunities: Building Resilience to Climate Variability Using Coastal Naturalization
- ▶ Gendered Impacts of Climate Change: The Zimbabwe Perspective
- ▶ Making Communities Resilient to Global Climate Change
- ▶ Sociocultural Impact of Climate Change on Women and the Girl Child in Domboshawa, Zimbabwe

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Climate Change and Water Management: Non-viability of Freshwater Irrigation in Viticulture

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Definitions

- **Dry farming** (also referred to as dryland farming) is the practice of retaining moisture from winter rainfall in the soil so to sustain the plant during its growing season in arid regions without irrigation.

- **Water footprint** measures the amount of water used to produce a good, service, or crop. It is comprised of **green** (rainfall), **blue** (freshwater, surface and ground), and **gray** (recycled) water. ***Terroir*** is the term used in the wine industry to denote the taste of a wine's climatic specificity (soil type, exposition (elevation and slope), grape variety).
- ***Vitis vinifera*** is a species of *Vitis*, the common grape vine that is indigenous to Europe and the Mediterranean region, central Europe, and south-western Asia.
- **Old World** refers to the *Vitis vinifera's* indigenous regions, primarily in Europe.
- **New World** refers to the countries where the *Vitis vinifera* was transported via migration, such as the USA, Chile, Argentina, South Arica, Australia, New Zealand, and Canada.

Introduction

As the world's water wars wage on, it is critical to examine the incidence of irrigation use in wine grape production as a climate change adaptation strategy versus the need for the sector to implement dry farming as its primary mitigation strategy. It is interesting to note that this thirsty $300 billion industry (Wine: Global Industry Almanac 2012) has escaped scrutiny in the global water competition debate, especially as it is an international sector capable of immediate and significant climate action. "The link between social systems and food production systems in the context of wine production has become a tenuous one. Vineyards are often portrayed as glamorous holiday destinations as opposed to places of agricultural production or as factories implementing highly-advanced technology. The consumer regards wine production as a benign "past-time", heavy with emotional attachments to historical and cultural allegories" (Johnson-Bell 2017). This blurs the causal link between the soil and the bottle. Wine is made from grapes (*Vitis vinifera*) and wine grapes are a luxury fruit crop. Indeed, they are the most important fruit crop in the world in terms of production and economic importance (Cramer et al. 2006; Vivier and Pretorius 2002) as well as being the fruit crop the most susceptible to climatic changes (Mozell and Thach 2014). History has shown that wine production occurs in relatively narrow geographical and climatic ranges. In addition, "wine grapes have relatively large cultivar differences in climate suitability, further limiting some wine grapes to even smaller areas that are appropriate for their cultivation. These narrow niches for optimum quality and production put the cultivation of wine grapes at greater risk from both short-term climate variability and long-term climate changes than other broader acre crops" (Jones and Alves 2011).

Wine and water use, then, is a relevant and useful test case for establishing sustainable water use in agriculture and water use as a whole. "Water is at the heart of adaptation to climate change, serving as the crucial link between the society and the environment" (United Nations 2018). Any climate action that assists in mitigating its waste is essential. Where "irrigated agriculture remains the largest user of water globally, accounting for 70% of global water abstraction" (OECD 2012), wine's average global water footprint may not be enormous compared to other crops, or even to other luxury crops, but its blue water (freshwater) use is disproportionate to its overall production values. Where luxury crops such as coffee, chocolate, and tea have among the highest global average embedded water content (blue and green), their water use is predominantly green water, not blue. As stated in the 2018 United Nations World Water Development Report (WWDR), the "key for change will be agriculture, the biggest source of water consumption and pollution."

In sites where irrigation is legally practiced, this is the greatest use of water in wine production. Eighty-three percent of the surface under vine is irrigated in the New World as opposed to 10% in the Old World (Montpelier.inra.fr). As both the need for irrigation in current planted acreage increases and the additional future acreage will need irrigation, it is clear that the wine grape can serve as the ideal "poster child" for illustrating the immediate need for drastic water management and for establishing the actions needed to ensure truly sustainable agriculture.

Climate Action in Viticulture: Following the Original French Model

There is one viticultural farming practice that could be coordinated at the international level: dry farming. This is a practice already enshrined in European wine law, where irrigation is banned in the quality wine appellations. However, with the increasing episodes of drought and heat, these irrigation laws are being relaxed, as opposed to being held as a viable mitigation strategy for the rest of the world to emulate. Perversely, the most logical way in which to safeguard both the world's future quality wine supply and its water supply is to implement dry farming as the sector's global industry standard: its default position. However, such a legislative move could prove impractical and too political. There exists a mindset among a proportion of producers that would prohibit the curbing of the perceived inalienable right to water. Though, if irrigation were banned internationally, both an economic and an ecological playing field could be created. Wine producers could survive longer, with smaller yields, true, but with better wine, healthier plants and soils, and less water.

This entry will demonstrate how the climatic, economic, legislative, and cultural collision hovering on the horizon will render irrigation impossible in many regions anyway, before international irrigation bans could ever be drafted, enacted, and enforced. It hopes to provide a wider perspective of a highly detailed issue in an industry which impacts numerous other sectors and to open the dialogue regarding the change needed to engender immediate climate action. With today's wine producers unable to sustain their yields without irrigation, whose soils cannot support further plant life; who cannot afford insurance, water, or water licenses; and who are diversifying or ceasing wine production altogether; it is time to ask the question: Wine or water?

Water into Wine

Wine's Water Footprint

The Water Footprint Network states that it requires 5 l of freshwater to produce a glass of wine without irrigation. Meaning that the 5 l are used in the winery. Add irrigation and that number rises to 110 l of water per 125 ml glass in a temperate climate and to 240 l and rising, in drought-ridden regions. These estimates are challenged, and there is controversy as to how to determine a wine's water footprint in the context of yields (Williams 2001), its end value (Aldaya et al. 2010), and its composition, that is, the proportions used of green, blue, and gray waters and the role of soil type and evapotranspiration rates. Each wine's footprint can be unique from region to region and even from plant to plant.

However, the more critical issue is to determine if any use of freshwater to irrigate a luxury crop for the sake of increased productivity, and hence, profit, is a viable and sustainable goal. The argument that justifies increasing irrigation to achieve higher yields and, thus, greater economic profitability, when higher yields will ultimately lead to lower quality and lower economic profitability, is illogical. Any profit afforded by the greater yields will eventually be consumed by the cost of the water. Irrigation has become adaptation's greatest ally as well as mitigation's greatest foe.

Climate change is redrawing the map of the world's vineyards (Hannah et al. 2013). The *Vitis vinifera* has always been comfortable "moving house." But in the past, the climatic changes have been slower, permitting adaptation. Today, there is an unparalleled rate of change. This is coupled with the fact that never in the history of viticulture has the industry been so firmly and comprehensively entrenched in economic and cultural identities. The changes will have varying effects on the different wine regions that will depend upon their ability to adapt. The relationship between temperature and wine quality is crucial in determining adaptation strategies. But most adaptation techniques, especially irrigation, negatively impact a wine's quality, its soil quality, and hence, its specificity, the hallmark of its luxury status (Johnson-Bell 2017).

Water use in viticulture is essential in every stage of the production process. Irrigation is the largest use, and as temperatures and droughts increase, so does the need for water (Mozell and Thach 2014). The *Vitis vinifera* is indigenous to

Europe and Central Asia. When it is grown outside these regions, typically in warmer, drier New World climates, irrigation is used where there is low rainfall during the growing season so to increase yields. In the driest parts of Australia, for example, 99% of the water use is for irrigation, as opposed to uses in the winery (Kilcline 2006).

Initially, commercial, mass-produced wines will continue to adapt via technology. They will continue as long as they can sustain the increasing water prices and are allocated the required water licenses from their local governments. Then, as increased drought and water shortages cause planted acreage to be pulled, it will be the dry farmers who survive. Wines of South Africa, CEO, Siobhan Thompson, recently suggested that the droughts and the move toward dry farming may benefit the Western Cape and force it to "rightsize" itself as the greatest impact from water shortages is being felt in the "bulk producing areas" (Schmitt 2018), confirming that their market is already experiencing this eventuality.

How Vineyards Are Adapting

Climate change is manifesting itself in a myriad of ways. Within the larger warming trend, there are more frequent and more erratic climatic events: unexpected hail storms, flooding, drought, and disease. Adaptation strategies vary depending upon the site-specific issues but can include rootstock and clonal selection, planting in higher altitudes and cooler coastal regions (where physically and legally possible), better canopy management, reduced tillage, trellising techniques, and changing to warmer-climate grape varieties, again, where legally permitted. There is also a groundswell of support for organic and biodynamic farming practices. "Fortunately, *Vitis vinifera* has a wide genetic diversity that can enable such shifts. However, within *Vitis vinifera*, there are few widely planted varieties that can produce quality wine in excessively warm climates" (Diffenbaugh et al. 2011).

"Sustainability" has become a wine trend. It is the new "organic." There is a plethora of regional accreditations and certifications (mostly voluntary) addressing key adaptation strategies and embracing organic and biodynamic farming practices. The majority of these programs focus on conservation of habitat and biodiversity as well as pest management, soil health, energy efficiency, green buildings, recycling materials, and water and waste reduction. If water management is mentioned at all, it is too often concerned only with water conservation within a system of irrigation. espousing the benefits of drip irrigation, regulated deficit irrigation (RDI), or the need for better water and soil moisture measuring tools. Absence is the acknowledgment that ceasing freshwater irrigation and choosing to dry farm would be the most effective sustainability measure.

It would be inaccurate to categorize dry farming as a strictly Old World farming practice. There are many New World wine producers who are long-time advocates of dry farming, while others are starting the slow and careful process of transitioning. There are wine producers in the most drought-ridden regions who are proving that dry farming works. British Columbia's Painted Rock Estate is in the midst of weaning their vines off water. Every year, they reduce irrigation levels. Will Bucklin's Old Hill Ranch in Sonoma, California, has Zinfandel vines that have not been irrigated since 1885. South Africa's Swartland is famous for its dry-farmed wines, mostly in part to the Swartland Independent Producers (SIP). In Chile, one of the worst irrigation offenders, high-profile producers are now transitioning. For example, Aurelio Montes in the Colchagua Valley has added a premium dry-farmed range to his portfolio. In California, the owner of the Bonny Doon estates in Santa Cruz, Randall Grahm, is an ardent pioneer of dry farming and its ability to translate *terroir*, believing that the best ways are the old ways. Finally, the Deep Roots Coalition in Oregon, USA, is a good example of private-sector action. Their mission is to have the farmers who currently irrigate convert to dry farming and have all new vineyards established without irrigation. As confirms John Paul of the Cameron Winery, "the ultimate agricultural system is essentially a self-contained order in which everything is recycled and the only significant inputs come in the form of sunlight and precipitation."

Irrigation as an Adaptation Technique

A Question of Taste and Waste

While irrigation is used to mitigate the reduction of yields due to drought, it also impacts wine quality and damages the soil. The issue is not confined to water conservation alone. "Irrigation" in viticulture is a wide term encompassing a variety of practices according to the amount of water use and the frequency with which the water is applied: from flood, or furrow irrigation, to spray irrigation, and to drip, or trickle irrigation. . .and then from the first day of the growing season and throughout to harvest, or once a week, or once a day, or continuously. It is accepted that irrigation contributes to higher yields, wider leaf area, more vegetative growth, and larger berries. The debate lies in whether or not these responses constitute a negative effect on wine quality. There should not be a debate: it is an established horticultural fact that irrigation reduces flavor in vegetable and fruit crops. Numerous studies have confirmed that reducing irrigation positively affects fruit nutritional quality by increasing anthocyanin and phenolic concentrations (Chaves et al. 2010; Bravdo et al. 1985), whether they be pomegranates, tomatoes, or peaches. Wine grapes are not exempt from the law of nature. On the other hand, too much water stress and the wine quality also suffer, reducing "the relative level of photosynthesis, resulting in lower fruit yields and quality" (Jones et al. 2005). It is a great balancing act. However, using irrigation throughout the growing and ripening seasons so to control moisture stress and yields is increasingly an unaffordable luxury.

Unirrigated vines create root masses that are forced deep into the soil to find moisture, and as they do this, they pick up nutrients through the soil formations. This is what dry farming advocates call "*terroir*": the taste of the place in which the grapes are grown. The French soil ecologist, Dr. Emmanuel Bourguignon, explains that irrigated vines often miss out on vital nutrients because their root systems remain on the surface, where the moisture, sun, and fertilizers are. Remaining on the top 30–40 cm of the surface also renders the plants more vulnerable to all climatic events. Bourguignon adds that "irrigation's increased vigor, or vegetative growth, creates a large canopy, which is particularly problematic in sunny climates because it increases photosynthesis resulting in high sugar and potential alcohol levels. This dilutes the *terroir* but exaggerates the varietal character. If you want to be unique, irrigation will make that very difficult" (Gibb 2013).

Soil salinity is another problem with irrigation (Sidari et al. 2008; Cramer et al. 2006), and the problem is not confined to viticulture. Arid soils are the most susceptible. When salt levels reach high-enough levels in the vine, the leaves start to display "leaf burn" or browning. Salts also change the structure of the soil itself and the way the roots grow, which affects the vines and, thus, the wines. Soil salinity means potentially phytotoxic salt components such as sodium, chloride, and boron, which can cause crippling decreases in vine vigor or even vine death at elevated levels (Teichgraeber 2006). Correcting soil salinity is currently a highly active area of research. The best way to decrease soil salinity is to drench or to flush the soil with freshwater. But if the vineyards suffering from soil salinity had such freshwater reserves at their disposal in the first place, they would not be irrigating. There is also research being conducted on the influence of organic materials on the physical and chemical properties of saline soils with low fertility (Wu et al. 2014). For example, biochar both regenerates soil by replenishing its organic matter and increases its ability to retain moisture, which is essential in dry farming.

Frustratingly, soil salinity research tends to focus on its physiological and metabolic effects, as opposed to its effect on chemical composition, volatile aroma compounds, and sensory characteristics on wine – its *taste*. It has been determined that there may be some grape varieties that are better suited than others to the influence of soil salinity, such as the Nero d'Avola in Sicily (Scacco et al. 2001). To determine other varieties that perform well in salinized soils would prove a useful adaptation tool for winemakers as they experiment with replanting.

Yields... a question of relativity

It is important to insert a discussion on the topic of yields, as low yields are considered the greatest deterrent to the dry farming method. Wine grape yields are measured either in tons per acre, tons per hectare, or hectoliters per hectare. How much volume is produced by a given weight of grapes is determined by a vast set of variables, from site selection (soil composition and exposition), grape variety, rootstock selection, planting density, trellising method, vintage conditions, harvest methods, winemaking methods, wine style, and indeed, the producer's winemaking ethos. Further, the measurement of land area has its own set of variables and is considered to be an indeterminate unit. To place it into a relevant context, note that premium wines are issued from low yields and lesser quality or mass-produced, commercial wines are those that are from high-yield vineyards. Low yields (for the right reasons) are considered the hallmark of premium wines. It is one of the factors that bestows upon them their luxury status. This is also why much of the discussion in the scientific community regarding crop yields is often skewered when on the topic of viticulture. Those who come to this topic from a general agricultural perspective too often assign to viticulture the same qualitative attributes as other crops and assume that high yields are desirable. In viticulture, low yields, when not due to disease or extreme weather conditions, are preferable.

To place this in a broad context: In the AOC (*Appellation d'Origine Contrôllée*) vineyards of France, for example, the Institut national de l'origine et de la qualité (INAO), as part of the Ministry of Agriculture, sets maximum yields at 60 hl/ha in the Loire's Sancerre appellation, 40–45 hl/ha in Burgundy's Meursault (white), and 35–37 hl/ha in Burgundy's (red) *grands crus* vineyards. In Bordeaux, Saint-Émilion has a maximum yield of 45 hl/ha, while their iconic sweet wines, Sauternes, average 25 hl/ha with the best estates producing yields of only 12–15 hl/ha. These are considered extremely low yields. And this is not to say that there are wine producers in the less-regulated vineyards in the south of France who produce more mass-produced wines with yields of 80 or 100 hl/ha. The monopoly on high yields is not held by the New World wine producers. However, the New World wine regions are not subject to the same wine laws regarding yields.

It is a highly subjective perspective. In many of the arid New World wine regions, there are premium wine dry farmers who consider their recent yields of 2–3 tons per acre as unviable, when in Europe, that equates to 27–40 hl/ha and would be held to be viable. "The vineyards of Napa Valley are intentionally farmed at lower yields bringing only the very best grape to harvest. Growers here, year-in and year-out, bring an average of 4 tons per acre to crush overall, which is consistently half the California state-wide average" (Napa Valley Vintners' Association 2018). Four tons per acre is approximately equivalent to 54 hl/ha or more, which is the upper limit of the European AOC yields. So while a producer in Paardebosch, South Africa, laments a yield of 3 tons per acre (50 hl/ha), that is a perfectly viable yield for a Chianti Classico producer in Tuscany. This difference in perspective, and in market forces, is what is partially heeding the progress of dry farming.

Dry Farming

Not Just "Not Irrigating"

Dry farming is an ancient farming practice rooted in antiquity. "In the more or less rainless regions of China, Mesopotamia, Palestine, Egypt, Mexico and Peru, the greatest cities and mightiest people flourished in ancient days" (Widtsoe 1910). In contrast, irrigation was a comparatively modern concept in the context of cultivated food production and was embraced as a method to increase yields and to alleviate the inherent vagaries of annual growing seasons.

Dry farming is not the same as rainfed agriculture. They differ in the annual rainfall of their respective regions. Rainfed agriculture is a form of farming practice wholly dependent on rainwater for irrigation. Dry farming is the practice of retaining the moisture from winter rainfall in the soil so to sustain the plant during its growing season without irrigation in arid regions that typically receive less than 20 in. (50 cm) of annual precipitation. In ideal vineyard conditions, rainfall is distributed equitably throughout the year. When it falls primarily in the winter and not during the growing season, then this is when dry farming is practiced. In viticulture, dry farming can be practiced with as little as 9 in. of annual rainfall, depending on the actual demand for water of any particular vine and as is determined by vine age, variety, rootstock, soil type and drainage (for both topsoil and subsoil), slope, topsoil depth, day and night temperatures, humidity, wind, depth of water table, crop load, canopy management, vine health, sun and UV exposure, and when the water is applied, among other considerations.

Dry farming is not simply, not irrigating. It works to conserve soil moisture during long, dry periods primarily through a system of tillage, surface protection, and the use of drought-resistant grape varieties. Dry farmers often plant winter cover crops to increase the infiltration rate of winter rains, reduce runoff and erosion, provide nutrients and organic matter for the soil, and increase soil moisture content. They also experiment with tilling and non-tilling methods, as well as disc the soils, use a harrow to create a dust mulch, and use a roller over the mulch to seal it and the subsoil. Soil fertility is increased with compost. And biochar, as stated earlier, is being explored as a remedy to soils that have been salinized by excessive irrigation and enhance water retention. Animals are also introduced into the vineyards, and careful plant pruning and grape cluster thinning are practiced so to keep water use of the vine to a minimum.

Transitioning from Wet to Dry

The principle behind converting a vineyard from irrigation to dry farming is that the irrigation water is slowly and gradually reduced on an annual basis, so as to avoid any shock or damage to the vines. Determining how much reduction in irrigation is required is achieved by assessing the soil information and the use of the same data employed when determining irrigation amounts. The process can take from three to five growing seasons. For example, areas with greater precipitation and soils with sufficient water-holding capacity and deep rootstocks will require less time to transition, while vineyards with less annual precipitation, planted with riparian rootstocks in shallow, sandy soils with tight planting densities, would be difficult, if not impossible, to transition.

The Impediments: Economic Versus Ecological Viability

The greatest deterrent to adopting or transiting to dry farming, again, is the loss of profit due to the lower yields. Yet these can be greatly offset by the long-term savings afforded by dry farming. Dry-farmed vineyards incur lower costs, both in terms of start-up and maintenance. Irrigated vineyards require the extra costs of the irrigation system, the trellising system, the water, as well as all maintenance. Dry farmers will only have the cost of watering the vines for the first years. CAFF data reports that dry-farmed vineyards average $6000 per acre as opposed to $30,000 per acre for an irrigated vineyard (Lambert 2015). How much water is saved due to dry farming is a gray area. There does not exist sufficient quantitative research, and data thus far is on a case-by-case basis. Some Napa Valley dry farming estates estimate that a minimum of 16,000 gal per acre of water is saved when compared to neighboring grape farmers who irrigate lightly (CAWSI 2018).

If a South African dry farmer resorts to irrigation at the end of the growing season, or if a producer in Bordeaux abandons their organic farming methods at the end of a disastrous vintage, they do so to “save their crop.” But this does not mean that their vines were not producing any crop; it means that their vines did not produce enough crop to meet their anticipated yields. It is not an ecological construct but an economic one. Presently, it is only those wine producers who are voluntarily engaging in sustainability practices who are taking the largest risks for the industry. If they are forced to abandon these practices at the final hurdle due to competition from their non-practicing peers, then this poses an enormous inequity and retards the advancement of the adoption of sustainable farming practices. There needs to be a level playing field.

Legislative Restrictions and Consumer Expectations

Water is also a rights issue. "As the global population grows, there is an increasing need to balance all of the competing commercial demands on water resources so that communities have enough for their needs" (United Nations 2018). So, in the same instance that sustainable farming programs are voluntary, water laws are being enacted and enforced on both national and local levels across the globe. Water is being rationed, even if a producer could afford the increasing costs. For example, VinPro, a nonprofit company which represents 2,500 South African wine producers, states that the majority of areas in the Western Cape have seen their water rights cut in half, forcing producers in the north of the region to select which vineyards to save. As a result, estimates for the 2018 harvest volumes are forecasted to be 20% lower in yields on average. The recent water crisis has strained the industry, raising the question of priority for uses not considered essential to fulfilling a human right to water (Larrick 2018).

Over the last decade, grape growers in SE South Australia have had their water entitlements converted to volumetric allocations, have experienced a reduction in annual rainfall, and have seen a rise in the salinity of irrigation groundwater. Most wine producers have shifted from flood and sprinkler irrigation, which was still widely used in the last decade, to precision drip irrigation (Stevens and Pitt 2012). Still, thousands of grape growers have not been able to afford their water bills and have had to cease their production. In Australia's Riverina wine region, severe drought conditions have forced more than 10,000 families, mostly sheep and wheat farmers, off their land. Wine producers are also having to cease their business activities. The creeks and streams of the Murray-Darling river system are where around 1,300 growers produce more than 400,000 tons of grapes, approximately one quarter of Australia's total. These vineyards have "relied on highly-regulated irrigation systems flowing from enormous reservoirs in the nearby Snowy Mountains" and can do so no longer. Many vineyards have been abandoned to soil salinity, unable to grow any crop at all (Johnson-Bell 2017). In the recent past, winemakers were faring better than other farmers because their business is deemed so "important to the local economy that it has been guaranteed water" (Mercer 2008). Chardonnay was put before wheat and livestock. This preferential treatment is no longer physically possible.

From this debate over water rights, the role of the educated consumer comes into force. Increasingly, the consumer is making the link between wine and agriculture. Consumers want eggs to be free-range, chicken to be corn-fed, and vegetables to be organic. The provenance of foodstuff is now a key market leader, and there is evidence that this demand has translated into the drinks industry. Unilever claims that "over a third of consumers are now actively seeking out brands and companies based on their social, environmental and ethical impact and behaviour. YouGov puts that figure at 37%" (Unilever 2018). And Nielsen research shows that "75% of millennials are prepared to spend more for a sustainable product, up from 50% in 2014." Nielsen also recently reported that supermarket sales of organic food and drink in the UK have risen by 4% this year (Nielson 2015).

A Lack of Incentive and Insurance

Instead of insurance being used as an incentive to farmers to conserve water, it has become an important "last-ditch" adaptation tool: a safety net. The US Congress is presently working on the "Agriculture and Nutrition Act of 2018." One of its key elements is crop insurance which helps protect farmer income in times of volatile production when crops are damaged by droughts or floods (Agriculture and Nutrition Act of 2018). But "crop insurance is good for farmers, but not always for the environment" (Fullerton et al. 2018). An example of this is the policies offered to South African wine producers. Drought insurance is cost prohibitive and often not issued if the wine producer does not have an irrigation system in place, thus encouraging irrigation as opposed to supporting water conservation. Californian wine producers are encouraged to rely upon their crop insurance policies as their primary backup method of drought management, with such advice as "growers have several options for addressing risks through the purchase of crop insurance, an important sustainability tool" (California Sustainable Winegrowing Alliance 2018). Authors from the University of Illinois Institute of Government and Public Affairs confer that "while it plays an important role, studies have shown that crop insurance encourages overuse of resources, particularly water, and makes the agricultural system less resilient in the face of climate change. Modifying crop insurance to reduce incentives for unsustainable farming practices could be an effective way to ensure the resilience of our future agricultural system" (Fullerton et al. 2018).

Do the French Have It Right?

Irrigation in European vineyards has always been illegal. This was partially to reduce yields during the 1930s and 1950s when overproduction and low prices were an issue but also in acknowledgment of the qualitative advantage. Now, with the recurring droughts in many parts of France, the INAO and the EU are having to relax irrigation laws in the Mediterranean. The INAO is responsible for the implementation of French policy on official signs of identification of the origin and quality of agricultural and food products and regulates such things as maximum yields (as mentioned above), the maximum vineyard surface allowed, winemaking practices, permitted grape varieties, pH and alcohol levels, vinification processes, etc.

Wine laws in the New World are more lax and are less concerned with associating an appellation with a particular grape or style of wine. For example, white Burgundy must be made from the Chardonnay grape and red Burgundy from Pinot Noir. The New World vineyards do not have the same restrictions. They are permitted to plant whatever variety they wish, wherever they wish. This has both advantages and disadvantages; a discussion thereof is outside of the scope of this entry.

With the décret n° 2006-1527, JORF n°282 of 6 Décembre 2006, irrigation became (very quietly) legal in France. But the most water-efficient method of irrigation, drip, was outlawed in preference for spray irrigation. Further, the period of irrigation was limited to between 15 June and 15 August, which is the flowering and ripening seasons, as opposed to between budburst and flowering, making it difficult for producers to have any control over their crops, especially as nature's inherent time line keeps shifting. More worrying still is the new project, Aqua Domitia, intent on bringing irrigation water supplies from the Rhône Valley to Béziers and Narbonne. The project was initiated by the region of Languedoc-Roussillon, which today is the most irrigated vineyard in France, with some 23,000 ha or 10% of the region (Martin 2016).

Is allowing more irrigation in France a step backward or forward? Olivier Martin, Président délégué de la Féderation des Vins de Nantes and co-owner of the Domaine Merceron Martin, states that "it is a shame to see people undo all the work Mother Nature has already done. To start irrigating means to invite all the root systems back up to the surface. More and more, with the heat and the irrigation, the traditional French wines will not be French anymore. They will taste like they come from anywhere. But many French winemakers are happy to now have the high yields that can be found in the rest of the world."

More recently, following the décret n° 2017-1327 of 8 September 2017 regarding AOC vineyards, the legislation has had several amendments, allowing irrigation after 15 August and allowing underground drip irrigation systems. Crucially, also, the décret has been revised to ensure that irrigated parcels keep to the original dry farming yields. Only dry farmers are allowed to exceed the traditional maximum yield limits. The French may have found a balance that could be implemented throughout the industry. However, it would be preferable if EU wine laws were to retain their irrigation ban and yield limits but to relax their planting restrictions.

How Much Longer Is Irrigation Viable?

In South Africa's Stellenbosch region, Warren Granat-Mulder, Rust en Vrede's Export Manager, revealed that diversification is already very much part of the South African mindset. "Lots of our neighbors are growing apricots and other crops. Wine is not viable. Dry farming can be a struggle even with the right soils and winter rainfall. Because of the heat. At 40°, the stress is too much and the vines shut down. People will adapt until they can't anymore. Then they'll diversify, and then they will migrate."

Viticulture is different from other crops. Diversification and migration are not palatable options. It is one exercise to relocate a wheat field or a tea plantation, but it is quite another to do so with a 300-year-old château and its infrastructure or to cease wine production altogether. Yet, wine producers who continue to use irrigation as an adaptation technique will be placed in a holding pattern until "irrigation as an adaptation technique" and "dry farming as a mitigation solution" collide.

Conclusion

For viticulture to survive, to go beyond adaptation, and to become resilient, it must not only take responsibility for its role in water conservation, but it must also protect its soil, its low and healthy yields, and its quality, or its "luxury" status will be lost. This cannot be achieved through irrigation. Many wine producers already understand that the *Vitis vinifera* will 1 day outstay its welcome and will have to migrate to cooler climates. Assisting winemakers to envision this outcome and the ensuing ramifications is part of being resilient to climate change. The winemakers who do not embrace such realities, however unthinkable, risk being the ones who will be destroyed by adversity as opposed to merely being changed by it.

If the European wine laws on irrigation continue to relax until irrigation is used in all appellation levels, while in the New World wine regions irrigation becomes impossible due to water shortages and legislative restraints, an interesting role reversal could ensue. Eventually, only the dry farmers will survive. The New World's mass-produced wines will fall out of the marketplace, despite their initial financial ability to invest in technology and weather the climate storm. But their advantage will not last. At the same time, the Old World will be increasing its yields and taking the previous place of the New World wines. Until, having irrigated itself into dilution, it, too, can no longer adapt. Then again, ironically, those Old World producers who can will return to dry farming. It will come full circle, albeit with the wine map greatly altered and, perhaps, not so recognizable.

It is time to halt the use of irrigation in viticulture. When an environment is contrived and manipulated to such an extent in order to accommodate a crop's production process, when local government legislation prioritizes viticultural export products in lieu of food crops, and when the very essence of a crop's value and identity is altered beyond recognition, then assisted migration at a forced pace may be the only option.

Climate action in viticulture is a natural fit. The wine industry is a sector possessing a comparatively strong and coherent network between its stakeholders and local and international government. It also possesses an enormous knowledge bank of historical and modern climate data. There is also, comparatively, a strong sustainability mindset as well as strong international marketing and media/communication structures already in place. Wine production also has a long value chain encompassing all adaptation issues; from land use, agriculture, water rights and conservation, transport, energy, employment, and social care to investment and insurance models. Its processes, especially that of European wine law, provide a perfect mitigation "template." We can no longer afford to irrigate a luxury crop. This is a sector that cannot be exempt from climate change adaptation, especially when it has the ability to take the lead in mitigation solutions. The world needs more food, not more wine.

Finally, there is also much to be hopeful about. While there will be many wine producers who will not survive climate change, climate change is also responsible for the creation of the newly emerging, exciting, and sustainable wine regions. How this world map will be configured will depend entirely on the industry's response to the question: wine or water?

Cross-References

► Climate Change Literacy to Combat Climate Change and Its Impacts

▶ Climate Risks and Adaptation to Crop Yield in Pakistan: Toward Water Stress Tolerance for Food Security
▶ Desertification, Climate Change, and Sustainable Development
▶ Food and Climate Change: Their Connections and Mitigation Pathways through Education

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Climate Change Awareness: Role of Education

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Definitions

Environmental education is an interdisciplinary process involving educators, teachers, parents, and scientists to stimulate individuals from several ages to explore environmental issues and to contribute to improve and protect the environment. The main objective of environmental education is to help the general public to develop a deeper knowledge of environmental importance and weaknesses and to have the skills to make informed and responsible decisions (Pooley and O'Connor 2000).

The **scientific literacy** is a process to obtain knowledge and understanding of scientific concepts, essential for individual decision-making, from environment protection, citizenship, and sustainable economic productivity (Spellman and Price-Bayer 2018).

The term **climate change** refers to global-scale climate change and/or regional climates over time. It includes significant climate variable changes, resulting in increased air and ocean temperatures, melting ice, rising sea levels, droughts, flooding, increased rainfall, and other impacts (IPCC 2014).

Background

Climate change is a global issue that threatens the survival of the planet (Ojala 2012; IPCC 2014). There is a general consensus that climate change is changing the Earth biosphere, producing an increasing extinction of organisms, destroying ecosystems, and affecting severely human economy and health (Johnson et al. 2018). Therefore, it is urgent to change attitudes and concepts, and it is urgent to increase the public eco-literacy and implement solutions. The complexity of a changing world, resulting from climate changes, must involve several generations and sectors of the human society, for the search and implementation of effective climate mitigation actions. In this context, the process of develop an eco-conscious generation will be crucial, with children being the key to this challenge. It is well known that, within the human society, the age group of children will be most affected by the increasing effects of climate change because of their greater fragility and sensitivity, especially in extreme poverty contexts (Amato et al. 2016). Children are a common basis for all dimensions of sustainable development; thus, no advances in sustainability will occur in coming decades without multiple generations contributing to societal improvement (Chan 2013). The science literacy programs with children will contribute for a more eco-conscious generation, directly influencing the adults, with knowledge and effective will to mitigate the present and near future changes in climate.

This chapter is expected to contribute to these issues, exploring those questions, including some concepts and definitions of science literacy, environmental education as tools to inform the general public, and in particular the children, about the importance of ecosystems protection, the causes and effects of climate change, and how to involve the educators, teachers, parents, and scientists and society, in general, to work on solutions to mitigate those effects.

The Causes and Effects of Climate Change

Climate variation can result from both natural processes and factors and more recently due to anthropogenic activities through emissions of greenhouse effect gases. In fact, since the pre-industrial revolution, the combined impacting human activities as burning of fossil fuels and deforestation have caused the concentrations of heat-trapping greenhouse gases (GHG) to increase significantly in our atmosphere, driven by and exponential increase of economy and global population (EPA 2012, 2017; IPCC 2014). This scenario has led to an unprecedented increase of atmospheric concentrations of carbon dioxide, methane, and nitrous oxide (IPCC 2014). The main cause of climate change is global warming, a result of greenhouse effect, with increasing negative impacts on biosphere. In normal conditions, atmosphere retains some of the Sun's heat, allowing the Earth to maintain the necessary conditions to host life (EPA 2012). However, the increasing anthropogenic activities maximize the greenhouse effect, causing the planet's temperature to increase even more (EPA 2012). The enhancement of this complex process results in increased energy amount being trapped in the Earth, especially in the oceans that absorb the majority of this energy. In fact, more than 90 percent of the warming that has happened on Earth over the past 50 years has occurred in the ocean (Johnson et al. 2018), being responsible for an increasing extinction of sea life. The warming of ocean water is raising global sea level due to the polar ice melting, compromising coastal human structures (Johnson et al. 2018; IPCC 2014). In addition, climate change-related risks are increasingly affecting worldwide ecosystems and population health (Tong and Ebi 2019).

Health and Climate Change: The Effects on Children

Climate change is increasing the burden of climate-sensitive health determinants and outcomes worldwide. The frequency and intensity variations in temperature, humidity, seasonal weather, and flooding patterns have expanded the geographic range and seasonal survivability of many vectors of disease (Patz et al. 2003; Wu et al. 2016; Ziegler et al. 2019).

The increase of seasonal weather changes also contributes to the mobility and expansion of common vector organisms (e.g., rodents and mosquitoes) to wider latitudes (Sutherst 2004; McMichael 2017). These issues combined with increased human mobility and density in urban centers will exponentiate the prevalence of vector-borne and waterborne illnesses (Barlett 2008a, b; Ziegler et al. 2019). Globally, there are clear evidences that the increasing of malaria, dengue fever, and cholera diseases and the increase illnesses associated with air pollution and aeroallergens are attributable to climate change (Perera 2017; Ziegler et al. 2019). In addition, recent studies have demonstrated changes in production, dispersion, and allergen content of pollen and spores because of climate change with an increasing effect of aeroallergens on allergic individuals (Xu et al. 2012; Tong and Ebi 2019). This proliferation of contagious and dangerous diseases is even more problematic when considering the risk groups, including chronically ill, elderly, and children. In fact, children are particularly vulnerable to these health issues because of their greater sensitivity, potentially greater exposure, and their dependence on caregivers (Ebi and Paulson 2007).

This problem becomes even more delicate when the first to be affected include low-income families and children from lower-income countries. Barriers to vaccinations and other primary care services as well as increased exposures due to inadequate housing and poor vector control in impoverished communities leave persons living in poverty at increased risk from infections known as neglected infections of poverty (Tong and Ebi 2019; Ziegler et al. 2019). Additional threats to children health are related to the exponential rise of GHG emission, resulting from the urbanization and high levels of vehicle emissions and being responsible for increasing frequency of respiratory diseases (Frederica 2017). All these evidences stress the urgent need of mitigation actions and adaptation to the impacts of future climate variability. In this context, children can be considered more than a vulnerability group; with an effective environmental literacy, they can develop new capacity as active agents to play a role in addressing the challenges they confront related to climate change (Tong and Ebi 2019).

Educating for Sustainability

Environmental Education: How to Educate Children to Respect Nature

During the last decades, the main goal of environmental education programs has been to change environmental knowledge through increasing environmental knowledge; however, recent studies and evidences suggest environmental educators must also focus in changing environmental attitudes, emotions, and beliefs (Pooley and Connor 2000; Ojala 2012; Pendergast et al. 2017; Ziegler et al. 2019). The evolution to an increasing digital society also adds new challenges, especially in identifying reliable and robust sources of information. However, these new digital platforms can and should be used as a new opportunity for scientists and educators to translate the research results, disseminate, and discuss them with the society.

The environmental education process must involve educators, teachers, parents, and scientists to stimulate children to explore environmental issues and to contribute to improve and protect the environment. The activities must be adapted to the age ranges and, also, be in line with scholar programs, which will educate with the basis of scientific knowledge, essential for an effective environmental protective attitude. The translation of science can be applied through interdisciplinary activities, developed by educators, teachers, and invited scientists, designed to lead to the resolution of environmental challenges (Battro et al. 2017). These activities must, also, involve parents in scholar habitat, with the implementation of environmental consciousness at home. This activities' expansion, involving all the family, promotes the desirable indices of public awareness and knowledge of environmental issues.

Some examples of activities to be developed in school can include board games, protected areas visits, questionnaires, photography contests, recycling activities, cleaning of areas (e.g., school grounds and participation in beach cleaning activities), construction activities (e.g., ecopoints, herbaria, miniature ecosystems, construction of a solar panel), and small and interactive presentations promoted with invited scientists and parents (FAPAS 2004; Eisenack 2013; Battro et al. 2017).

The main short-middle term goal of these activities and programs is to teach critical thinking to individuals, increasing public awareness and knowledge of environmental issues in a changing world (Spellman and Price-Bayer 2018). Environmental education does not advocate a particular viewpoint or course of action; in fact, these interdisciplinary activities teach individuals how to weigh various sides of an issue through critical thinking, and it enhances their own problem-solving and decision-making skills (Mendonca et al. 2012; EPA 2017).

Use Science Games and Activities for Learning

Besides the exemplified activities and games for children to use and learn about the environmental protection, there are many others that can be developed by scientists and educators in scholar environment. These games and activities must be, also, complementary with scientific level expected in scholar programs. Some examples of activities for pre-scholar ages include illustrative stories, multimedia books (physical or projected stories), and manual activities, with the construction of small mock-ups (e.g., ecopoints) and drawings. These activities can and should always be accompanied by small questions, in order to contextualize them. The activities for basic school can include board games (with scientific background) and organized visits to protected areas and research facilities (Eisenack 2013). Here the projected messages can be more extensive and always interactive. At the level of secondary school, the critical knowledge must be/should be enhanced using examples from scientific studies and small meetings with scientists, science summer schools and visits to laboratories.

Changing Concepts and Attitudes

How to Teach Kids About Climate Change

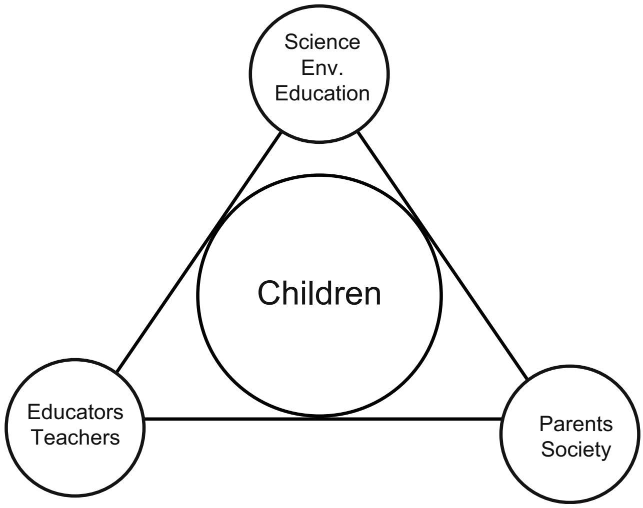
Global climate changes, driven by the consequences of human activities and population growth, are altering the Earth in a magnitude that pose current threats to human health, with the extent of these risks projected to increase over coming decades if additional, proactive actions will be not taken (IPCC 2014; Tong and Ebi 2019). Some of the most reported variations are related to changes in temperature, precipitation, cloudiness, and other climatic phenomena in relation to historical averages. The simplest way to transmit the main issues, related to climate changes, to children is to simplify and explain to them that the way human beings are living their lives is changing the world in a negative way. The multimedia resources can be an useful tool, especially in the basic school ages. A great way to introduce climate changes to children is with pictures, a video, or an integrative presentation, showing the beauty of nature (e.g., forests, mountains, rivers). The preschool ages can also experience the wonder of the natural world, climbing the trees and playing in the dirt; the experience to marvel with colorful plants and flowers will be a crucial component of the process. This first component shall be followed with the presentation of the GHG emissions, the devastation of large areas of forests, and some effects of these irresponsible activities. Here the degree of effects (impact) must be carefully measured according to the age of the students; it is imperative to talk with children about the causes and effects of climate change without making them think the planet is condemned. It will be very important to explain and exemplify to children that climate change threatens to destroy this beautiful, blue and green world and thus it is very important to preserve it (Pooley and O'Connor 2000; Rooney 2019).

The Role of Educators, Teachers and Parents: Build Positive Family Eco-friendly Activities

Climate change is part of both parents and children's future and health. Mitigating the projected impacts of climate change requires cooperative tasks involving generations. It is very important for children to take a leading role in helping their family and friends to become more eco-conscious, as it will help them develop habits for a sustainable life (Ojala 2012; Monroe 2019). If the school transmits the positive facts about the world around them, it will contribute to create environmentally friendly families with daily habits of cutdown on waste and pollution, also as an example for other families. The intergenerational learning, including the transfer of knowledge attitudes or behaviors from children to parents, may be a promising pathway to overcoming socio-ideological barriers to climate concern (Lawson et al. 2019). Some of these changing attitudes and concepts can include, for example, reducing the waste of water and plastic, reducing the dispensable use of the car, and recycling. Children can also participate with their parents in projects such as a beach cleanup. It is very important for parents to follow eco-conscious attitudes, also as an example for children. For early-age children, the climate change concept is abstract; however, they are receptive to new knowledge and make part of an eco-generation and part of the urgent solution (Rooney 2019). Recent studies demonstrated that children can have an effective role in creating change now and in the future (Lawson et al. 2019).

Conclusions and Future Directions

One of the main objectives to implement effective scientific literacy is for the children and future adult to be able to understand, describe, explain, and predict natural phenomena, understanding science from several sources, and to involve society in the search for solutions. The application efficacy of this complex challenge is based on an interdisciplinary and closed interlinked network, involving educators, teachers, parents, scientists and society, in general, to work on solutions to mitigate climate change effects (Fig. 1).



Climate Change Awareness: Role of Education, Fig. 1 Triad with the three main intervenients for an effective environmental education, with the focus on climate change literacy

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Climate Change Effects on Human Rights

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Definitions

The climate change effects on human rights are the consequences of climate change and climate change adaptation strategies on the enjoyment of human rights as guaranteed by International Human Rights Instruments. Climate change affects the natural environment primarily. But human rights analysis focuses on the anthropocentric interests to these environmental changes: how does climate change affect human rights. The traditional notion of human rights suggests that individuals should be protected by state interference with the enjoyment of their fundamental human rights. In the case of climate change, human rights are under a threat due to a global environmental phenomenon, creating a challenge over imposing state duties to protect the affected human rights. Although the link between climate change and human rights is evident, there is little legal response that will efficiently address the protection of the rights of affected people amidst climate change effects.

Introduction

The 2030 Agenda for Sustainable Development made explicit declarations over the need to commit to achieving sustainable development and protect human rights. "We resolve, between now and 2030, to end poverty and hunger everywhere; to combat inequalities within and among countries; to build peaceful, just and inclusive societies; to protect human rights and promote gender equality and the empowerment of women and girls; and to ensure the lasting protection of the planet and its natural resources . . . As we embark on this great collective journey, we pledge that no one will be left behind. Recognizing that the dignity of the human person is fundamental, we wish to see the Goals and targets met for all nations and peoples and for all segments of society. And we will endeavour to reach the furthest behind first" (UN General Assembly 2015). The Agenda utilizes language, common to human rights documents recognizing human dignity as a primary concern. In the Agenda, "human dignity" coexists with aims for the protection of the natural environment and natural resources. In addressing these combined aims, the Agenda seeks to eliminate inequality by providing that amidst climate change and its consequences as well as throughout the implementation of adaptation measures, "no one will be left behind" (UN General Assembly 2015). The document attempts to align eco-centric interests with human-centered interests, by seeking to ensure the protection of natural resources and achieve social cohesion for the benefit of current and future generations. This combination of aims is relatively rare and one that is not easily translated in legal rules, whether environmental laws or human rights laws. In addition, this combined approach is vulnerable to criticism, since the value of protecting the environment is overshadowed by a focus on humans and their needs in a rapidly changing natural environment. The reality is that the speed by which changes are witnessed amidst climate change creates multidimensional challenges. It therefore requires a combined and balanced approach through legally binding efforts.

The Birth of Human Rights Protection

Foundations of human rights, dated from the thirteenth century, derive from natural law theory – laws should be created to comply with natural justice – aiming at regulating human conduct (Bates 2013). With the French Revolution embodying the theories of Rousseau and Montesquieu over the meaning of natural rights and social contract, the impact of the French Declaration of the Rights of the Man and Citizen (1789) influenced the schools of thought to come, leading to the formulation of legal rules (Bates 2013). Human rights, although discussed and formulated historically, only gained an explicit recognition and one that afforded a legal protection, in the post-World War II era. Prior to the end of World War II, there was little to suggest the setting of obligations on states to protect the rights of their citizens. Even more novel was the notion that one state could interfere in the affairs of another state in ensuring such a protection.

Following the atrocities witnessed during World War II, a new approach was necessary under international law that required the setting of rules. These rules aimed at eliminating state interference with people's rights. After the establishment of the United Nations, the UN Commission of Human Rights, chaired by Eleanor Roosevelt, was tasked with drafting the UN Declaration of Human Rights. The reported debates over several matters including the interpretations of "human rights" in different languages indicate political and diplomatic factors affecting the process (Whelan 2010). Although a groundbreaking moment in history, the document was never intended to be legally binding, making it vulnerable to further criticism (General Assembly 1948). The Universal Declaration of Human Rights was a non-legalistic document but one that created moral duties on states to protect the rights, inherent to all humans by nature, equally. Ultimately, the Universal Declaration on Human Rights created general moral duties on states to ensure the protection of individuals' rights within their territories. This vertical relationship is better evidenced in the later internationally adopted documents of the United Nations, where states would be held liable for failing to meet their obligations in protecting the most vulnerable. Although such a lack of protection did not warrant sanctions, the political implications of inaction and the "naming and shaming" of serial human rights violators forced several states to comply with their international obligations, ensuring, to an extent, the universality of human rights (Franklin 2015).

The Effects of Climate Change on the Different Categories of Human Rights

These different UN human rights instruments protected different categories of rights. In general, human rights were traditionally seen as being separated in three categories of rights. The first-generation rights, or first category of rights, included civil and political rights such as the right to life, protection of privacy, and freedom from torture. The International Covenant on Civil and Political Rights came into force in 1976 and provided for the protection of this first category of rights. The focus on these rights was considered pivotal to the maintenance of a democratic society. The International Covenant on Economic, Social and Cultural Rights came into force in 1976 as well and reflected the need for protection of rights such as the right to education and the right to adequate standard of living. But, their legal enforcement has been problematic, given their scope and the difficult obligations states have in protecting them. The obligations to protect these rights could be too onerous, especially for developing countries, considering that the protection of these rights is linked to a control of the country's economic resources (Alston and Goodman 2013). Failure to comply with these obligations could also affect the protection of civil and political rights, considering that all rights are "indivisible, interdependent, and interrelated" (UN General Assembly 1993). The final category – third-generation solidarity rights – includes the right to development provided by the Declaration on the Right to Development. The right to development should be interpreted as the right to pursue development and not a right to be developed (Donnelly 1985), although there are multiple interpretations of the applicability of this right. The right to development has been controversial since its formulation, with some suggesting that it is pivotal to the protection of the remainder of human rights and others questioning its legal applicability (Alston and Goodman 2013).

The significance of the separation of human rights in categories is prevalent when discussing the effects of climate change on human rights. While climate change seems to affect primarily economic, social, and cultural rights, inevitably this has implications for the enjoyment of civil and political rights. Furthermore, one can argue that the third-generation rights are similarly under threat, since an obstacle to development can affect the enjoyment of the remainder human rights. These dilemmas are augmented when trying to identify the human rights violator. While states have duties to protect human rights, measures are reactionary to this rapidly developing phenomenon and difficult to be implemented in affected developing states. Ultimately, the traditional notions of human rights and state duties are blurred when trying to address the human rights effects of climate change.

Sustainable Development and Human Rights

The concept of sustainable development and its initial definition was formulated in 1983 by the World Commission on Environment and Development (the Brundtland Commission) which expressed a link between the environmental, economic, and social aspects of development, with a view to protecting the interests of current and future generations (World Commission on Environment and Development 1987). This approach required "intergenerational solidarity" which is an introduction of "intragenerational morality" (Stephens 2010). The interests of future generations are not only limited to the remainder of natural resources but also their ability to enjoy their fundamental human rights. But this comes contrary to the traditional scope of human rights law which covers human rights violations and not potential human rights violations affecting future generations. This disagreement between the two different concepts becomes futile due to the urgency of addressing the current problems, such as climate change affecting current generations, with a view to ensuring the welfare of future generations (Weiss 1990).

The idea of sustainable development was the result of the association between environmental degradation and its consequences to the human living conditions, inevitably connected to the protection of human rights. Therefore, the objectives of sustainable development can be traced in prevailing human rights norms as well as environmental law and economic growth goals. Efforts should be proportionally implemented and ensure that one category does not impede development in the other. For example, the protection of human rights is a prerequisite to achieving sustainable development and one that relates, prima facie, to social and economic factors (Taillant 2003). Inevitably the categories intersect. For instance, identifying and protecting those rights which are affected by environmental challenges is pivotal within the concept of sustainable development (McAllister 1992). The efficient protection of the environment leads to adequate and efficient protection of rights affected by environmental challenges. Evidently, this means that any measure that aims at addressing climate change is a measure that satisfies first human interests rather than nonhuman interests. Although this approach can be criticized as anthropocentric (Davies et al. 2017), the focus of human rights is the protection of the person, and therefore any linkages drawn from the Sustainable Development Goals are similarly anthropocentric.

This relationship was affirmed at the World Conference on the Human Environment in 1972 (United Nations 1972). The protection of human rights was directly applicable to the improvement of these human living conditions. Therefore the association of environmental degradation with the safeguarding of human rights was present since the early sustainable development strategies. Likewise, in 1992, the Rio Declaration indicated this linkage between sustainable development and the protection of human rights (UN General Assembly 1992). The declaration not only provided for guidelines for taking the necessary measures for achieving sustainable development, but also through Principle 10, it provided for people's procedural rights in order to achieve sustainable development. The aims of sustainable development as well as the need for collective efforts toward achieving its aims were expressed in 2002, at the World Summit on Sustainable Development (UN General Assembly 2002). The attention was shifted away from a combined consideration of sustainable development and human rights to a more environment-centered approach. Through the Johannesburg principles adopted, there was a commitment toward sustainable development, and a commitment to the UN Millennium Declaration was also affirmed. The goal of the 2002 Johannesburg Summit was to find better ways for the implementation of Agenda 21 10 years after its adoption. Therefore the focus remained on tackling environmental degradation and poverty as well as other "patterns of unsustainable development" (UN General Assembly 2012). But the subsequent resolution of RIO+20 stressed the importance of protecting human rights, as part of achieving sustainable development. Reaffirming the previously established sustainable development aims for "the promotion of economically, socially and environmentally sustainable future," the resolution emphasized the need for recognizing their interlinkages (UN General Assembly 2012). It highlighted the importance of protecting the rights enshrined in the Universal Declaration of Human Rights, with a special attention on women's rights. The resolution repeatedly addressed the idea of empowering people by way of participating in sustainable development, thereby making associations with the protection of human rights in the context of sustainable development through the protection of the right to participate in the relevant decision-making process. These links are more frequent in the Sustainable Development Goals.

The Sustainable Development Goals and Human Rights Protection

Sustainable development and human rights protection are greatly linked through the protection of social elements and environmentally linked elements to the enjoyment of fundamental human rights. Nevertheless, the Millennium Development Goals did not reflect adequately on this interdependent relationship and in some occasions seemed to undermine the importance of protecting human rights in achieving these goals (Darrow 2012). As Alston explained, human rights and sustainable development were like "two ships passing in the night" missing a valuable opportunity to meet and align their aims (Alston 2005). As a result of setting separate goals, the applicable indicators were not aligned with the human rights obligations of each state (UNHCHR 2013). Identifying this gap, the post-2015 Agenda for Sustainable Development specifically mentioned the UN Charter, the Universal Declaration of Human Rights, and other human rights treaties including the Declaration on the Right to Development. This declaration suggested an approach which is anthropocentric and based on human rights, with an attention on ensuring participation in decision-making, equal and fair enjoyment of the development benefits, allowing self-determination, and eliminating discrimination. These objectives, in line with sustainable development, require a universal and collective cooperation (UNHCHR 2015).

Although the Millennium Development Goals reflected mostly on economic, social, and cultural rights, the Sustainable Development Goals reflected on all three categories of rights.

The 2030 Agenda for Sustainable Development reflects strongly on the protection of human rights through the 17 goals. "The 2030 Agenda for Sustainable Development marks a paradigm shift towards a more balanced model for sustainable development aiming to secure freedom from fear and freedom from want for all, without discrimination on any ground. Strongly grounded in international human rights standards, the new Agenda strives to leave no one behind and puts the imperative of equality and non-discrimination at its heart" (Transforming our World). Human rights "language" is used more frequently, and explicit declarations over the need to protect specific human rights are also often. This has been characterized as an "unprecedented" opportunity to align human rights protection with the Sustainable Development Goals (UNHCHR 2015). To date, no legally binding obligation has been set to that effect.

Sustainable Development Goal 13 and Human Rights

Traditionally the foundations of human rights protection focused on the protection of the individual rights from state interference. But with the effects of climate change deriving by non-humans, the relationship between the victim and the human rights violator is near impossible to determine. Nevertheless more recent formulations of responses to climate change include recognition of the adverse effects of climate change to the enjoyment of human rights. The Paris Agreement "[reaffirmed] that climate change is a common concern of humankind, and that Parties should, when taking action to address climate change, promote and consider their respective obligations on human rights, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations, as well as gender equality, empowerment of women and intergenerational equity" (UN 2016). Although this gives an insight into the concerns faced by these vulnerable groups, it does not provide specific guidance for a human rights law response to these.

Amidst a general recognition of the link between the enjoyment of human rights and an "environment of quality," the links between climate change and human rights are obvious (Boer 2015). The major difference is that while private and public actors would be identified as those triggering human rights violations, climate change is a different phenomenon, albeit one that should be addressed through national measures, meeting state responsibility in combating its effects. The number one challenge when identifying human rights violations amidst climate change-related challenges is that there is no clarity over who causes climate change in order to place the blame for any related human rights violations. This would require a complicated exercise of awarding blame over greenhouse gas emissions, when in reality burden sharing in addressing the effects of climate change on people should be a priority (Türk and Nicholson 2005). Despite the fact that the Climate Change 2014 Report by the Intergovernmental Panel on Climate Change recognized that climate change is a human-induced phenomenon, the burden of climate change is carried around the world despite the contributions to the greenhouse gas emissions (IPCC 2014). According to the UN, "States should take into account human rights obligations and commitments relating to the enjoyment of a safe, clean, healthy and sustainable environment in the implementation and monitoring of the SDGs, bearing in mind the integrated and multi-sectoral nature of the latter" (UN General Assembly 2016). This means that, to have an accurate image of who is responsible over specific interferences with human rights amidst climate change, the state violator has to be identified as well as the victim and the specific right affected. Given the initial aims of human rights law and the cross border effects of climate change, this creates a legal lacunae.

The United Nations High Commissioner for Human Rights has identified the main links between human rights and climate change to be the following: to (1) address climate change and limit the effects of climate change on the enjoyment of human rights; (2) ensure that all people are able to adapt to climate change; (3) guarantee accountability and remedies for the negative effects of climate change on human rights; (4) ensure the availability of resources to ensure the implementation of sustainable development and one that includes human rights considerations; (5) ensure global cooperation on achieving protection of human rights, given the cross border effects of climate change; (6) ensure that the needs of current and future generations will be met amidst these efforts; (7) ensure everyone should benefit equally from science and its applications; (8) protect human rights from non-state actors such as business activities; (9) act against discrimination and ensure equality; and (10) promote informed participation in decision-making (UNHCHR 2016). The main focus of these points is eliminating equality when addressing the effects of climate change and during the design and implementation of adaptation strategies, ensuring a protection across generations with the participation in decision-making of all parties. To that effect, the Human Rights Council has called for the implementation of anti-discrimination laws. "From a human rights perspective, lack of access to education, health, food security, employment, housing, health services and economic resources may often amount to a failure to achieve internationally agreed human rights" (Human Rights Council 2016). It should be noted that the language in expressing the relationship between human rights and climate change is carefully formulated. The attention is shifted toward facilitating human rights protection rather than identifying potential human rights violations.

With a focus on climate change and its severe environmental and social consequences, a human rights approach to environmental protection concentrates on the social problems caused by environmental degradation, creating objectives for empowerment toward better protection of the nonhuman environment. The effects of climate change have been mainly experienced in low-income areas and/or developing countries where the emissions of greenhouse gases were low. Achieving sustainable development should depend on the application of both environmental law and human rights law as well as other fields like law on disaster management and humanitarian law, targeting emerging problems that derive from climate change consequences (Mayer 2012). For example, attention should be paid to the human rights of "climate refugees," who are claiming protection under the 1951 Refugee Convention based on alleged human rights violations amidst climate change effects (Refugee Appeal No. 72185/2000).

The Human Rights Council has repeatedly highlighted the dependence of the enjoyment of fundamental human rights on the addressing of the effects of climate change. The consequences of climate change on food, water, and shelter have obvious effects on the enjoyment of rights related not only to the right to food, water, and shelter but also to the right to life and right to enjoyment of private and family life. The Human Rights Council acknowledges that amidst environmental challenges and during the implementation of environmental protection measures, freedom from discrimination is pivotal. The Human Rights Council Resolution on Human Rights and the Environment recognized "that human beings are at the centre of concerns for sustainable development, that the right to development must be fulfilled in order to meet the development and environmental needs of present and future generations equitably, and that the human person is the central subject of development and should be an active participant in and the beneficiary of the right to development" (UN General Assembly 2016). The resolution called upon states to take into consideration the fulfilment of their human rights obligations when implementing their obligations under the Sustainable Development Goals. A prevailing matter has been the protection of human rights amidst climate change but also during the implementation of adaptation measures.

The Indicators

The 2030 Sustainable Development Goals stressed the importance of ensuring the protection of the "human right to safe drinking water and sanitation and where there is improved hygiene and where food is sufficient, safe, affordable and nutritious." These human rights aspects are affected by climate change and its effects such as floods, droughts, and rising sea levels. The further commitment to protecting the first category of rights reinforced the importance of protecting human rights as part of achieving sustainable development, a connection that was not present in previous sustainable development declarations. The agenda required the elimination of "distinction of any kind as to race, colour, sex, language, religion, political or other opinion, national or social origin, property, birth, disability or other status" (UN General Assembly 2015).

One can hardly "operationalize" the implementation of human rights without indicators. This problem has been addressed by commentators, as well as UN bodies. According to 2030 Agenda, the new indicator framework should be informed by human rights, in measuring progress. This approach meant that the indicators were not only formulated in order to take into account human rights, but the necessary data should have been collected, analyzed, and disseminated according to the established human rights principles (UN General Assembly 2015). The targets and indicators of Goal 13 are promoting the taking of action by states to implement adaptation measures to climate change and ensure education of people on these matters. In more detail, Indicator 13.1 "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries" has direct links to the protection of the right to life. The remainder of the indicators have little to no relevance to legally binding human rights protection provisions. Issues related to the effects of climate change and specific threats to the enjoyment of human rights derive mostly from other goals and their targets which also address the right to health; right to adequate food; right to safe drinking water; and the right of all peoples to freely dispose of their natural wealth and resources. But this is not satisfactory. One of the major concerns around human rights protection and climate change comes from the emerging crisis of "climate-induced migration." The increased movement caused by the severe consequences of climate change, such as floods, drought, rising sea levels, and increased frequency of extreme weather phenomena, warrants a more careful attention over the affected human rights of "climate refugees" and addressing them under international law. Specific human rights focused actions within SDG 13 is pivotal to addressing emerging challenges in line with established human rights provisions.

The Future

Addressing Goal 13 from a human rights angle requires alignment of climate change adaptation policies with human rights law. Such proposals have been made in relation to environmental policies and human rights law at a regional level (e.g., Antonopoulos 2018; Pavoni 2015). The most notable climate change focused attempt was made by the Global Network for the Study of Human Rights and the Environment (GNHRE 2016). The Declaration on Human Rights and Climate Change takes a novel approach in addressing the human rights aspects of climate change, by considering the interests of both the human and the nonhuman world in its wording. The declaration asks for a more careful consideration of the rights of members of vulnerable communities that are most likely to be affected by the multidimensional consequences of climate change such as indigenous populations. Most notably, the declaration clarifies both people's rights amidst climate change and state duties in addressing the extraterritorial character of the phenomenon. Such clarity should be a priority for all legally binding documents to come seeking to address the human rights aspects of climate change.

Cross-References

▶ Climate Change Agreement
▶ Climate Change Effects on People's Livelihood
▶ Climate-Induced Displacement and the Developing Law
▶ Role of Conferences on the Environment and Sustainable Development in Combating Climate Change

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Climate Change Effects on People's Livelihood

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Definitions

Climate and Climate Change

Generally climate is defined as the long-term average weather conditions of a particular place, region, or the world. Key climate variables include surface conditions such as temperature, precipitation, and wind. The Intergovernmental Panel on Climate Change (IPCC) broadly defined climate change as any change in the state of climate which persists for extended periods, usually for decades or longer (Allwood et al. 2014). Climate change may occur due to nature's both internal and external processes. External process involves anthropogenic emission of greenhouse gases to the atmosphere, and volcanic eruptions. The United Nations Framework Convention on Climate Change (UNFCCC) made a distinction between climate change attributable to human contribution to atmospheric composition and natural climate variability. In its Article 1, the UNFCCC defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (United Nations 1992, p. 7).

Livelihood

Livelihood refers to the means of making a person's or supporting family's living. For instance, a village person's livelihood can be farming, fishing, or raising livestock. According to Chambers and Conway (1991), a "livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living" (p. 6). In a broader sense, a livelihood is sustainable when it can maintain assets and resources for the present and the future and enabling it to cope with, and recover from, external shocks such as climate change impacts and other natural hazards (Scoones 2009). Recent understanding of livelihood seems to be applied to a wider variety of topics ranging from income, poverty, food security, and health through to human settlement (Scoones 2009).

Introduction

Climate change effects are broadly defined as the consequences of anthropogenic climate change, which involve both existing and potential harmful effects on human and biophysical systems (Folke et al. 2002). Climatic effects are not only disrupting established functions of ecosystems and biodiversity but also posing strain on the long-term sustainability of the planet's ecosystem for future generations (Rockström et al. 2009). Scientific observations since 1950 confirm that frequency, magnitude, duration, and spatial extent of natural hazards and extreme weather events associated with climate change have increased in many parts of the world (IPCC 2014). Climate change stimuli can disrupt land uses, freshwater, and marine resources and impact overall ecological balance (IPCC 2014). In climate change research, the overall impacts of climate change cannot be measured without accounting for its impacts on human systems and well-being (Rockström et al. 2009). Hence, it is necessary to know how climate influences ecosystems which in turn influences the livelihood of people that depend on ecosystems in many regions of the world.

The biophysical impacts of climate change on people have initially been examined in isolation from existing social-economic and political contexts (Reed et al. 2013). During the last two decades, this approach has been criticized with a view that climate change vulnerability will not take place separately from the existing social-economic contexts, which influence sustenance of productive livelihood of people across the world (Blaikie et al. 1994; Bohle 2001; Hilhorst and Bankoff 2004). Given that livelihood refers to the means of obtaining basic necessities for living (such as income, food, water, housing), it is clear that those who depend more on natural resources will face greater climate change specific livelihood vulnerabilities (Reed et al. 2013). In recent years, attempts have been made toward more integrated approaches in analyzing climate change impacts on people's livelihood, which involves both biophysical means and sociopolitical mechanisms (Reed et al. 2013). In fact, climate change impacts are contributing to rise of global poverty and impacting means of basic human necessities including food, clothing, housing, and income (United Nations 2015). However, there is no succinct way of synthesizing how climate change impacts on livelihoods; different scholars have focused on a wide range of overlapping issues. For the purpose of this chapter, climate change impacts on livelihoods have been categorized into two differing parts. Part I deals with how various climate change impacts influence people's livelihoods in rural versus urban regions across the world. Part II discusses some cross-sectoral issues relating to climate change impacts on livelihoods, including agriculture, food security, land use, water resources, and human settlements.

Part I: Climate Change Impacts on Poverty-Driven Livelihood: A Trans-local Analysis

It is now widely acknowledged that climate change is causing major obstacles to poverty reduction (United Nations 2015). In particular, the pressure of global climate change on livelihoods is closely experienced by the societies largely dependent on natural resources. Globally, the increased number and frequency of natural hazards and extreme weather events and the rising number of poor people being affected by such calamities support this assumption (Winsemius et al. 2018; Park et al. 2018). Though in absolute terms wealthier people lose more assets or property from natural hazards, in relative terms poor people experience greater loss of assets and access to basic services while experiencing disasters or adverse climatic events (Hallegatte et al. 2017). Authors including Karim and Noy (2014) and Hallegatte et al. (2017) have documented impacts from natural hazards on poverty and human livelihoods. The authors found that while experiencing stressful situations linked with climate change and other disruptions across the poorer regions of the world, poor households tend to smooth their food consumption at the cost of non-food items or benefits such as healthcare and education (Karim and Noy 2014). Moreover, the impacts of climate change on livelihoods will differ across regions and geographical spaces. Is it argued that the impacts of climate variability and change may have different types of influences on people's livelihoods in rural versus urban regions

(Nawrotzki et al. 2015). Because the complex interconnections between rural and urban regions vary largely, the exposure to climate change is not only determined by biophysical components but also by social-economic and political factors (Ofoegbu et al. 2017).

Firstly, climate change will have significant impacts on rural livelihoods due to a greater proximity to natural resources and dependency on local ecosystem services for basic livelihood activities, including farm and non-farm activities (Dasgupta et al. 2014). The rural poor in many countries are highly dependent on agricultural income and other *farming related activities*. Besides farming communities, households residing close to forests in many developing countries are less adaptive to climate change, often due to their lower education level and lack of institutional intervention to help them managing various natural resources (Fisher et al. 2010). Hence, many communities in less developed countries are becoming more vulnerable to the impacts of a disaster on their yields and loss of forest resources. Natural hazards such as floods not only destroyed crops and seed reserves in many agricultural-dependent countries but also sparked food prices shock among rural communities across the world (Cheema et al. 2015).

Niles and Salerno (2018) assessed the association between climate shock and food security in 15 different countries in South Asia, Africa, and Latin America and demonstrated that the recent climate change will not only impact on natural resources but also will pose future threat to food security in the developing world. Despite their vulnerability to drought and flooding, rural people in developing countries often tend to raise more market oriented and less drought resilient breeds of livestock to support their income and economic savings (Nkedianye et al. 2011). Often the rural communities which lack access to infrastructure, basic services, and employment opportunities become largely dependent on local forest resources for income and other livelihood activities (Naidoo et al. 2010; Pailler et al. 2015). However, rising temperatures, changes in precipitation, increased level of flooding, prolonged droughts, and frequency of other natural hazards, including cyclones and sea level rise, are obstructing crop production and plantation growth (FAO 2016). In brief, changing climate and weather patterns have significantly constrained the livelihoods of rural communities in developing countries, causing natural resource degradation and increased levels of social inequality (Gentle and Maraseni 2012).

In remote rural areas, isolated communities who lack access to market and transport connectivity are more likely to suffer from food crises if local production is impacted by climate change (Safir et al. 2013). In the Philippines, Safir and colleagues (2013) found that food consumption decreased in remote rural areas with decrease in precipitation; however, households residing closer to a highway were not affected by such negative rainfall shock. Extreme weather events such as flood not only damage roads but also affect transport infrastructure, limit food distribution, and obstruct people's access to markets to sell or purchase food. Given that agriculture is the major occupation in many developing countries, climate change will impact agricultural employment, including how people farm their own lands, and work on other people's farms and other enterprises which are directly or indirectly dependent on agriculture (FAO et al. 2014).

Secondly, in urban areas, climate change impacts on livelihoods are complex and often associated with extreme weather events (Revi et al. 2014). Extreme events such as flooding can damage houses, water, and transport infrastructure and cause unemployment. For instance, Rasch (2015) assessed urban vulnerability to flood in 1276 Brazilian municipalities and showed that urban populations who are at the frontier of flood risks in different regions of the country are from lower social-economic backgrounds, with higher unemployment rates and lower household income. Additionally, heat waves can impact both performance and health conditions of workers in manual occupations and adversely affect their financial well-being (Kovats and Akhtar 2008). Extreme weather events also cause food insecurity to low income urban residents because of higher food prices. Urban consumers mainly depend on a combination of food supply networks, whereas a major supply can come from distant locations. Extreme weather events such as flooding can damage roads linking rural and urban areas, disrupt food distribution networks, and cause shortage of food supply (Battersby 2012). Rodriguez-Oreggia et al. (2013) examined effects of natural hazards on poverty at the municipal level in Mexico and found that floods and droughts lead to significant increase in poverty. Other studies also generated similar evidence in various urban settings where the increased number of disasters increased poverty rates to a significant level (Hallegatte et al. 2018).

Historically, many large cities were established near rivers and coastlines because of the benefits of less expensive transportation and market connectivity. The United Nations estimated that by 2030, about 60% of people worldwide will live in cities (United Nations 2006). Cities with an exponentially increasing population in coastal regions such as Central Java are becoming subject to increased levels of livelihood vulnerability due to a lack of income and other socioeconomic difficulties (Handayani and Kumalasari 2015). Hallegatte et al. (2013) also provided a quantification of present and future flood loses in 136 large cities across the world. Their study cautioned that the current standard of resilience in most of the coastal cities against storm surges and flooding are useful to withstand current extreme weather events, whereas future losses and damages are likely to be exacerbated in many coastal cities. Moreover, it is much difficult for resource poor countries to manage urban hazards due to lack of long-term planning and implementation (IMF 2017). In the long run, various climatic disruptions are likely to bring compounded impacts on less resilient cities where the devastating loss can take long-term toll on people and property such as land degradation, loss of natural resources, unemployment, and increased health expenditure due to post disaster traumas (UN-HABITAT 2014). In brief, the increasing population in the context of recent climate change is exacerbating stress and pressure on urban livelihoods; disadvantaged people who work in primary sectors are likely to become immediate victims of environmental degradation in urban areas (Handayani and Kumalasari 2015).

Nevertheless, it is also critically important to consider the cross-scale interactions between rural and urban regions while considering climate change impacts on livelihood. Urban areas are typically dependent on natural resources including land, water, and energy. Large-scale supply chains have been widely used for rural-urban dependency on food supply and energy resources (Güneralp et al. 2013). Climate-related shocks and extreme weather events frequently affect such supply chains and commodity flows from rural to urban areas (Satterthwaite et al. 2008). For example, the extended drought periods in the Mississippi river area resulted in reduced water flow which significantly interrupted barge traffic and delayed commodity flows within the United States (Morton et al. 2014). Again, adverse climatic conditions can increase local unemployment and cause unmanageable financial pressure at the household level. This situation can attract a large number of people to migrate to cities from rural areas, where migration can be chosen as an alternative livelihood strategy. However, in cities, social inequalities between local residents and new migrants can increase frustration and social unrest, which may also spur urban violence (Østby 2015). The latter part of this chapter will discuss how disadvantaged migrants become exposed to new sets of risks after migrating to cities.

Part II: Climate Change Impacts on Livelihood: Cross-Sectoral Analyses

Climate change is affecting many sectors within the larger contexts of human-environment systems (Rockström et al. 2009). Sectors most critically affected by climate change include agriculture, forest, biodiversity, coast, energy, transportation, water resource, and society (Harrison et al. 2015). Many studies produced independent in-depth analysis on each of these sectors and issues related to climate change; however, such analysis ignored significant interconnections between various sectors (Harrison et al. 2015).

Ignoring cross-sectoral issues can undermine the actual impacts of climate change on both biophysical and human systems. For instance, changes in land use impact water quality and resources, which can ultimately impact food security, flood defense, and coastal settlements (Holman et al. 2008). The cross-sectoral risks of climate change will therefore influence human living conditions, human settlements, and food security. To date, a limited number of studies have focused on cross-sectoral impacts of climate change (England et al. 2018). The following section will review cross-sectoral analysis on the effects of climate change on people's livelihoods.

Impacts on Agricultural Production, Groundwater Reserve, and Food Security

Climate change impacts such as increased heat waves, droughts, floods, and storms lead to significant impacts on global agricultural production (FAO 2016). Since the actual impacts of climate change vary from one region to another, and also within a region (Vermeulen et al. 2012), many countries and poorer regions are suffering from disproportionate effects of food shortage and other agrarian crises (Swaminathan 2012). The rise of mean temperatures will disturb the duration of crop life cycles in South Asia and sub-Saharan Africa – regions already suffering from widespread hunger and poverty (Maharjan and Joshi 2013). In Latin American countries such as Mexico, increase in minimum and maximum temperatures due to climate change is reducing wheat yields (Lobell et al. 2005). Moreover, considering the highest emission trajectory situation by 2050, crop yields in Asia may decrease by 5–30% (Maharjan and Joshi 2013). The rainfed agriculture in South and Southeast Asia may become the hardest hit of this situation. According to FAO estimates on future demands for food consumption, by 2050, annual cereal production will be required to increase by up to 70% higher than 2006 levels (Alexandratos and Bruinsma 2012). Nonetheless, climate change is not the only factor impacting on food security; rapid population growth and economic and political changes that are taking place globally may have heterogeneous influence on food production across the world (Alexandratos and Bruinsma 2012).

Higher temperatures and changes in precipitation (especially where rainfall declines) will require increased groundwater-based irrigation in agriculture (FAO 2008). However, the expanded irrigation schemes for agriculture are driving enormous water stress in many regions of the world (FAO 2017). In the last century, the land area brought under agricultural irrigation has increased more than six times globally, from 40 million hectares in 1900 to above 260 million hectares at present (Chartzoulakisa and Bertaki 2015). This imposes pressure on availability and quality of groundwater given that many agricultural producers switched to machine-assisted groundwater-based irrigation. Further, the demand for agricultural irrigation may rise up to an additional 13.6% by 2025 (Rosegrant and Cai 2002).

Besides affecting species, ecosystems, rivers, and surface water users, concerns of groundwater depletion for agriculture include increased financial stress and debt burden for small holders in both developing and developed countries (McDonald and Girvetz 2014; Kabir et al. 2018a). For instance, in the northern drought prone areas of Bangladesh, expansion of groundwater-based irrigation and introduction of high yield variety of seeds increased crop production. However, the charged prices for such government-run irrigation facilities resulted in excessive production costs for small holders and other sharecroppers (Kabir et al. 2018a). In order to manage extra cost of groundwater irrigation, farmers often borrow money from multiple sources or microcredit institutions at the local level, which further compounds their household financial stress (Kabir et al. 2018a). Similarly, the irrigation schemes constructed so far in sub-Saharan Africa are difficult for the marginalized households to handle due to higher unit cost for water and significant income inequalities within irrigation communities (Manero 2017). MCdonald and Girvetz (2014) estimated that in the United States, climate change would increase average irrigation costs in the states already experiencing dry climate, which will add extra pressure on farming households. As the World Food Program (2017) cautioned, the risks of food insecurity may increase up to 20% due to climate change by 2050 unless necessary efforts are placed to enable the world's vulnerable agricultural regions to better adapt to extreme weather events, including drought and flooding.

Impacts on Surface Water Resources and Livelihoods

Climate change is affecting timing and location of precipitation, which is causing reduction of water flows and water levels in a number of rivers across the world (Kangalawe 2017). This directly results in a decrease of water availability for agriculture and other household needs. Moreover, climate change and other human interventions have resulted in changes in river water quality and temperature which is associated with uncountable loss in aquatic biodiversity. For instance, Bello et al. (2017) estimated impacts of climate change on water temperature in Malaysia and illustrated that most of the suburban rivers will become ecologically unsuitable to a range of aquatic species in the near future, compared with the rivers in rural areas. Again, warmer ocean surface temperatures along with increased temperature in the atmosphere can lead to increased wind speed and change the number, duration, and intensity of tropical storms (Bates et al. 2008). A list of infamous cyclones with destructive powers caused major flooding, destruction of property and natural resources, and loss of lives in the last few decades (Bates et al. 2008). These also posed major challenges for recovery efforts in the developing and developed world, with long-term impacts including chronic poverty, food insecurity, and lack of access to basic necessities.

Nevertheless, climate change impacts such as ocean acidification, rise in water temperatures, and water hazards also affect fish production, supply, distribution, and consumption, thereby affecting the livelihood of 500 million people in developing countries who are dependent on fishing and aquaculture (FAO 2009). The impacts of climate change affect fish habitat and population both in marine and freshwater systems (Ipinjolu et al. 2014). Declining water resources are linked with declining fish catch in the lakes and rivers for communities dependent on fishing (Kangalawe 2017). Moreover, coastal fishing communities are at the front line of global sea level rise. Fishing communities in low-lying countries such as Maldives and Tuvalu are vulnerable to sea level rise and involuntary displacement (ADB 2017). Coastal fishing communities in Bangladesh are vulnerable to sea level rise, flooding, and increased frequency of tropical cyclones. Again, the communities with large human population and heavily dependent on a diet of fish are highly vulnerable to climate change (FAO et al. 2014). For instance, fishing communities in the Mekong river in Southeast Asia are already experiencing salt water intrusion. The population of the Mekong river basin is above 60 million people, for whom fish and mollusks provide 80% of their protein intake (Sarkkula et al. 2009). In brief, climate change will affect aquatic environments, including changes in water quantity, quality, and freshwater biodiversity. The assessed and perceived impacts also include loss of income and food security as experienced by various affected regions and communities.

Impacts on Land Resources and Livelihoods in Low-Lying Regions

Evidence shows that increased carbon emissions during the last two centuries raised global mean temperatures and associated melting of ice sheets and sea level rise. Globally, about 600 million people currently live in low elevated coastal areas which are at the frontier of sea level rise (Dasgupta et al. 2014). Increased salinity from salt water intrusion is causing greater impacts on livelihoods, public health, and coastal ecosystems (IPCC 2012). Moreover, when degradation of land resources take place, it poses higher risks to social-economically disadvantaged people due to scarcity of food, income, and shelter (Bohle 2001).Scientific projections also indicate that by 2050, the progressing inundation from sea level rise may impact livelihoods of about one billion people around the world (Dasgupta et al. 2014). Additionally, land degradation attracts more people to overexploit the remaining productive lands, which results in further degradation. In the long run, the overexploitation of land resources can cause desertification and loss of biodiversity in the existing lands.

One least researched area while examining climate change impacts on lands involves riverbank erosion, which refers to the wearing away of the bank of a river or stream. Riverbank erosion is a recurring natural hazard in low-lying regions of the world. Hydraulic actions, such as the changing direction of river streams and water, create pressure against the banks and cause riverbank erosion. Heavy rainfall and flooding can also increase the intensity of riverbank erosion. Melting of glaciers can also raise water levels, increase intensity of water currents, and further influence riverbank erosion. Moreover, it is now argued that climate change will increase rainfall and precipitation in some regions of the world, which will exacerbate the intensity of riverbank erosion in the near future (MoEF 2009). When land areas are removed by river streams, it impacts human lives, crops, livestock, housing, forests, private property, and infrastructure (Mollah and Ferdaush 2016). Low-lying countries in the Bengal Delta, including Bangladesh and some parts of India, are highly vulnerable to riverbank erosion (Mollah and Ferdaush 2016). Riverbank erosion is the major reason why the landless population is growing in Bangladesh. Moreover, the perceived level of damage is higher for the poor people who lose their land for the first time due to riverbank erosion. As a result, farmers can become totally landless once they experience riverbank erosion. These people are forced to migrate to a new location, which do not provide them with access to similar assets and land resources. As a livelihood coping strategy, many adopt new skills and occupations, where farmers can become day laborers or street vendors (Rahman et al. 2015).

Impacts on Human Settlement and Livelihoods: Rural-Urban Migration

Although the deterministic relationship between climate change impacts and human migration is yet unsettled in academia and policy domains, numerous evidence show that anthropogenic climate change is altering the livelihood options of people in their habitual residence (Jayawardhan 2017). A number of influential studies (Tacoli 2009; Piguet et al. 2011; McLeman 2017) have attributed the increased rate of involuntary migration taking place across the world to the impacts of climate change. Myers and Kent (1995) projected that by 2050, about 200 million people will be displaced in response to the unmanageable impacts on livelihoods, linked to climate change and other natural hazards. IDMC (2014) claimed that in 2013, approximately 22 million people around the world were newly displaced due to the pressure of natural hazards, whereas many of those incidents were linked with climate change (IDMC 2014). In Asia, the number of displacement incidents increased significantly in the past decade along with a rising number of incidents of natural hazards (IOM 2010). For instance, in 2013, 17 out of 20 largest displacement incidents worldwide were noticed in Asia. Typhoon Haiyan, the strongest cyclone ever recorded at land caused over 7,000 death and displaced about four million people in central Philippines (The Daily Telegraph 2013). In the same year, cyclone Mahasen displaced about one million in the coastal areas of Bangladesh and approximately 35,500 people from Rakhine state in Myanmar (The Guardian 2013). In many cases, those who have been displaced due to such extreme weather events have lost livelihood opportunities in their usual places of residence (Biermann and Boas 2010). Moreover, existing government and nongovernment organizations and funding mechanisms in many affected countries are hardly equipped to restore basic livelihood opportunities to affected places (Biermann and Boas 2010).

In many resource poor country settings, the decision to migrate is often taken as an intuitive reaction to the climatic shock on people's livelihoods. Recent studies including Stojanov et al. (2016) contributed to the understanding of the relation between climate change impacts on livelihood and migration as an autonomous response at the community level. Studies also illustrated the pressure of climate variability and its impacts on pastoralists' livelihood in southern Ethiopia (Ayal et al. 2018), seasonal migration of agricultural labors during drought in the Sahel region (Black et al. 2011), and local migration as a prevalent livelihood strategy to cope with drought in northeast Brazil (Barbieri et al. 2010). Studies also suggested that recent climate change is severely impacting the agricultural sector and acting as migration push factors in many agricultural regions of the world. Islam and Hasan (2016) found that about 54% of the Cyclone Aila affected migrants in Bangladesh attributed their migration to damages to their homes and cultivable lands. Previously, Mallick and Vogt (2012) found that after Cyclone Aila, adults from households with the lowest monthly income had the highest migration rate from the affected coastal areas in Bangladesh compared with all others. Kabir et al. (2018b) demonstrated that unmanageable financial stress such as institutional microcredit burden is significantly influencing small holders' decision to migrate for long-term from the northern drought prone areas of Bangladesh. However, the majority of Bangladesh's disadvantaged rural population tend to adopt repetitive patterns of short-term or seasonal migration to supplement their livelihoods during lean periods (Martin et al. 2014). Involuntary migration can be a disruptive process, often involving financial, social, and emotional risks for the disadvantaged migrants and their family members; hence, it is often the last form of response to be attempted (McLeman 2017).

Nevertheless, involuntary rural-urban migration often replaces one set of risks with another, especially when urban destinations are poorly equipped to provide basic human necessities to the new migrants. Thus, migrants affected by climate change at their places of origin may become exposed to a second level of stress at urban destinations, where new hazards may reinforce existing vulnerabilities (McNamara et al. 2016). Urban areas are particularly exposed to unique climatic risks including urban heat island effect, impervious surfaces exacerbating flooding, and sea level rise in coastal cities (Doherty et al. 2016). In the fourth assessment report, the IPCC also warned that heat related mortality in urban areas will be increased in some regions as one of the consequences of the recent global warming (IPCC 2007). Since appropriate housing is not reachable for disadvantaged migrants in cities, the majority of the low income migrants in many cities live in slums or squatter settlements (Elsey et al. 2016). Due to a lack of education, access to social networks, and appropriate skills, slum dwellers are often forced to accept low-paying but difficult jobs in the informal economy (Pawar and Mane 2013). Although desperate efforts to improve their livelihoods are placed, the urban extreme poor lacks saving opportunities, access to basic services, and access to credit (Elsey et al. 2016). Moreover, due to the higher living costs in cities, many migrants living in urban slums leave their children at their rural residences in the custody of other family members. Ajaero and Onokala (2013) found that due to the pressure of sending remittance to the family members in rural areas, disadvantaged migrants living in cities suffer from low real income. Such a double financial pressure also limits their ability to access other basic needs including healthcare benefits when needed. In brief, increased financial expenditure, unhealthy living conditions, and lack of access to basic services are key issues for disadvantaged migrants in cities which are also associated with their lower capacity to recover from disasters and adapt to urban climate change impacts.

Moving Forward

This chapter focused on the interactions between climate change effects and human livelihoods through trans-local (between rural and urban) and cross-sectoral analyses. As rural and urban areas are strongly interconnected and interdependent, climate change is likely to exacerbate cross-scale interactions between these two regions. Again, understanding cross-sectoral impacts of climate change on livelihoods is critical because such insights will develop capacities of decision-makers with holistic views on climate change impacts, instead of considering single sectors in isolation (Harrison et al. 2015). Given that the Sustainable Development Goals adopted by the United Nations member states in 2015 cover 17 broad and interdependent goals ranging from "zero hunger" to "climate actions," a lack of sufficient response to climate change impacts will persistently erode the basis of these goals (Rodriguez et al. 2018). The rapid urban growth in the Global South, loss of agricultural yields, risks of hunger and undernutrition, land degradation, loss of biodiversity, increased water stress, and loss of human settlements among others are exacerbating existing livelihood vulnerability of the poor and disadvantaged people to climatic changes and other extreme weather events. Hence, tackling livelihoods sustainability demand practitioners stress the importance of such multidimensional climate change challenges, become well equipped with essential climate change adaptation planning, and recognize that different sectors will pose concomitant challenges for development managers due to various social-economic, environmental, and climatic uncertainties.

The examples presented in this chapter are not unique to climate change effects. However, these should be helpful to understand the climate change effect on people's livelihoods to a wide range of social-ecological settings and changes. To implement adaptation interventions that enhance support to the most vulnerable, it is imperative to improve our understanding of both how people are likely to be affected by climate change and other natural hazards and how they may possibly react to such circumstances. In order to properly understand future livelihood risks associated with climate change, more interdisciplinary research is necessary. This includes research that focuses on: (i) climate change impacts on human-environment systems and future social-ecological challenges; (ii) how individuals are likely to deal with different adverse climatic situations; and, (iii) increasing developing countries' capacity to monitor climate change effects to better understand cross-sectoral impacts.

Cross-References

- ▶ Climate Change Adaptation (CCA)
- ▶ Climate Change and Human Migration as Adaptation: Conceptual and Practical Challenges and Opportunities
- ▶ Climate Change Impacts and Resilience: An Arctic Case Study
- ▶ Climate Refugees
- ▶ Making Communities Resilient to Global Climate Change

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Climate Change Impacts and Resilience: An Arctic Case Study

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Definitions

Climate change is defined by the Intergovernmental Panel on Climate Change (IPCC) as an observable change in the state of the climate taking place over an extended period of time that may be caused by natural processes (i.e., volcanic eruptions) or external forces (i.e., anthropogenic changes to atmospheric composition, land use) (IPCC 2014). The United Nations Framework Convention on Climate Change (UNFCCC) takes a different approach, defining climate change as a change in climate that can be attributed directly or indirectly to anthropogenic activity and that changes the composition of Earth's atmosphere. According to the UNFCCC, this change is in addition to observed natural climate variability over a similar period of time (United Nations 1992).

Earth's climate has naturally fluctuated over the course of history due to internal forces such as variations in ocean currents, volcanic eruptions, and atmospheric circulation. However, since the postindustrial era, anthropogenic activities have led to a large increase in the concentrations of greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in the Earth's atmosphere (IPCC 2014). These GHG emissions (largely due to the burning of fossil fuels, deforestation, and agriculture) have resulted in an increase in global average temperatures.

Climate change impacts: Climate change can manifest in a variety of ways, with impacts ranging in occurrence and severity. Globally, a number of climate change impacts have been observed:

- Earth's land and ocean surface temperature increased 0.85 °C between 1850 and 2012, with each of the last three decades successively warmer than any preceding decade since 1850 (IPCC 2014).
- Thermal monitoring in northern Canada indicates that warming of permafrost has occurred in recent years, with summer thaw penetration increasing as early as the 1990s (Prowse et al. 2009). Approximately half of the permafrost in Canada is at risk of disappearing under projected global warming (Prowse et al. 2009). Warming and thawing of permafrost is causing engineering concerns related to infrastructure stability, for example, increased creep of foundations and frost heave on pilings (Instanes et al. 2005).
- The extent of sea ice in the Arctic has decreased in every season and in every successive decade since 1979 (IPCC 2014). The annual maximum ice area has reduced by about 2% per decade, and the annual minimum ice area has declined by about 5.6% per decade (Prowse et al. 2009). Variations in sea ice thickness and extent put a strain on indigenous communities in the Arctic who rely on safe travel over the ice for successful hunting expeditions (Ford et al. 2017).
- Ice sheets in Greenland and Antarctica have been losing mass over the last two decades, with the rate of ice mass loss from both ice sheets increasing substantially over the period from 1992 to 2011 (IPCC 2014). Melting of land-based ice sheets along with thermal expansion of the warming oceans contribute to sea level rise globally (IPCC 2014).
- Global mean sea level rose by 1.7 mm/year from 1901 to 2010 with that figure nearly doubling between 1993 and 2010 (IPCC 2014). Approximately 75% of observed global mean sea level rise since the early 1970s can be attributed to thermal expansion of the world's oceans and increased melting rates of glaciers and ice caps due to warming (IPCC 2014). Reef islands such as the Maldives with elevations of only 1–2 m above mean sea level are at risk of disappearing within this century if climate-induced sea level rise continues (Woodworth 2005).
- Storm surges, defined by the IPCC as a temporary increase in the height of the sea in excess of the expected level of tidal variation in a particular location, have increased since 1970 (IPCC 2014). Studies show that there could be a larger number of intense storms due to climate change, with mid-latitude oceans in particular projected to experience increases in extreme wave height (Hallegatte et al. 2011). Storm surges associated with climate change can lead to the flooding and erosion of coastal areas, stressing urban development and tourism industries in coastal communities (Toubes et al. 2017).
- Increased coastline exposure to waves and storms will lead to greater coastal erosion throughout the twenty-first century (IPCC 2014). In the Arctic, thawing of permafrost leads to hydrologic and geomorphic change making coastal areas more vulnerable to erosion (Chapin et al. 2006). Coastal erosion in Alaska has led to a loss of terrestrial habitat, causing some communities to relocate to safer areas (USGCRP 2018).
- As sea levels rise, saltwater is pushed further inland through rivers, deltas, and coastal aquifers (Hall et al. 2008). Saltwater intrusion is the infiltration of saline water into fresh

groundwater aquifers in coastal areas (Werner and Simmons 2009). High demand for groundwater during the summer and fall months in California can result in saltwater intrusion as aquifers are depleted (Hall et al. 2008). Saltwater intrusion into coastal aquifers can threaten drinking water supplies, infrastructure, and coastal and estuarine ecosystems (USGCRP 2018).

- Low-elevation delta regions, such as those in heavily populated areas in South Asia, are at a high risk of flooding as sea levels rise and precipitation patterns change (McGranahan et al. 2007). Future climate scenarios suggest that an increase in the frequency, magnitude, and extent of flooding in South Asia can be expected (Mirza 2011). Densely populated cities in South Asia tend to have heavily developed delta regions. These flood-prone areas are often populated by vulnerable communities without the means to relocate (McGranahan et al. 2007).
- Changing temperatures and shifts in the timing and magnitude of precipitation events are leading to increasingly large and destructive wildfires around the world. In California, for instance, wildfire frequency, size, and overall burned area annually are collectively increasing (Miller et al. 2009). The increased frequency and intensity of wildfires leads to increased risk to property and lives and a rising economic cost of fire suppression efforts (USGCRP 2018).
- As anthropogenic climate change progresses, there is a risk of increased frequency, intensity, and duration of droughts (Kiem and Austin 2013). Southeastern Australia, for example, has been experiencing an extended period of drought since the mid-1990s (Sherval and Askew 2012). Persisting drought leads to low financial returns in agricultural sectors, quickly spreading to associated industries and economies (Kiem and Austin 2013).

Resilience comes from the Latin root *resilire*, meaning to “spring back” (Davoudi et al. 2012). Multiple definitions of the term have since evolved, beginning in 1973 when C.S. Holling defined the difference between engineering and ecological resilience. Holling defined engineering resilience, or stability, as the ability of a system to return to an equilibrium state following a disturbance. The rate at which a system returns to equilibrium, along with its resistance to fluctuation, dictates how stable or resilient it is (Holling 1973).

Ecological resilience on the other hand is a measure of the persistence of a system despite an added stressor. It measures the magnitude of a disturbance that a system can absorb while still maintaining the same fundamental function and structure (Holling 1996). Ecological resilience allows for a system to change and acknowledges the presence of multiple states of equilibria with a greater focus on the ability to persist and adapt (Adger 2003).

Evolutionary resilience is a more recent iteration of the concept. In this view, natural and social systems are considered nonlinear (Folke et al. 2002). Evolutionary resilience therefore places a greater importance on the ability of a system to change, adapt, and transform in response to stressors (Walker et al. 2004). The IPCC, when defining resilience, takes the evolutionary approach. It places an emphasis on the capacity of social, economic, and environmental systems to manage a hazardous event, trend, or disturbance and to respond in ways that maintain the system’s essential function and structure while also fostering the capacity for adaptation, learning, and transformation (IPCC 2014).

Introduction

Climate Change Impacts

Anthropogenic contributions of GHG emissions into the atmosphere through the burning of fossil fuels, deforestation, and agriculture have been shown to cause increases in global temperature (IPCC 2014). Global climate, over the last six decades, has been changing rapidly when compared to natural variations that have occurred throughout Earth’s history (USGCRP 2017). As of 2018, human activities are estimated to have caused approximately 1.0 °C of global warming above pre-industrial levels (IPCC 2018).

However, changes in climate can vary drastically across the planet with some regions experiencing warming greater than the global average and, at the same time, lower average temperature changes over the ocean than over land (IPCC 2018). There has also been a significant decrease in total precipitation (rainfall) in southern Europe, China, and southwestern Australia, while precipitation has increased in much of Canada, northern Europe, and Scandinavia (Dore 2005). The annual extent of snow cover in the northern hemisphere has been steadily decreasing due to increased spring and summer melt, yet the United States, Canada, and Russia have all experienced an increase in annual snowfall (Dore 2005).

Historic emissions commit Earth to some degree of future warming regardless of efforts to mitigate climate change. Indeed, models suggest that global temperatures could increase by 1.5–2 °C by 2100 (IPCC 2014). Mitigation efforts, largely via emissions trading schemes and carbon markets, have been the primary focus of climate change policy (e.g., Birchall et al. 2015; Birchall 2014). Yet GHG emissions continue unabated throughout much of the world. With extreme climate impacts rising temporally and spatially, the need for adaptation is becoming increasingly important. Recent reports released by the IPCC and the US National Climate Assessment (NCA) show growing evidence that climate change impacts will have a significant effect on both natural and human systems globally. Addressing issues of vulnerability will be crucial to the resilience of communities and urban centers across the globe and will require radical social and economic shifts (Carter et al. 2015).

Vulnerability to Climate Change

Sources of anthropogenic GHG emissions have historically been concentrated in a small number of developed countries, while many of the populations that are most vulnerable to the impacts of climate change have contributed little to global GHG emissions (IPCC 2014). Climate change is not limited geographically, and GHG emissions from one country or region can lead to global changes in climate. Urban areas with high population density and infrastructure development are especially vulnerable to the impacts of climate change (Carter et al. 2015).

According to the United Nations, more than 50% of the world's population currently lives in urban areas (United Nations 2018). This figure is expected to rise to more than 60% over the next three decades, with most future urban population growth expected to occur in developing countries (Wilby 2007). As urban populations increase globally, cities and their elected officials will be important actors in future direction and decision-making on climate change. Not only do cities account for more than 40% of global GHG emissions, they are also uniquely vulnerable to the effects of climate change (Rosenzweig et al. 2011). Due to high concentration of land development in urban areas, cities experience unique microclimates that can magnify the effects of climate change. The urban heat island effect, which causes urban areas to be warmer than the surrounding countryside, can be exacerbated by more frequent heat waves associated with climate change (Rosenzweig et al. 2011). Further, replacement of vegetated surfaces with impervious built surfaces leads to reduced infiltration of rainwater runoff, which will cause a higher risk of flooding with projected variations in the frequency and intensity of precipitation (Carter et al. 2015).

Vulnerability to climate change is not solely determined by climate impacts, it is also largely subject to various non-climate-related elements, including socioeconomic factors, demographic shifts and trends, and resource accessibility (Baker et al. 2012). In developing countries urbanization is occurring more rapidly, with the challenges described above exacerbate pronounced stressors such as ageing infrastructure, improper land use, and income inequality.

Pressure on land in developing countries often leads to development of vulnerable spaces such as flood-prone areas, with the poorest of the population living in these locations (Nicholls 1995). Climate change impacts tend to have a greater effect on vulnerable populations such as the elderly or those with low income. Inequities among socioeconomic groups are projected to become even more pronounced as climate change progresses (Rosenzweig et al. 2011).

Poverty, gender, ethnicity, and age have all been documented as factors that affect vulnerability of urban populations to climate hazards (Tyler and Moench 2012). These social elements, when combined with the physical processes of climate change impacts, can lead to various, potentially poorly understood, secondary effects such as displacement of vulnerable populations (Carter et al. 2015). Moreover, populations that do not have the resources to adapt to climate change impacts will experience higher exposure to extreme weather events. This is particularly true for low-income populations in developing countries and also remote locations such as the Arctic (IPCC 2014). Arctic communities are often located in isolated areas with limited seasonal accessibility and experience greater social, health, and economic disparities, compared to communities in more populated regions. These disparities, along with a strong dependence on the environment, make Arctic communities especially vulnerable to climate change impacts (Larsen et al. 2014).

Climate change impacts have the potential to affect communities globally, disproportionately impacting low-income and socially vulnerable populations. Adaptation programs are thus becoming increasingly necessary to address vulnerabilities and build resilient communities.

Restrictions to Adaptation

While communities around the world are developing adaptation programs, efforts remain largely uncoordinated and inconsistent (Wallace 2017). There is often a deficit in local, relevant, and easily accessible research to support the development of adaptation plans (Baker et al. 2012). If the public and local government decision-makers are not well educated on the impacts of climate change, barriers can arise that impede policy action and implementation. Many adaptation policies and plans involve expensive investments and long-term commitments, which can be financially restrictive. Indeed, uncertainty surrounding the timing and severity of climate-related impacts, combined with limited resources and funding, and conflicting objectives among interest groups, can lead governments to prioritize more concrete and short-term issues over climate change adaptation (Baker et al. 2012; O'Brien et al. 2006). Even when a community and local government are engaged and supportive of adaptation policies, implementation can be hindered by jurisdictional conflicts over who can or must take action on a particular initiative (Rosenzweig et al. 2011). Inconsistencies in legislation across state and federal levels of government and even among local governmental departments can form constraints on policy development and execution (Wallace 2017).

Improving Urban Resilience to Climate Change

Mitigation, through management of anthropogenic contributions to GHG emissions, has been the primary approach when responding to climate change; however, with projections committing Earth to at least some degree of warming, the need for adaptation is becoming increasingly apparent (Wallace 2017). Community resilience to climate change can be seen as the basis for increasing adaptive capacity (Bulkeley and Tuts 2013). Determining the adaptive capacity of a community requires considering the potential impacts of climate change in the context of social, physical, and governing structures already in place. Stressors such as resource scarcity can affect a community's resilience and capacity to adapt to future climate hazards (Bulkeley and Tuts 2013).

Creating resilient communities prepares them for future known and unknown impacts of climate change. A more resilient community is able to absorb larger climate stressors without changing in fundamental ways. If and when massive transformation occurs, a resilient community will be able to successfully reorganize (Folke et al. 2010).

Climate Science

Reliable research is essential in supporting successful adaptation planning and policy. Uncertainty with regard to local climate change projections, however, has the potential to form barriers to action (Ford et al. 2017). Policy-makers and stakeholders need access to data on regional-and local-scale climate change impacts and vulnerabilities in order to effectively plan long-term adaptation responses (Carter et al. 2015). Despite the prevalence of large-scale climate models and data, there is often a lack of relevant research on local-scale climate impacts. This makes it difficult to project how climate change will affect individual communities, which hinders decision-makers' ability to negotiate and assemble resources for local adaptation policy (Baker et al. 2012; Picketts et al. 2016). Improved knowledge, covering a range of disciplines, is essential to support government action in developing effective adaptation responses to climate change (Nicholls 1995; Baker et al. 2012).

Political Leadership

Political leadership is critical for climate change adaptation and resilience. However, there are often various limiting factors in developing successful government adaptation policies. As mentioned above, a lack of reliable research paired with the inherent variability associated with climate change impacts can make it difficult to gain political buy-in for adaptation. Further, local governments are often dealing with limited resources and tend to focus on more immediate and short-term issues; planning for future and uncertain climate change impacts can be overwhelming (Baker et al. 2012; Wallace 2017).

Research suggests that mainstreaming of climate change policies so that they are integrated into existing procedures and policy goals can help to enhance community resilience to longer-term climate impacts while still dealing with present-day issues (O'Brien et al. 2006; Ford et al. 2007; Wallace 2017). In order to increase effectiveness, developing comprehensive and achievable climate change adaptation policies requires consideration of, and integration with, current government policies (and coordinated across governance scales). Additionally, the process of developing policy should be consistently revisited and improved as experience grows; a successful adaptation policy will remain responsive to changing conditions and human requirements (Nicholls 1995).

The sharing of information and resources is crucial to identifying and implementing successful policies (Baker et al. 2012; Bulkeley and Tuts 2013; Carter et al. 2015). Climate adaptation policies should be supported by consistent legislation at all levels of government with additional collaboration and engagement among various public and private stakeholders in the community (Baker et al. 2012; Bulkeley and Tuts 2013; Picketts et al. 2016; Wallace 2017). Local governments, while critical players in adaptation planning, cannot act fully independently of external forces. Often, a community's adaptive capacity is tied to global and regional economic, technological, and environmental trends (IPCC 2014). At the same time, policies established at higher levels of government without consultation with local governments or institutions can lead to unforeseen consequences down the line (Baker et al. 2012; IPCC 2014). To improve efficiency, standards for climate adaptation plans should be coordinated by national governments, while consulting local governments and acknowledging the highly variable context of different communities (Baker et al. 2012; IPCC 2014). National governments can also facilitate local government efforts through ongoing funding to help enable long-term planning around climate change preparedness (Baker et al. 2012).

In order to be successful, resilience-building processes must be inclusive, allowing participation and involvement by all invested parties including vulnerable community members most affected by climate change (Tyler and Moench 2012; Bulkeley and Tuts 2013).

Adaptive Measures

Adaptive measures that build resilience to climate change can take many forms depending on the specific vulnerabilities of a community. They can come in the form of institutional, educational, and behavioral change; development of early warning and proactive planning information systems; physical infrastructure development; integrated natural resources management; etc. (IPCC 2014).

Harman et al. 2015 discusses three main categories of adaptation to climate change: planned retreat, accommodation measures, and protective measures. *Planned retreat* involves organized withdrawal or regulated restrictions on development in hazardous coastal areas affected by sea level rise, erosion, storm surges, etc. (Harman et al. 2015).

Accommodation measures consist of revised building codes and changes to urban design, allowing populations to continue to develop and live in areas affected by climate change impacts while reducing sensitivity and/or exposure to those impacts (Harman et al. 2015). Increasing green space in developed urban areas is considered a valuable accommodation response, as green spaces can mitigate the urban heat island effect by reradiating less heat than built surfaces and providing cooling through evapotranspiration while also creating attractive spaces within urban centers (Carter et al. 2015).

Protective measures can be used to shield coastal communities from the impacts of climate change. These can be implemented through hard defenses, such as dikes or sea walls, or soft defenses such as beach nourishment or coastline naturalization (Harman et al. 2015). As sea levels rise and the potential severity and frequency of storm surges increases, hard defenses can prevent flooding and reduce coastal erosion (Harman et al. 2015). Coastline naturalization can help to protect developed areas from the impacts of climate change (Harman et al. 2015; McDougall 2017). Allowing a coastline to either remain in or return to its natural state can reduce the risk of flooding associated with sea level rise and storm surges while also providing a form of erosion control (Cormier-Salem and Panfili 2016).

Successful implementation of adaptive measures should involve public disclosure at all stages. Open communication with at-risk populations allows the public to be involved in adaptation planning while also making them aware of any hazards associated with climate change in their community (Bulkeley and Tuts 2013; Harman et al. 2015).

A Case Study of the Arctic

Vulnerability in Arctic Communities

The Arctic is warming at a rate two to three times that of the global average (IPCC 2018). Since the 1950s, average annual temperatures in the Arctic have risen by about 2 –3 °C and in the winter by up to 4 °C (ACIA 2005). The effects of climate change in the north are not going unnoticed; communities, governments, and indigenous organizations in the Arctic have all expressed concern over the risks associated with climate change and the urgency for appropriate action (Ford et al. 2007).

Climate variability in the Arctic has always affected the way of life of northern populations. High winds, fog, and ice breakup in the summer and extremely low temperatures and blizzards in the winters heavily influence daily activities (ACIA 2005). In recent years, seasons have become less consistent, with shorter spans of extremely low temperatures and an increasing daily temperature variation (ACIA 2005). As the climate continues to change in the north, warmer seasonal temperatures have led to increased unpredictability of sea ice conditions, melting permafrost, and, subsequently, coastal erosion (Ford et al. 2008). These changes are impacting infrastructure, food systems, livelihoods, and human health and well-being (Ford et al. 2017). Thawing permafrost and coastal erosion have already damaged infrastructure and heritage sites along the Beaufort Sea coast and caused planned retreat and relocation of entire coastal communities in Alaska (Shaw et al. 1998; Bronen and Chapin 2013). Reductions in the extent, stability, and seasonal duration of sea ice, along with less predictable weather patterns, have affected traditional hunting and subsistence activities of Arctic indigenous groups (Krupnik and Jolly 2002).

Both indigenous and nonindigenous peoples in the Arctic have traditionally been quite resilient to climate variability. For instance, hunters will adjust their hunting trails, the timing of their excursions, and even the animals they hunt in an effort to cope with large seasonal and inter-annual fluctuations in weather patterns and natural resources availability (Chapin et al. 2006; Ford et al. 2007; Larsen et al. 2014). However, with more extreme projected climate impacts, the resilience of northern communities will depend heavily on successful implementation of strategic long-term adaptation policy.

In Canada, for example, most of the funding allocated to adaptation by the federal government is used for climate research with very few examples of the research translating over to concrete implementation of adaptation policy (Ford et al. 2017). In order to develop adaptation programs and strategies that build a community that is resilient to both the physical and socioeconomic impacts of climate change, it is imperative that policy-makers and local leaders focus on understanding the nature and scale of climate impacts on their local community.

Resilience and Adaptation in the Arctic

Arctic communities, with small populations and limited industrial activity, contribute little to global GHG emissions (Ford et al. 2007). However, these communities are especially vulnerable to the effects of climate change due to their strong cultural ties to the environment and a heavy dependence on hunting and fishing to support their way of life (Larsen et al. 2014). As the climate in the Arctic becomes increasingly variable and extreme, adaptation is quickly becoming a necessity for building and maintaining resilience in these communities.

Coastal erosion caused by a combination of sea level rise, increased storm surges, and changing winter sea ice patterns affects a large number of coastal communities in the Arctic. In fact, the US Government Accountability Office found that flooding and erosion affect 184 of the 213 Alaska indigenous villages. Thirty-one of these villages are imminently threatened, and 12 communities are planning to relocate (Bronen and Chapin 2013).

As coastal communities experience increasingly devastating effects, local governments find themselves allocating greater resources to infrastructure repairs and shoreline defenses such as sea walls. In the past, sea ice protected coastal communities by creating a barrier to storm-related waves and surges; however, the intensity of storms combined with changing sea ice conditions has resulted in elevated rates of coastal erosion and significantly damaged engineered defenses (ACIA 2005; Bronen and Chapin 2013).

Determining appropriate adaptive responses requires ongoing assessment of a community's vulnerability and its capacity to adapt through protection in place, managed retreat of at-risk structures, or community-wide relocation (Bronen and Chapin 2013). In the United States, for example, erosion control and flood protection efforts have not been sufficient to eliminate risk in some communities, despite significant state and federal resource expenditures (Bronen and Chapin 2013). When engineered controls are no longer feasible, many communities are forced to relocate to areas of lower risk. Relocation and managed retreat can be extremely costly as infrastructure, housing, and livelihoods must be rebuilt (Bronen and Chapin 2013).

As climate change progresses, it is important to create a governance framework to help communities faced with relocation to understand how they can access funding or technical assistance to support adaptation (Albert et al. 2018). Government should be able to dynamically respond to communities faced with coastal climate change impacts and provide support through post-disaster recovery, protection in place, hazard mitigation, and relocation while considering the humanitarian needs (Bronen and Chapin 2013).

For many Arctic indigenous groups, more than just their homes and infrastructure are affected by climate change. Traditional daily activities such as hunting and fishing are almost entirely dictated by environmental conditions such as sea ice thickness, snow depth, and winter storms (ACIA 2005). Financial limitations can restrict hunters from purchasing equipment such as GPS devices, immersion suits, and personal locator beacons needed to keep them safe in unpredictable conditions (Ford et al. 2007). Economic and institutional support through government funding and public programs can help to build resilience in Arctic communities where there are often high levels of unemployment and limited job opportunities and where much of the population is reliant upon hunting as a source of income or subsistence (Ford et al. 2007). The small equipment fund from Nunavut Tunngavik Incorporated and the disaster compensation fund from the Government of Nunavut are examples of programs that provide hunters with the means to purchase safety equipment, to help better prepare for climate variability (Ford et al. 2007).

Communities throughout the Arctic, depending on their geography, infrastructure, and economic drivers, will experience vulnerability to climate change in different ways. This discrepancy highlights the need for local stakeholder engagement when planning adaptation policies in the Arctic. Engaging with local communities throughout the planning process allows the most vulnerable individuals to have a voice. Stakeholder engagement is especially important in Arctic communities due to the ongoing value placed on Inuit traditional knowledge, or Inuit Qaujimajatuqangit (Ford et al. 2017). The high adaptive capacity of northern indigenous peoples in the past has been largely attributed to the dynamic nature of traditional knowledge (Larsen et al. 2014). The long-term success and implementation of climate adaptation plans in the Arctic is more likely if policies are closely tied to indigenous cultural values and historical knowledge (Ford et al. 2007). Policy-makers should engage local community members and elders throughout the planning and development process to ensure policies appropriately address vulnerabilities and cultural values.

Climate change research in the Arctic has become increasingly widespread as the region has been recognized as an early warning opportunity to understand how climate change may impact other areas around the globe (Ford et al. 2012). While a majority of climate research conducted in the Arctic is related to physical climate change impacts, research on the human dimensions of climate change in the Canadian Arctic is on the rise (Birchall and Bonnett 2018; Birchall 2019). Research has also begun to focus on the importance of indigenous traditional knowledge and the impacts that climate change is having on human interactions with the environment (Ford et al. 2012). Despite these increases, there are still geographic disparities limiting local research across the widely dispersed communities and regions of the Arctic (Ford et al. 2007). Due to the significant differences in vulnerability and adaptive capacity between regions, geographic disparities in research can lead to large knowledge gaps that may then affect local policy-makers' ability to develop successful adaptation policies. Remote Arctic communities often struggle with a lack of access to reliable, up-to-date research and climate projections (Ford et al. 2017). Increasing the geographic scope of climate research in the Arctic will help to improve access to accurate and reliable climate data and projections.

With climate change impacts already influencing communities in the Arctic, indigenous peoples have begun to implement their own adaptation strategies (Larsen et al. 2014). Indeed, hunters have adapted their activities to account for environmental change, including changing the timing and location of hunting and fishing areas, combining new technologies with traditional knowledge, taking more supplies while hunting, and constructing permanent shelters on land as refuge from storms (Larsen et al. 2014). Communities in the Arctic are well equipped with a long history of resilience and adaptation to change. However, with environmental variability exacerbated by current (and projected) climate change, historical adaptation methods may no longer be sufficient. Proper government funding and support along with continued scientific research will be needed to supplement traditional knowledge and foster ongoing resilience in future generations.

Opportunities

As the Arctic continues to warm, some changes in the physical environment will eventually provide new opportunities and benefits to industries such as agriculture, biofuels, forestry, and shipping (ACIA 2005; Chapin et al. 2006). Warmer summer months and longer growing seasons will increase the productivity of many crops in the Arctic, allowing for development of agricultural industries. In Iceland, for instance, the production of grain has increased over the last two decades (Larsen et al. 2014).

Warmer seasonal temperatures open up the Arctic Ocean to longer shipping seasons and additional shipping routes. A decrease in sea ice thickness will positively affect shipping operations by reducing the need for ice breakers and thereby reduce overall shipping costs. An increase in shipping in the Arctic Ocean could also enhance economic trade of natural resources in the region. With improved transportation conditions to bring products to market, industries like mining and agriculture will be much easier to sustain and develop (ACIA 2005).

While most opportunities arising from climate change in the Arctic tend to benefit commercial industries, there will be some benefits to traditional practices as well. Increased prevalence of storm surges, for example, can benefit some hunting and harvesting activities: late-season storm surges wash clams onto beaches, making it easier to harvest them; whitefish can be trapped uprivers behind sand dams formed by the storm surges. In addition, later freeze-ups can provide hunters with a longer period to use boats to hunt spotted seals and caribou; however, this does come with increased risk as hunters must face increasingly variable weather. Storm surges and late-season high water also provide remote communities with a source of fuel in the form of logs that wash up on mud flats (ACIA 2005).

Despite the benefits to small communities and indigenous peoples in the Arctic, the negative impacts are likely to outweigh the opportunities. Moreover, positive development for commercial industries in the Arctic may result in future conflict with smaller communities and indigenous groups.

Future Directions

The degree of future climate change is dependent upon both anthropogenic and natural responses. Mitigation strategies, along with the response of ecosystems to the changing climate, will dictate the extent of global warming and climate change impacts (Carter et al. 2015). How urban areas and communities adapt to these changes in climate is largely in the hands of government decision-makers and stakeholders and their action in the coming years.

Programs to enhance resilience to climate change are emerging. The Building Adaptive and Resilient Communities (BARC) program, for instance, was designed by ICLEI (Canada) to help local communities to respond to the impacts of climate change by developing and implementing adaptation plans. (http://www.icleicanada.org/programs/adaptation/barc) The 100 Resilient Cities program, launched by the Rockefeller Foundation, provides cities from across the globe with the resources necessary to adopt and incorporate resilience planning into their government processes. The long-term goal of 100 Resilient Cities is to build a practice of resilience among governments, organizations, and individuals around the globe. (http://www.100resilientcities.org/).

The 2014 IPCC Fifth Assessment Report on climate change warns that the ongoing emission of GHG's will lead to continued warming and long-lasting changes in all components of the climate system. These changes increase the likelihood of severe, pervasive, and irreversible impacts for people and ecosystems (IPCC 2014). Building resilient communities around the world is crucial to maintaining the well-being of human and natural ecosystems in the face of a changing climate. Increasing the inherent capacity of a community to manage future unknown stresses and shocks through strategic preparation will facilitate a more resilient system better able to deal with unforeseen hazards (Tyler and Moench 2012).

Cross-References

- ▶ Climate Change Adaptation (CCA)
- ▶ Climate Change Planning: Understanding Policy Frameworks and Financial Mechanisms for Disaster Relief
- ▶ Community Planning Opportunities
- ▶ Green Climate Fund (GCF): Role, Capacity Building, and Directions as a Catalyst for Climate Finance
- ▶ Immediate Climate Vulnerabilities: Climate Change and Planning Policy in Northern Communities
- ▶ Making Communities Resilient to Global Climate Change
- ▶ Vulnerability
- ▶ Vulnerable Communities: The Need for Local-Scale Climate Change Adaptation Planning

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Climate Change in Human History

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Definitions

Climate change's definition is clearly presented by the Intergovernmental Panel on Climate Change (IPPC), and it reports any change over time, whether due to natural variability or as a result of human activity (IPPC 2014). Here, the impact of climate change on Man and his societies will be analyzed from his earliest ancestors to the present day. It is important to highlight the importance of the climate and its variability in the evolutionary process that led to the appearance of the first Men and then the first *Homo sapiens*, as well as the process of bio cultural evolution that was developing in those early days. Analyzing cultural capacity and human resilience to climate change, we will debate the interaction between Man and environment and their ability to influence each other. Discussing when anthropogenic impact (human actions) overlap the natural one in the determination of climate change, we enter a period in which some authors call to Anthropogenic (Human Age). This period is characterized by the abnormal occurrence (in space and time) of extreme weather events such as floods, droughts, tsunamis, hurricanes, and storm surges (among others).

Introduction

Since there is life on Earth the atmosphere that surrounds it has been modified, altering and conditioning the survival of the various living organisms that have emerged and developed there. The changes in temperature and circulation of the atmosphere and oceans, creating different thermal changes between air, sea and land, have led to the change of the planet's climate, determining extinctions of varying dimensions as well as the flowering of new life forms. Mankind and their ancestors did not escape this reality, obviously in a dimension proportional to the length of their life cycles.

After the tropical conditions that allowed the dispersal of the first anthropoid primates between Africa and Eurasia during much of the Miocene, a slow cooling occurred, that isolated the populations confined since then to the tropical forests of Southeast Asia and sub-Saharan Africa. And it was precisely among these latter populations that the bipedal primate appeared. They were identified by archeology, paleontology, and genetics as the earliest direct ancestors of the first Men, the hominis.

The recognition of this reality was the product of more than two centuries of research in various areas of knowledge, which led to the determination of the great antiquity of Earth and then of Man himself. We have since tried to understand the conditions under which Man's emergence and subsequent evolution took place, without forgetting the environmental context in which it occurred. Themes that are still the subject of multiple debates about the facts that are being clarified and the interpretations that surround them.

But if among these facts the recognition of the profound climate changes that accompanied Man in its long existence was soon identified, the importance or impact of these changes as a conditioning or determining element is far from consensual.

The determination of the great antiquity of Man, based on the evidence of contemporaneous evidence of the remains of human activity with ancient extinct animals, was established in the mid-nineteenth century, in parallel with the formulation of Charles Darwin's theory of evolution and the recognition of the existence of an Ice Age. However, if the connection between these different realities was suggestive from an early stage, the complexity of each one of them and the difficulty in correlating them temporally with each other was not easy.

The study of the variation of percentages of oxygen isotopes conserved in the ice sheets of Greenland and Antarctica or in the sediments deposited in deep seabed's, together with the development of new methods of radiometric dating, made the situation change, over the last decades. The glacial climate cycle that settled on Earth just over 2.5 years ago (Ma) has since that translated into more than fifty cold phases, interspersed with short periods of warming. This has allowed for a correlation between such climatic variations and many of the most significant episodes of Human History. But it is also important to recognize the significant climatic variation that since the end of the last glacial period marked the phase of continuous warming that then settled.

In smaller historical time it is possible to recognized impressive climatic oscillations, such as Little Ice Age and its consequences in anthropic behavior. Nowadays some authors of different scientific areas trying to relate climate changes with some of the most significant moments of Human History.

The impact of the human activities of latest historical times in this complex reality is being discussed. This situation, gaining significant amplitude, could justify the recognition of a recent period in the History of the Earth called Anthropocene: the period when Man overcame nature in determining the variation of climate.

Origins

As far as the evolution of Man is concerned, many see in genetic variation, in several adaptive behaviors (such as competition), or in the increase of cognitive capacity itself, key elements for its development. The impact of climatic variations on the evolution of mankind, however, has had an increased recognition and the recent contributions of epigenetics have given new breath (Osborne 2017).

According to the *Turnover Pulse Hypothesis*, this process would preferably have taken place in moments of marked environmental change, characterized or not by an increase in aridity, when more specialized species may have been extinct and, therefore, less well adapted. Speciation would focus on more general species, susceptible to adapt to the new environmental conditions (Potts 2012).

For *Variability Selection Hypothesis* the evolutionary process of Man would not focus on a certain significant moment of the change in its environmental context. It would be the unpredictable variability of this context that would highlight the species with a more adaptive flexibility, favoring them in evolutionary terms (Potts 2012).

But in the context of these relations between the first Men and their environment, the importance that periods of greater climate stability may have had in their evolutionary process is also recognized. It allows for the development of competitive behavior between different species, favoring certain characteristics or adaptive behaviors in the detriment of others (Maslin et al. 2015).

These different hypotheses of development of the evolutionary model do not excluded each other. It is also assumed that the evolution of a particular species may even have occurred at certain moments with the intervention of these different processes or with some of them (Maslin et al. 2015).

If we go back to the origins of the earliest direct ancestors of Man, there are some (few) fossils, where it was sought to glimpse the development of the bipedalism. The fragmentation of a good part of these fossils remains did not allow clarifying this hypothesis; however their possible association with bipedal locomotion could be due to the prevalence of climatic conditions responsible for savannah expansion (Domínguez-Rodrigo 2014).

However, this view was contradicted by the reconstitution of the paleoenvironmental context of *Ardipithecus ramidus*, a fossil that presents clear climbing adaptations, verifying that they would have lived in a fairly wooded habitat (Potts 2012). But if this interpretation did not allow many researchers to continue to advocate the appropriateness of the so-called savanna hypothesis, it was also considered that the *Ardipithecus* (as well as the *Australopithecus* that followed them) lived in different ecosystems. This forced these hominines to develop bipedal and arboreal skills that would allow them to adapt to both open spaces and much more wooded areas, surviving in different times and spaces to the climatic variations that have led to the aridity and to wetter phases.

The evolution of the hominines had, later on, important developments with the extinction of the *Australopithecus*, the appearance of the *Paranthropus* and the emergence of the genus *Homo*. These events occurred in East Africa between about 3 Ma and 2 Ma, coinciding with the installation of the glacier climate cycle, when the intense cooling of much northern areas was locally accompanied by phases of pronounced aridity (Potts 2012).

The appearance of Man is not only witnessed there by the identification of their oldest known fossils, but also by its association to knapped stone tools used in the processing of animal carcasses. This suggests a strategy of more intensive exploitation of available resources, in a context where the existing environmental conditions would determine their scarcity, apparently favoring the *Turnover Pulse Hypothesis* (Maslin et al. 2015). However, recent studies recognized a more variable pattern in the reconstitution of the paleoenvironments that in the region followed the evolution of the first Men. Aridity phases being interrupted by periods in which increased humidity and precipitation (determined the growth of the great lakes of East Africa), opening the door to *Variability Selection Hypothesis* or even explanatory models of evolution, where the different hypotheses of interaction between Man and the environment would be combined.

When around 1.8 and 1.7 Ma the first Men began their diaspora, going out of Africa for the first time, the environmental conditions were also not very different (Maslin et al. 2015). Dry and humid phases occurred in Africa, during which more complex knapped tools occurred locally, with the production of bifacial artifacts from Acheulean. The scenario that also accompanied the appearance of the first modern men in Africa – *Homo sapiens* – was not very different. The recent research of this reality has not ceased to bear fruits, due to the recognition of the antiquity of early *Homo sapiens*, with the identification of fossils dating back some 300,000 years and also the significant variability of traits among its oldest representatives (Hublin et al. 2017). In association with archeological contexts geographically dispersed by Africa, they suggest a polycentric origin for these populations, in connection with fragmented habitats and ecosystems. It was a situation in which the succession of periods of increase of dryness or humidity was decisive for the creation of refuges where these populations evolved in a relatively isolated way (Scerri et al. 2018).

The dispersion of these populations of anatomically modern Men out of Africa ran from 100,000 onwards, conditioned by rhythmic climatic variations. In Eurasia the process is probably related to a context of replacement of the archaic populations surviving there, not without previous processes of hybridization between the populations involved, now properly documented by genetics.

In Europe, this process lasted 45,000 years, during a period marked by a global climate cooling, which was accompanied by significant variations with a millennial or secular expression, during which new populations arrived but also during which the extinction of Neanderthals was recorded. The occupation of globe areas where the presence of Man was still unknown occurred almost simultaneously. First with the early arrival of the first *Homo sapiens* to Australia (Sahul) (there are more than 50,000 years ago), and much later to America, crossing the lands of the Bering Strait (around 14,000 years ago, with the descent of sea level in the peak of the last glaciation).

Occupying the most distinct ecosystems, from the tropics to the Arctic, as well as arid and coastal environments, or through areas of significant altitude, these first Men became a successful species on a world scale. Corporating a new ecological niche – “generalist specialist” – not only through their presence in the most diverse environments, but also through their ability to adapt to them (Roberts and Stewart 2018).

The end of last glaciation opening the door to challenges for the humanity. Since then our planet has known and punctuated by oscillations of lesser expression, which accompanied human societies from the post-glacial period to present day.

From Post Glasciar to the Great Empires of Antiquity

After the last glacier maximum, which lasted between 24,000 and 30,000 years, a warming process began, particularly well-marked from 14,000 years onwards, with the end of the Younger Dryas, which had its full expression at the beginning of the Holocene, 11,700 years ago (Shuman 2012). Since then, a retreat of major ice masses has been witnessed, accompanied by a rise in ocean waters from 14,000 onwards, when the melting process began to significantly affect Antarctica.

But this phase of Earth's environmental history, if it corresponded to a "Long Summer" that marked the development of human civilization on the planet, was also accompanied by climatic variability with a differentiated temporal and spatial expression, which investigations have are seeking to identify and characterize (Fagan 2004).

In Northern Africa, for example, between 11,000 and 5,000 years, the position of Earth's axial tilt, conditioned by the "wobble" cycle, precession, determined the development of the African Humid Period (deMenocal and Tierney 2012). Well documented in the geological records and in the iconography of the locally rock art, where pontificate scenes of pastoralism and hunting antelopes that were crossed with large African herbivores in a Green Sahara divided by old lake basins. The end of this humid period coincided with the expansion of pastoralism in the African continent and the development of Ancient Egypt civilization around the Nile, which allowed for the slow absorption of the populations expelled from the Sahara.

The 8200-Year Event was a very different expression, which translated into an abrupt cooling, registered differently in much of the Northern Hemisphere for a period of a century and a half (Shuman 2012). The phenomenon resulted in a catastrophic discharge into the Atlantic from the icy waters of Lake Agassiz, formed by the gradual melting of the Laurentide Ice Sheet, which still covered part of North America. This resulted in a strong disturbance of the Atlantic Southern Overtunning circulation (AMOC) and also in a marked cooling of the climate of vast Northern Hemisphere regions, accompanied by severe droughts in some areas.

The climatic changes that have taken place throughout the Holocene have been reflected in the development of prehistoric societies. Beginning with the adaptations to which changes in available resources led to the transition to the post-glacial period, with a greater sedentarization of populations and intensive exploitation of smaller species, in particular of river or marine origin. This resulted in the emergence, although often in a differentiated way in space and time, of Mesolithic communities, in a process that later, in the zones of temperate latitudes favored by the presence of animal and vegetable domesticated species, was translated by the appearance of the first Neolithic societies.

Often some analyzes focus on more specific case studies, using particularly precise data, as happened recently with the analysis of the oxygen and carbon isotopes of a stalagmite from the cave of the SW Peloponnese that allowed to accurately date the paleoclimatic record that accompanied the end of Late Bronze Age in the east Mediterranean (Finné et al. 2017). Associating the 3150-year-old destruction of Nestor's Mycenaean Palace in Pylos to a short humid period, which was nevertheless preceded by an arid phase sufficiently expressive to be associated with the collapse of the local agriculture which determined their destruction.

With an economy largely based on the development of agricultural activities, the Empires that later came to flourish around the Mediterranean were often conditioned by the climatic variations that occurred. The Roman Empire, by its geographic dimension and temporal duration, knew a distinct incidence of climate change in its different provinces and throughout its history (Brooke 2014). In any case, in a global way, the development of the Empire took place in a hot period that marked the final part of the Holocene, between 250 BC and AD 400, which is generally designated as Roman Warm Period. Initially marked by relative climatic stability and marked warming, accompanied in some areas by increased humidity and in others by relative aridity. This allowed the development of viticulture to the west in somewhat unusual latitudes, while to the east, increased humidity around the Black Sea allowed the local increase of cereal crops.

From AD 200 onwards, stability gives way to the west to some turbulence, with the development of a colder and drier climate, which preceded the division between the Roman Empire of the East and the Roman Empire of the West.

A pronounced later drought in the middle of the fourth century led groups of shepherds to explore pastures further south, pushing the barbarians against the frontiers of the Empire.

A Troubled Story

We are absolutely aware that the division of mankind's History in epochs is controversial and does not possess an adequate meaning (that is to say: it is according to reality). In truth, these periods vary depending on the global region which we are referring to. Not only that, but they generally focus on a quite European paradigm of Historical division. Nonetheless, we will employ conventional methods of periodical division, but only because of the ease and accessibility (in terms of content exposition) and of comprehension of the particular highlights we have chosen. When it comes to Medieval Age, for instance, one of the parameters used to establish its beginning is the fall of the Western Roman Empire – assumed as a symbolic moment of change – the deposition of its emperor: Odoacer (in 476 AD). This means that, at the turn of the fifth century, there is a fall of certain cultural and civilization parameters that leave an empty space that later would be occupied by Arabs (that congregate and maintain the essential principles and writings that preceded the Greek and Roman civilizations). In the West of Europe, this happened due to the priests of the Catholic Church, a movement that became known as Patristic. One of the most important figures of the Patristic was, unarguably, St. Augustine of Hippo (354–430 DC). Moving on to the content that interests us here (climate), St. Augustine wrote, in his Confessions: "What is time? If no one asks me this, I know it; but, if they do, and I wish to explain it, I know nothing else." Because it was written in Latin, the notion of time here may be translated as chronological time. However, some authors (like the Portuguese geophysicist and climatologist José Pinto Peixoto, 1922–1996) have adapted the sentence in a way in which time was interpreted as meaning "climate." In other words, the sentence should be read as following: "What is climate? If no one asks me this, I know it; but, if they do, and I wish to explain it, I know nothing else" (Peixoto 1995). In truth, as far as our analysis is concerned, it is irrelevant how the term is interpreted (even though we adhere to the chronological interpretation of said term). Both chronological time and climate were, then, empirical realities, resulting of what is called phenomena (which simply means "what was being perceived"). However, it's important to distinguish climate from atmospheric states. People would, necessarily, experience the phenomena of atmospheric states (cold, warmth, rain, dryness, etc.), but they were unaware of what the climate would be, and they were even less aware of climate changes. We are talking of a pre-instrumental period. This is important because we must remember that certain instruments with higher precision used to analyze climate changes had not yet been. Not only that, but this analysis also implies the possession of a series of meteorological indexes that were also non-existent at that time. In fact, both of these things would only become a reality between the fifteenth and the seventeenth centuries (with the invention of the pluviometer, thermometer and the barometer – which allow for a rigorous reading of humidity, temperature, and atmospheric pressure). Even more important than this, however, is the change in the traditional notion of climate (which happened in the twentieth century). This change relates to how the average normal conditions of the atmosphere were viewed; at first they were viewed as a random phenomenon, but later where interpreted as a dynamic one – one which could provide us with models of future predictions.

This does not invalidate that, overtime (and Medieval Age certainly was no exception) climate and its oscillations, whilst a lot less acute in Pre-Historical periods, where not felt and did not produce effects. Ferdinand Braudel, a renowned historian of the École des Analles, compares climate to a maestro, because he calls it a violent agent or, at least a powerful dominating force, capable of impacting everything (Braudel 1998).

Not wishing to be a deterministic when it comes to the role of climate in Mankind's History, because there are many factors that come in to play (and these factors do influence it), but, at the same time, we cannot also dismiss Braudel's claim, when he underlines the importance of climate as a major element in the evolution of Human communities throughout time.

We have to highlight what is called the Medieval Warm Period (we will simply refer to it as MWP from now on). The delineation of this period of medieval warming is not only highly discussed, it's also highly debatable. One thing, however, is certain: from the height of global warming registered in the first centuries of the Christian era (with temperatures of about 1 °C – superior to those of the MWP or even current ones) we entered a phase of softening and then of cooling that was prolonged until the beginning of High Medieval Period. Around the seventh and eighth centuries, there is a slight inversion of the global cooling tendency that coincidentally (or maybe not) is contemporary of the Expansion that would be the Carolingian Empire in Western and Central Europe. However, the MWP truly starts around the years 900/1000 (depending on which author you consult). This is true for the Northern hemisphere, but, for other latitudes, this fact is debatable as a result of the effects of the North Atlantic Oscillation (which, we will now refer to as NAO).

Today we know that climate in the North Atlantic Basin, or more concretely in Europe is determinate by the NAO annual [or yearly] index that consists of the difference of the atmosphere pressure – at the sea level – between Stykkissholmur/Rekjavik (Iceland's low pressure center) and Ponta Delgada (Azores high pressure center). When the NAO presents a positive index, we can expect strong winds and hot and humid atmosphere with a lot of rain fall in the winter in North Europe. On the contrary, in South Europe we verify that the winters are cold and dry. But if the NAO index is negative the result is exactly the opposite: North Europe winters are rigorous and dry and in the South the opposite occurs.

So, in every moment we have to be aware that not only that climate analysis is very complex, but also that varies depending on the parts of the world that we are addressing. Therefore, when we refer to the MWP we must be conscious that the warming was not generalized: the interaction between atmosphere and sea made the behaviors geographically heterogeneous. Despite this, it was in this warm period in the North of the Europe that the Vikings made their expeditions, arriving in Iceland (still in the ninth century), Greenland (at the end of tenth century) and in North America (mid eleventh century). We can verify a demographic increase with the consequent enlargement of cultivated areas or conquest of new land for agriculture (for example, with deforestation or drought in marshy areas). It is also the time when Western Europe decided to militarily expand to the Middle East through the holy war or Crusades (Bastos et al. 2018). On the other hand, authors such as the historian Stanley Campbell (2016) underlined the intense disturbances observed between the end of the twelfth century and the fourteenth century (in these case nothing to wonder about because opinions are divided, as some considered this as a century of recession). The focus of these perturbations were mainly centered on economic conflicts, wars and also where the ecological stress caused by the gradual worsening of the climate was beginning to make itself felt. In other words we can say that the resilience of natural and social systems seemed to approach of theirs own limits. International trade involving Europe and Asia had declined dramatically. In the transition from the thirteenth to the fourteenth century there was a widespread drought in South-East Asia. Monsoons began to fail, and Angkor, the capital of the Khmer empire (usually known for its abundance of water), had to limit water distribution (Dias 2016). The Mongol empire began to disintegrate, in Greenland the Vikings colonies declined. Entering the fourteenth century crisis began to be the rule everywhere.

According to the historian John L. Brooke (2014), around the middle of fourteenth century the world entered Pre-Modernity. He sustains his theory on two paradigms: on one hand, the communities of the "New World" began to be affected by the medieval dry's spell; on the other hand, the societies of the "Old Word" felt the first manifestations of the Little Ice Age's (from now on we will refer to the Little Ace Age by the initials LIA). Once more it is very difficult to establish a date for climate change, like LIA undoubtedly was. It is easier for scientists to agree about the end of LIA (around 1850 and the end of nineteen century) than about the beginning of this climate phenomenon. We have all heard of the terrifying trilogy that marked the fourteenth and fifteenth centuries with famines, pestilences, wars and death. At the end, it is possible to document the four horsemen of the Apocalypse, which announced the end of times. The famous Black Death (1346–1355), one of the most devastating pandemics in World History, probably coming from Central Europe, penetrating on the points where the Silk Road passed and causing the death of about 1/3 of the world's population of the time. Today it is known that this disease is caused by the bacterium *Yersinia pestis*, always present in rodents of the semi-arid regions of Tibet, Mongolia and Central China. The fleas of these rats are precisely the transmission vehicle of the Black Death. It is possible that, with the MWP, the moister air from the West led to the growth of vegetation with the consequent increase of communities of wild rodents. In fact, there are reports of high mortality between the late thirteenth century and the first half of the fourteenth century in areas where these animals are natural. Is it obvious that this enormous dissipation of human life was facilitated by poor nutrition of the people. This was the result of a succession of bad years resulting in the aggravation of agricultural climatic conditions that caused the devastation of crops and the incredible rise of foodstuffs prices. Is it appropriate to say that the LIA started here? The fact is that the climate is determinate by the incidence of solar radiation, atmospheric and oceanic circulation and volcanism. Now as far as the solar radiation is concerned, this period is marked by the so-called paired Wolf minimum, which may be an explanation for this negative cycle (Dias 2016). This cycle is fairly limited and from 1350 to 1400 a new cycle of a higher solar radiation incidence is registered, which corresponds to a maximum of Chaucer (Dias 2016). To add to this fact, the Iberian Peninsula was in a negative NAO, with wet and relatively warm winters. This is when Portugal conquers Ceuta, in Northern Africa (1415), which is considered by some authors the beginning of modern times.

The influence of climate on the development of European voyages to the usually called "New World" is not known. The unquestionable fact is that when Portugal began the maritime expansion, it gave rise to a new world order. This adventure was immediately followed by Spain and, later, England, Holland and France (seventeenth century). Since then, the world was never the same and there are those who consider that this was the first time so-called globalization happened. Between the mid-sixteenth century and the mid-seventeenth century, at the peak of LIA, average temperatures of winters may have been 2 °C lower than those observed in the late twentieth century in most of Europe and North America (Dias 2016). Meteorological extreme events where frequent and so it's not strange that in the Iberian Peninsula, for instance, there's recorded processions *pro-pluvia* (clamming Good to rain) or *pro-serinitate* (exactly the opposite) (v.g. Alcoforado et al. 2000).

In the eighteenth century, although still in full LIA, a climate amenity is already visible. Historically this is historian Eric J. Hobsbawn called The Age of Revolutions (Hobsbawn 1996). In the set of "revolutions" that mark the take-off to the contemporary period (technological, economic, political, social, etc.), it is important to emphasize the industrial revolution that began in England in the mid-eighteenth century. Some authors seems to considered that we are in presence of the beginning of Anthropocene, i.e., the turning point from which Man has taken over the command of climate changes, making the Human footprint the essential mark on world environmental system (Lewis et al. 2015).

The "Anthropocene"

The acceptance of the Anthropocene as a geologic era that happens to the Holocene is not yet widely accepted within the scientific community. In fact, to recognize the existence of a new era in the history of the Earth, the proxies that characterize this era must be engraved on the rocks, like a geological unequivocal stratum. Most climatologists, meteorologists, oceanographers, physicists and chemical scientists (among others researchers) seems to agree on the following: (a) increase of CO^2 in the atmosphere; (b) progressive melting of the ice caps; (c) mean sea level elevation (NMM). These seem to be clear indices of a change in weather patterns and therefore a climate change. However, climate change has always existed throughout the ages and the human communities as well as the other communities of living beings always had to live with them. How? By adapting themselves, trying to mitigate their effects (Freitas et al. 2018) or, worst scenario, succumbing to them – as was the case of extinct species of dinosaurs (at least of the largest), at the end of the Cretaceous (about 66.5 million years ago) when an extreme weather event (as is characteristic of long periods where climate changes occur) resulted in the collision of a meteorite with Earth. This resulted in a huge explosion that carbonized billions of animals instantaneously, raising a cloud of dust so thick, blocking sunlight and making Earth an extremely cold planet.

But we wonder if we can raise a parallelism between the end of the Cretaceous and Modernity? Did the climate change indices listed above leave records which allow us to of a new era: the Anthropocene?

The first scientist that use the term Anthropocene was the micro-biologist Eugene Stoermer in the eighties of the previous century. Stoermer was specialized in the study of diatoms and, obviously, was sensitive to results from this proxy that pointed to human-induced climatic changes. However, the term Anthropocene would only enter in to ordinary language when the atmospheric chemistry Paul Crutzer, winner of the Nobel Prize in 1995, introduced it to popular lexicon. To Crutzer the Anthropocene refers to human behavior in Earth's atmosphere over the past centuries, and is so significant that it should constitute a new geological era.

We do note that this conviction of Crutzer is not consensual. Just like it's not consensual that the early Anthropocene default is the unfailing mark of Man on the environment, in particular when climate is concerned. Some authors consider that the Anthropocene started about 10,000 years ago, in the Neolithic period, with the beginning of agricultural practices that caused a change of concentration of various gases in the atmosphere. Others argue that it was with the Industrial Revolution (which became widespread from the UK, in the mid-eighteenth century) and the massive use of fossil fuels that begins to increase of release of greenhouse gases in the atmosphere. Others think the end of the Holocene and the beginning of the Anthropocene only happens after end of World War II with the globalization of consumer behavior, always based on the use of fossil fuels, that caused the increased production of waste (such as plastic, for instance) and the great increase in the emission of CO^2 into the atmosphere (Simon and Meslin 2015).

We would not discuss this matter here. We just want to underline the essential: regardless of this being a geological era -the era of Man or Anthropocene – the truth is that it seems clear that we are in a period of global warming that configures a climate change. Symptoms of this are the recurrence of extreme weather events such as occurrence of storm surges, annual occurrences of cyclones, droughts, floods, etc.

The Paris Conference, in 2015, established global targets for all countries to ensure the sustainability of the planet. The commitment is to achieve four zeros: emissions, deforestation, waste and extinction. The 195 countries that integrated the Paris Agreement adopted the first-ever universal, legally binding global climate deal. These countries submitted comprehensive national climate action plans in order to limit the temperature increase to 1.5 °C, since this will significantly reduce the risks and the impacts of climate damage. According to this goal, this will provide the increase in global average temperature to well below 2 °C above pre-industrial levels (Paris Agreement 2015). The previous compromise perfectly shows how History and the best knowledge of the past can be useful to understand the present and preserve the future. That was the main focus of History: to better know the past in order to aptly manage the present and prevent future problems more efficiently.

We will finish with promising perspective. This new time doesn't have to be necessarily and irreversibly catastrophic. If *Homo sapiens* sapiens decides to use the growing technological power to improve people's lives protect the environment and stabilize the climate, this will be sufficient to charge the outcome.

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Climate Change Literacy to Combat Climate Change and Its Impacts

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Synonyms

Climate literacy; Climate science literacy; Carbon literacy

Definitions

Literacy

UNESCO (2004) defines literacy as "the ability to identify, understand, interpret, create, communicate, compute and use printed and written materials associated with varying contexts [. . .] enabling individuals to achieve their goals to develop their knowledge and potential and to participate fully in their community and wider society" (p. 13). Literacy can also be defined as competence or knowledge in a specific area.

Climate Change Literacy

If literacy can be defined as competence or knowledge in a specific area, then climate change literacy is competence or knowledge in the area of climate change, its impacts, and its solutions. The goals of climate change education entail:

> that the learner has an understanding of the basic science of climate and climate change; that people and organizations can make informed decisions; and that our behavior changes to a degree that we are not causing the climate to change from our actions, but instead we become stewards of the Earth and its climate so as to ensure the sustainability of humanity and all other species on which we depend. (Compass Education 2014, p. 9)

Introduction

Climate change literacy is a vital element in strategies for meeting the United Nations Sustainable Development Goal (SDG) 13: "Take urgent action to combat climate change and its impacts." Developing climate change literacy – individually, institutionally, and societally – entails understanding why it is important, who must be involved, what it includes, where and when it takes place, how to deal with challenges that arise, and what the end result, a climate change-literate citizen, will look like.

Why Is Climate Change Literacy Important?

Achieving Sustainable Development Goal 13

With the global average temperature still rising, greenhouse gas emissions still increasing, and extreme weather events and wildfires still intensifying, the climate change emergency (Carter 2018) calls for "urgent and accelerated action by countries as they implement their commitments to the Paris Agreement on Climate Change" (UN 2016). Achieving commitments to the Paris Agreement and meeting Sustainable Development Goal 13 will not be possible without widespread climate change literacy.

Knowledge of climate change science is necessary for developing policies and making decisions that will effectively combat climate change and its impacts. Miléř and Sládek (2011) see climate change literacy as essential to both mitigation and adaptation. "Climate literacy is crucial for future low-carbon living" (p. 150). "Without climate education, climate disruption is unavoidable. Even if humanity fails to stabilize climate, climate literacy will be urgently needed for adaptation" (p. 153).

SDG Target 13.3 is "to build knowledge and capacity to meet climate change." This means "improving education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning" (UN 2016). Climate change literacy is that knowledge, and the knowledge is, in turn, part of human and institutional capacity.

Meeting Other SDGs

Climate change literacy is also necessary for understanding how to minimize the disruptions caused by a changing climate that could hamper the successful implementation of other SDGs. For example, the effects of global warming on heat waves and soil moisture will impact SDG 2 – Zero Hunger. "Adverse climate events" already share the blame for a rise in world hunger that started in 2015 (FAO 2018); ocean acidification will impact SDG 14 – Life Below Water by making it more difficult for calcifying organisms (such as mollusks, corals, some plankton, etc.) to build shell or skeleton due to their dependence on abundant carbonate (Tanhua et al. 2015). Furthermore, because the goals are interconnected, the key to success for one goal might involve meeting the targets for another goal (e.g., SDG 7 – Affordable and Clean Energy will lead to lower carbon emissions from energy production; SDG 16 – Peace, Justice, and Strong Institutions will lead to fewer carbon-intensive conflicts). Climate change literacy plays a role in understanding how each of these SDGs can be met.

Filling Knowledge Gaps and Fixing Misconceptions

Local, national, and global surveys (e.g., Lee et al. 2015; Marcinkowski et al. 2011) consistently show a general public that either lacks awareness of climate change or does not understand it.

Analysis of a global survey (over 100 countries) found that more than a third of the world's adults have never heard of climate change (reported by McSweeney 2015). For some countries, such as South Africa, Bangladesh, and Nigeria, that number rose to more than two-thirds of the adult population.

> The study says that education is the "single strongest predictor" of public awareness of climate change. Improving basic education and public understanding of climate change are vital to garner support for climate action, the researchers add. (McSweeney 2015)

Building Sustainable Societies

According to Climate Literacy: The Essential Principles of Climate Science (the climate change literacy "bible"), a climate-literate citizenry is essential for protecting fragile ecosystems and building sustainable communities that are resilient to climate change. "Such understanding improves our ability to make decisions about activities that increase vulnerability to the impacts of climate change and to take precautionary steps in our lives and livelihoods that would reduce those vulnerabilities" (U.S. Global Change Research Program 2009a).

Who Is Climate Change Literacy For?

Will it be possible to achieve SDG 13 without a climate change-literate populace? "The focus [of this goal] is on establishing an enabling environment for climate change adaptation, mitigation, and sustainable development to occur, through national policies that promote the participation of all citizens, especially marginalised communities, in adapting to climate change" (Open Development Cambodia 2018).

Miléř and Sládek (2011) pose a key question: "Do we need climate literacy for all? If we look at the timescale, in the short term it is not a realistic objective to achieve. But, in the long term at least, basic climate literacy for all is crucial" (p. 152). Given the climate change emergency time crunch (IPCC 2018), should climate change literacy initiatives be prioritized by most to least influential audience?

> The world needs climate literate leaders to make correct decisions and implement tough measures. It is a duty of politicians to set the rules which can guide the world to a healthy, pleasant and earth-friendly low-carbon future.... We suggest that effective climate education should be selective. It is better for the society to have one climate literate

> politician than one climate literate carpenter. Of course every individual has a human right of climate literacy. But in the limited time we have, it is not a realistic goal to achieve climate literacy for all. (Miléř and Sládek 2011, pp. 151–152)

Three populations must be climate change literate in the short term if society-wide literacy is to follow. "If the society had climate literate leaders, journalists and teachers, the public would receive relevant information from them" (Miléř and Sládek 2011, p. 153).

Members of society who, once climate change literate themselves, have the influence and opportunity to spread awareness, teach understanding, and encourage participation in mitigation and adaptation strategies include:

- Students at all levels
- Parents and other community-minded citizens
- Elected leaders and decision-makers
- Civil servants, especially those in charge of policymaking
- Educators at all levels
- Journalists
- Doctors and others working in health care
- Farmers and others working in the food system
- Faith leaders and others working in social justice

What Are the Vital Components of Climate Change Literacy?

In practice, climate change literacy is a combination of competencies that can include (1) knowledge of climate system science, (2) understanding of the impacts and threats of climate change, and (3) motivation to make informed decisions to implement mitigative and adaptive solutions to the climate crisis (in short, what causes climate change, what climate change causes, and what can be done about it).

Climate change literacy also includes skill in systems thinking and, more and more, in communicating about climate change. Climate change literacy "presents information that is deemed important for individuals and communities to know and understand about Earth's climate, impacts of climate change, and approaches to adaptation or mitigation" (U.S. Global Change Research Program 2009a).

> The ultimate goal then, is that we have positive impacts on the climate with regards to stabilizing and mitigating emissions of greenhouse gases, along with the capacity to adapt to the consequences of climate change. What is obvious to many now, is that knowledge about climate change alone will certainly be insufficient to motivate the necessary change in behavior that is required to achieve the above stated goals. (Compass Education 2014)

Knowledge of Climate System Science

"Climate science literacy is an understanding of the climate's influence on you and society and your influence on climate," as defined in Climate Literacy – The Essential Principles of Climate Science: A Guide for Individuals and Communities (USGCRP 2009a).

Facet 1: Scientific Literacy Although science knowledge is the foundation of climate change literacy, scientific literacy is not widespread (Abrahams 2015). For example, according to Suzuki and Hanington (2018), "Many people aren't familiar with the precise definitions of scientific terms [such as the term "theory"], and this can lead to misunderstanding."

> Global warming theories are based on a wide range of research and knowledge, from the physics of the greenhouse effect to science regarding ocean currents, the carbon cycle, wind patterns and feedback loops. There may be some uncertainty about warming rates and consequences, but there's no doubt the world is heating because of human activity—mostly through burning fossil fuels and damaging or destroying carbon sinks like forests and wetlands—and that the consequences are already severe and will worsen if we fail to act decisively. (Suzuki and Hanington 2018)

Part of scientific literacy is acknowledging expertise; climate scientists assemble and share their research data and conclusions through research journals and the Intergovernmental Panel on Climate Change, or IPCC (2018).

> The scientific community uses a highly formalized version of peer review to validate research results and our understanding of their significance. [P]eer review does not guarantee that any particular

> published result is valid, [but] it does provide a high assurance that the work has been carefully vetted for accuracy by informed experts prior to publication. (United States Global Change Research Program 2009a)

Facet 2: Climate as a System The second facet of knowledge of climate system science is an understanding of the climate system, especially in relationship with forests, oceans, and other global and local ecosystems.

> [C]limate literacy draws on climate science (i.e., the dynamics of the earth–atmosphere–ocean–biosphere across spatio-temporal scales), the quantitative and geospatial technologies by which it is understood, and the interconnectedness of human beings with their environment. The appreciation of the complexity of climate literacy is firmly grounded in the systems approach that is central to the earth sciences and geosciences. (Dupigny-Giroux and Cole 2018)

Facet 3: Fundamental Terms, Concepts, and Principles of Climate Science to Be Understood Key climate science terms (as defined in United States Global Change Research Program 2009a):

- Weather and weather forecast
- Climate and climate forecast
- Climate variability
- Climate change
- Global warming
- Climate system
- Likely, very likely, extremely likely, virtually certain
- Mitigation
- Adaptation
- Fossil fuels
- Feedback
- Carbon cycle

Key climate science concepts (as defined in IPCC 2014 and elsewhere):

- Abrupt climate change
- Irreversible climate change
- Tipping points
- Large-scale singularities
- Albedo
- Reasons for concern
- Amplifying feedbacks
- Triple ocean degradation (heating, acidification, oxygen depletion)
- Climate change commitment
- Carbon cycles (short and long term)
- Extreme weather events
- Climate sensitivity
- CO_2 equivalent
- El Niño/La Niña
- Emission scenarios
- Runaway [not runaway greenhouse]
- Geoengineering
- Global warming potential
- Carbon sources/carbon sinks
- MOC (meridional overturning circulation)

Key principles of climate science (as explained in USGCRP 2009a):

1. The sun is the primary source of energy for Earth's climate system.
2. Climate is regulated by complex interactions among components of the Earth system.
3. Life on Earth depends on, is shaped by, and affects climate.
4. Climate varies over space and time through both natural and man-made processes.
5. Our understanding of the climate systems is improved through observations, theoretical studies, and modeling.
6. Human activities are impacting the climate system.
7. Climate change will have consequences for the Earth system and human lives.

While it is not expected that any one person will ever completely understand every fundamental climate science concept, "[f]ull comprehension of these interconnected concepts will require a systems-thinking approach, meaning the ability to understand complex interconnections among all of the components of the climate system" (United States Global Change Research Program 2009a).

Understanding of the Impacts and Threats of Climate Change

Anthropogenic climate change is damaging to many aspects of the natural and built environments and to human and environmental health and well-being. Climate change literacy involves gaining an understanding of risk and of the risks, impacts, and threats of a changing climate.

> In the coming decades, scientists expect climate change to have an increasing impact on human and natural systems. In a warmer world, accessibility to food, water, raw materials, and energy [is] likely to change. Human health, biodiversity, economic stability, and national security are also expected to be affected by climate change. Climate model projections suggest that negative effects of climate change will significantly outweigh positive ones. The nation's ability to prepare for and adapt to new conditions may be exceeded as the rate of climate change increases. [. . .] The impacts of climate change may affect the security of nations. Reduced availability of water, food, and land can lead to competition and conflict among humans, potentially resulting in large groups of climate refugees. (USGCRP 2009a)

There are several ways to learn about the impacts and threats of climate change. These include observation of impacts in one's own environment; experiential learning in a laboratory setting, for example, with a "predict-observe-explain" strategy (see Sharma 2017); research into what is happening around the world (see Union of Concerned Scientists n.d.); extending empathy and compassion to those already impacted (see DARA's Climate Vulnerability Monitor 2012); and through narrative and the humanities:

> Teaching the science and policy of climate change is necessary but insufficient for helping students to develop a robust climate literacy. Climate change educators must also teach students how to evaluate historical trends, to unpack the assumptions in shared cultural narratives, to grapple with ethical dilemmas, and more generally to traverse the turbulence of feeling that is a hallmark of living in a time of global climate chaos. In short, climate literacy must include the skills and strategies of the humanities, and specifically literary and cultural studies. (Siperstein 2015)

Motivation to Make Informed Decisions to Implement Mitigative and Adaptive Solutions to the Climate Crisis

According to Azevedo and Marques (2017), climate literacy includes "attitudes, beliefs, motivational orientations, self-efficacy, and values" (p. 9). They found that in the literature, the most valued attitude is making informed and responsible decisions, suggesting that the goal of climate change literacy is "the possibility of acting upon that knowledge, in the personal, professional and communal lives" (p. 9). Climate change literacy, therefore, should include the learning necessary to make informed decisions about climate change solutions.

The guiding principle for informed climate decision-making is "Humans can take actions to reduce climate change and its impacts" (United States Global Change Research Program 2009a). Climate change literacy is relevant to all citizens, so that they are "able to make informed and responsible decisions with regard to actions that may affect climate" (USGCRP 2009a). An understanding of the Earth's climate system improves the ability to make decisions about activities that increase resilience and reduce vulnerability to the impacts of climate change.

> Informed climate decisions require an integrated approach. Reducing our vulnerability to these impacts depends not only upon our ability to understand climate science and the implications of climate change, but also upon our ability to integrate and use that knowledge effectively. (USGCRP 2009a)

According to the US Global Change Research Program (2009a), mitigating and adapting to climate change "will bring economic and environmental challenges as well as opportunities, and citizens who have an understanding of climate science will be better prepared to respond to both." For example, according to Jacobson and Delucchi (2010), the main barriers to getting to 100% clean energy are social and political, not technical or economic. Climate change literacy can assist in overcoming such barriers to the achievement of effective mitigation.

It is vital to remember – and respect – the sustainable development principles of intragenerational equity and intergenerational equity when making decisions related to climate change mitigation and adaptation.

> Actions taken by individuals, communities, states, and countries all influence climate. Practices and policies followed in homes, schools, businesses,

> and governments can affect climate. Climate-related decisions made by one generation can provide opportunities as well as limit the range of possibilities open to the next generation. Steps toward reducing the impact of climate change may influence the present generation by providing other benefits such as improved public health infrastructure and sustainable built environments. (United States Global Change Research Program 2009a)

Communicating About Climate Change

An increasingly prevalent competence in climate change literacy programs is the ability "to communicate in a meaningful way about climate and climate change" (Azevedo and Marques 2017, p. 9), which is made difficult by polarized views on climate change (Kahan et al. 2012) and other challenges.

> Unfortunately both the politicians and the public have been manipulated by powerful lobbying by the oil and coal industry. Widespread denial of anthropogenic climate change competes with the data reported by climate scientists. Peer-reviewed articles are written in scientific language which is not easy to understand. The media tends toward sensationalism and often misrepresents scientific results. (Miléř and Sládek 2011, p. 152)

Azevedo and Marques (2017) uncovered a gap between the "two cultures" of science education and science communication. They recommend considering both technoscientific and humanistic perspectives of climate change together in order to improve climate change communication (p. 11). Strategies they collected for bridging this gap include:

- Providing local, unbiased climate resources and monitoring their use by the intended audience
- Dispensing science information within the context of a story (thereby increasing the chances of its being understood and recalled)
- Using sophisticated, networked visualization tools
- Collaborating closely with several stakeholders ("to provide scientific information compatible with the public's cognitive processes") (p. 10)

Hendricks (2017) suggests focusing on the "framing" of a message, not just the facts about climate change.

> It turns out the language you use and how you frame the discussion can make a big difference. The problem isn't that people haven't been given enough facts. It's that they haven't been given facts in the right ways. Researchers often refer to this packaging as framing. Just as picture frames enhance and draw attention to parts of an image inside, linguistic frames can do the same with ideas.

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Metaphors are an effective way to provide frames when communicating about climate change. For example, in one study, reading about the "war" against global warming led to greater agreement with scientific evidence showing that it is real and human-caused than reading about the "race" against global warming (Hendricks 2017). "This group of participants indicated more urgency for reducing emissions, believed global warming poses a greater risk and responded that they were more willing to change their behaviors to reduce their carbon footprint."

Where and When to Educate for Climate Change Literacy

> There is a growing gap between what is known about climate change by the scientific community and what is understood by the public. There is an urgent need to enhance climate literacy, which is currently critically low as proved by several surveys. We assume that efforts towards climate literacy should be intensified. (Miléř and Sládek 2011, p. 155)

Opportunities to learn about climate change and to develop climate change literacy exist in and out of school, in three arenas: (1) formal education, (2) nonformal education, and (3) informal education. "Climate education can be formal (schools) and informal (media, museums, libraries, zoos)" (Miléř and Sládek 2011), with nonformal education situated in between.

Climate Change Literacy Through Formal Education

Formal education is a mandatory, continuous process, with an official structure and curriculum and leaving certificate (Palumbo et al. n.d.). Otto (2018) finds that "the classical educational system is the first important lever for climate literacy"

(p. 132), as borne out by Indicator 13.3.1 (Education on climate change) of Sustainable Development Goal 13, which relates to the number of countries that have integrated mitigation, adaptation, impact reduction, and early warning into primary, secondary, and tertiary curricula, the goal being to improve education, awareness-raising, and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning by 2030.

There are three levels of formal education where learning for climate change literacy can take place (note: these levels might have different names in different jurisdictions): (1) preschool and primary (early elementary), (2) late elementary (middle) and secondary, and (3) tertiary or postsecondary (colleges and universities).

Miléř and Sládek (2011) ask, "[W]hat level of knowledge is appropriate for different ages of pupils?" (p. 150). It is important for educators and educational researchers to determine what (and how) to teach for climate literacy respecting the different developmental stages or readiness levels of students. Below are some examples of climate change teachings at different levels (see also section "What Are the Vital Components of Climate Change Literacy?" for specific terms and concepts).

Level 1: Climate Literacy for Preschool and Primary School (Early Elementary)

- Nature bonding (Johnston 2007)
- Weather observation and simple weather terminology (Johnston 2010)
- Food growing
- Fun, hands-on, discovery learning
- Naturally integrated learning

Level 2: Late Elementary School (Middle School) and Secondary (or High) School

- More complex climate terms and concepts
- Scientific literacy
- Ecological principles involved in the climate system and climate change (Johnston 2010)
- Energy literacy (USGCRP 2009b)
- Real-world problem-solving through sustainable development principles
- Integrated and holistic learning across subject areas (science, history, geography, language/communications, mathematics, art, health)

Level 3: Postsecondary Institutions (Universities and Colleges)

- Innovative teaching approaches (UNESCO 2010)
- Interdisciplinary whenever possible (to cross the divide between humanities and sciences) (Siperstein 2015)
- Multidisciplinary action research
- Simulations (such as the World Climate Project simulation)
- Team-based learning using the principles of sustainable development
- Critical discourse analysis in climate change communication

> Climate science is a highly interdisciplinary, pedagogically challenging subject that does not fit easily into discipline-based science curricula or assessments. Curricula and the teaching of climate change therefore need to promote pedagogical approaches that take the challenges of interdisciplinarity into account. (UNESCO Climate Change Initiative 2010, p. 11)

Technical and Vocational Education and Training (TVET)

"TVET performs a crucial role in developing the skills, knowledge and attitudes needed for the world of work and human well-being" (UNESCO 2010, p. 12).

- "Green" economies skills training in renewable energy and other technologies
- Incorporation of elements of climate change adaptation and mitigation to contribute to reductions in energy consumption and greenhouse gas emissions
- Skills needed in and by communities affected by climate change (i.e., climate change refugees) (UNESCO Climate Change Initiative 2010, p. 12)

One way to deepen or intensify education for climate change literacy at any level or in any arena is through integration. "It is increasingly relevant to reflect and value an interdisciplinary approach to teaching and learning, because it is a key factor in climate change education and awareness" (Alves and Azeiteiro 2018).

According to Azevedo and Marques (2017), climate change literacy now needs an "integrative, inter/transdisciplinary and epistemological model" (p. 3) and a "re-thinking [. . .] to encompass the multiplicity of perspectives we face when trying to understand and participate in discussions about the complex issues posed by our contemporary post-industrial society" (p. 10).

Climate Change Literacy Through Nonformal Education

Nonformal learning is structured and organized learning that is intentional, planned and offered by an educational provider, and deliberately chosen by the learner, but it does not lead to formal certification or qualification. People of all age groups can participate in nonformal education, which can be offered through courses, workshops, seminars, etc. (Palumbo et al. n.d.).

Much nonformal education for climate change literacy is done through distance learning, a strategy that provides a high level of accessibility for learners. Alves and Azeiteiro (2018) point out that online learning has the "capacity to reach an extensive number of people, scattered around the world and with diversified cultural backgrounds."

One objective of the UNESCO Climate Change Initiative: Climate Change Education for Sustainable Development (CCESD) (2010) is "to raise awareness about climate change and enhance non-formal education programmes through the media, networking, and partnerships" (p. 14).

Climate Change Literacy Through Informal Education

Informal education is defined as non-institutionalized learning realized through activities in everyday situations and interactions within the context of work, family, and leisure (Palumbo et al. n.d.).

While formal education engages mostly the youngest generations, which is important for the future development of society, "informal education has the power to engage people of all ages and can achieve quick response" (Miléř and Sládek 2011, p. 153) – an important advantage given the urgency of the climate crisis.

Many climate change literacy initiatives in informal settings such as museums, libraries, zoos, and outdoor recreation venues now focus on lifelong learners and their participation in activities such as citizen science (research collaborations between scientists and the general public) (Dupigny-Giroux and Cole 2018).

Another significant source of informal learning for the general public is the media. A challenge for climate change literacy through media is that "[t]he rapid expansion of digital media has led to the wider dissemination of fake news articles, with the fast-paced nature of the modern newsfeed culture also encouraging less critical evaluation of news sources" (Fake news threatens a climate literate world 2017).

> It is reasonable to assume that it [understanding of climate change] will be at least partly shaped by access to media, and the quality of media coverage in each respective country. If the news sources you pay attention to don't report the issue at all, or don't explain the causes, it's unlikely most people will get the information from other sources. (Tien Ming Lee and Anthony Leiserowitz in McSweeney 2015)

Miléř and Sládek (2011) explain the dilemma that ensues when the media are climate change illiterate and the public is media illiterate:

> On one hand the politicians usually follow public opinion, thus the public has the power to force the politicians to take action. On the other hand the public is confused by media spin and climate education is a slow process and not very effective. (p. 152)

Two strategies are needed to solve this twofold problem. First, the UNESCO Climate Change Initiative (2010) calls for "increasing media literacy through training for journalists on facts and myths around climate change [to provide] another means to deliver and reinforce relevant and accurate messages." Next are calls for media literacy for the public. "To be climate change literate, the public must first be media literate, since print, TV and radio reports and opinion pieces are the main ways that the public gets its information about climate change science" (Cooper, in Ramanujan 2011).

How to Deal with Challenges to Climate Change Literacy

Is Denial the Opposite of Climate Change Literacy?

Are climate change deniers simply those who don't understand the science of climate change? According to research (Kahan et al. 2012), the answer is no. The psychological mechanism at work is identification with cultural values, leading to cultural polarization.

> Ordinary members of the public credit or dismiss scientific information on disputed issues based on whether the information strengthens or weakens their ties to others who share their values. At least among ordinary [people], individuals with higher science comprehension are even better at fitting the evidence to their group commitments. (Yale study concludes public apathy over climate change unrelated to science literacy 2012)

In this study, those with "the highest degrees of science literacy and technical reasoning capacity were not the most concerned about climate change. Rather, they were the ones among whom cultural polarization was greatest" (Kahan et al. 2012).

> According to Kahan, the study suggests the need for science communication strategies that reflect a more sophisticated understanding of cultural values. "More information can help solve the climate change conflict," Kahan said, "but that information has to do more than communicate the scientific evidence. It also has to create a climate of deliberations in which no group perceives that accepting any piece of evidence is akin to betrayal of their cultural group." (Yale study concludes public apathy over climate change unrelated to science literacy 2012)

According to Braman, a co-researcher, the solution won't be found in trying to increase trust in scientists or awareness of what scientists believe. He concluded that "[t]o make sure people form unbiased perceptions of what scientists are discovering, it is necessary to use communication strategies that reduce the likelihood that citizens of diverse values will find scientific findings threatening to their cultural commitments" (Why "scientific consensus" fails to persuade 2010).

Some of the Terms and Metaphors We Use Are Inaccurate or Misleading

According to John P. Holdren (2007), former senior science and technology advisor to US President Barack Obama, the term "global warming" is a misnomer. "It implies something gradual, uniform, and benign. What we're experiencing is none of these." Holdren uses "global climate disruption" instead.

Another problem arises when a term has both a colloquial meaning and a (different) scientific meaning. For example, Rebich and Gautier (2005) discovered that the term "aerosol" was often used incorrectly to describe a type of greenhouse gas, "which we considered to be evidence that many students were making colloquial use of the word aerosol (to mean CFC [chlorofluorocarbon]) and hadn't learned the scientific meaning of the term [a tiny solid or liquid particle suspended in air or gas]" (p. 361).

The term "greenhouse effect" is an example of a term that leads to "flawed mental models" (in this case of shortwave and longwave radiative processes); Rebich and Gautier (2005) found that some students:

> understood the greenhouse effect as the trapping of this extra (reflected) solar energy by greenhouse gases or clouds. Other students thought it was the greenhouse gases themselves being trapped. This misunderstanding of the greenhouse effect may result in part from the direct analogy to a greenhouse maintaining heat by trapping warm air inside. In many cases, it seemed that longwave radiative processes did not play any part in students' models of the greenhouse effect, which indicates that they probably do not conceive of the earth (let alone greenhouse gases and aerosol particles) as radiating bodies. (pp. 360–361)

One solution to this challenge is to help those learning about climate change to examine and reflect on their prior knowledge, metaphors, and mental models and schema relating to climate science concepts and terminology.

Misconceptions or Faulty Prior Knowledge

Rebich and Gautier (2005) gleaned from various researchers that the prior knowledge which learners bring to their learning – the "scaffold" for their future learning – "is a very strong determinant in what information they attend to, how that information is perceived, what learners judge to be important or relevant, and what they are able to understand and remember" (p. 356).

But while prior knowledge can be seen as "the foundation for integration of new concepts, it is also commonly viewed as an obstacle to conceptual change" (Rebich and Gautier 2005). Existing mental models can prevent adoption of new scientific learnings by limiting learners' perception and processing of conflicting information. Research shows that misconceptions can be resistant to instruction and that prior knowledge can be characterized by "affective entrenchment related to social values, ideology and identity" (p. 356).

> Presumably higher levels of affective entrenchment would correspond with greater difficulty in achieving conceptual change. Revision of misconceptions may also prove costly at the level of cognitive processing if revision of a particular mental model will require revision of a number of related models. (p. 356)

According to the Climate Literacy and Energy Awareness Network (CLEAN), the most common misunderstanding about climate change is that the Earth's climate has changed naturally in the past; therefore humans are not the cause of global warming, which is a non sequitur. They provide analogies to help debunk this "myth."

> At the heart of this misconception is the idea that if something happens naturally, then it can only happen naturally. But of course that's not true. Here are some examples. Forest fires occur naturally. Does that mean that arson is a hoax? People die of natural causes. But sadly, people are sometimes murdered. But if people can die on their own does that mean that murder does not happen? It rains, which makes my lawn wet. But sometimes, a sprinkler is used to make the lawn wet. So the lawn can become wet for either natural or human-caused reasons. Rivers have always flooded. But some floods are either caused by or made worse by human actions. If a dam ruptures, the resulting flood is because of humans—not because floods happen on their own. Many processes on Earth have more than one cause. The presence of a natural cause does not negate the reality of a human trigger. (CLEAN Question 11)

Because a principal factor in whether respondents in a global survey (Lee et al. 2015) consider climate change a threat was whether they consider climate change to be human-caused, education to correct misconceptions and faulty prior knowledge can be vital to their climate change literacy.

Gaps in Knowledge

Pretests given to students before teaching them about climate change can identify gaps in their knowledge. For example, Rebich and Gautier (2005) identified gaps in:

- Awareness of thermal expansion as a cause of sea level rise
- Appreciation for feedbacks in the climate system
- Understanding of the connection between the greenhouse effect and the hydrological cycle via water vapor
- Knowledge of the historical context of climate change
- Understanding of the mechanisms of global climate change
- Appreciation of the role of computational models in climate change research (pp. 362–363)

"Our efforts to modify the course curriculum to facilitate meaningful learning will be based in part on knowledge of these misconceptions [and gaps in knowledge], and modifications to our instructional approach will depend on our interpretation of their likely causes" (Rebich and Gautier 2005, p. 360). Any gaps still present at the summative evaluation can be addressed in future offerings of a course or program on climate change.

Scientific Illiteracy

Scientific literacy is the basis and starting point for climate science literacy.

> Science, mathematics, and technology have a profound impact on our individual lives and our culture. They play a role in almost all human endeavors, and they affect how we relate to one another and the world around us. . .. Science literacy

> enables us to make sense of real-world phenomena, informs our personal and social decisions, and serves as a foundation for a lifetime of learning. (American Association for the Advancement of Science 2007)

Scientific illiteracy can, therefore, pose a significant barrier to teaching or learning about climate change, its impacts, and the mitigation and adaptation measures necessary for dealing with it. Effective science teaching in educational institutions is a societal policy choice – one that takes years to produce its effect in a scientifically literate generation of graduates.

However, in the meantime, people who know that they are not scientifically literate can learn how knowledge is created in science. For example, an understanding of scientific concepts and practices such as weight of evidence, peer review, shifting baselines, different timescales, the precautionary principle, and ecological limits to science (Johnston 2007) can give these individuals the confidence to accept and act on what they don't actually understand.

Leaders, Educators, and Journalists Can Be Climate Change Illiterate

People in positions of power and influence might not have the level of climate change literacy needed for them to avoid passing on misconceptions and faulty knowledge. For teachers and others, there are web-based and other resources that are designed to help them become prepared to teach climate science or pass on climate change knowledge, deepening their own knowledge as they go. (See, e.g., CLEAN's Climate Literacy Quiz.)

Cognitive Dissonance

When those who have learned about the urgency of the climate crisis see no evidence of urgent action around them, especially from their leaders, cognitive dissonance can be the result. The evidence (what they're witnessing) does not match (indeed, it contradicts) their new understanding, belief, idea, or values about climate change, causing mental conflict or discomfort, even feelings of helplessness and immobilization. It is important to note that these feelings are not caused by climate change or learning about it, but by the lack of urgent response to climate change on the part of leaders that were trusted (Olofsgård 2018).

A Climate Change-Literate Citizen . . .

Climate change literacy is an understanding of one's influence on climate and climate's influence on oneself and society (U.S. Global Change Research Program 2009a). A climate change-literate person is, therefore, someone who:

- Has a basic understanding of the climate system (including "the essential principles of all aspects of Earth's system that govern climate patterns,") as well as the natural and human-caused factors that affect it
- Is aware of the fundamental relationship between climate and human life and the many ways in which climate has always played a role in human health
- Understands how climate observations and records, as well as computer modeling, contribute to scientific knowledge about climate
- Knows that climate science can inform our decisions that improve quality of life
- Learns how to gather information about climate and weather, accesses scientifically credible information about climate, and has the ability to assess the validity of scientific arguments about climate and to use that information to support their decisions
- Communicates about climate and climate change in a meaningful way
- Makes scientifically informed and responsible decisions with regard to actions that might affect climate (p. 4)

Put in an abbreviated way, society will benefit from a citizen who:

- Understands how our climate works
- Knows how to distinguish fact from fiction
- Talks about climate in a meaningful way
- Makes informed and responsible decisions (Climate Literacy (2016), an e-learning program in Europe)

In short, the climate change-literate citizen understands the science of climate change, as well as the importance of employing it as the basis for decisions on mitigation and adaptation measures in the face of its impacts.

As Chad Kauffman (2014) explains in *Our Changing Climate: Introduction to Climate Science*, an e-textbook on climate change, "We have choices. We can fatalistically accept climate change and do nothing about it or, based on scientific understandings of Earth's climate system, we can reduce, and even prevent, negative impacts through mitigation and adaptation."

Cross-References

- ▶ Climate Change Adaptation (CCA)
- ▶ Climate Change and Education
- ▶ Climate Change Impacts and Resilience: An Arctic Case Study
- ▶ Climate Change Literacy to Combat Climate Change and Its Impacts
- ▶ Climate Change Mitigation
- ▶ Massive Open Online Courses (MOOCs) and Their Role in Climate Change Education

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Climate Change Mitigation

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Definition

Climate change mitigation refers to actions to reduce or prevent emissions of greenhouse gases (GHG) causing human-induced climate change. Mitigation can be reached by using new technologies, fostering renewable energies, making older energy systems more efficient, or changing management practices or consumer behavior. According to the Intergovernmental Panel on Climate Change (IPCC 2014), mitigation can be defined as "the effort to control the human sources of climate change and their cumulative impacts, notably the emission of GHGs and other pollutants, such as black carbon particles, that also affect the planet's energy balance. Mitigation also includes efforts to enhance the processes that remove GHGs from the atmosphere, known as sinks."

Climate change is a modification in the statistical distribution of weather patterns that lasts for an extended period of time. Climate change may refer to an alteration in average weather conditions or in the time variation of weather within the context of longer-term average conditions. In many regions, temperature changes and sea-level rise are putting ecosystems under stress and affecting human well-being. Because mitigation lowers the anticipated effects of climate change as well as the risks of extreme impacts, it is part of a broader policy strategy that includes adaptation to already happening climate change impacts. Adaptation and mitigation should be considered holistically as two faces of the same effort to combat the negative impacts of climate change.

Introduction

The most diffused among GHG is carbon dioxide (CO2) that is released in the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees, and wood products and also as a result of certain chemical reactions (e.g., manufacture of cement or glass). CO2 is removed (or sequestered) from the atmosphere when it is absorbed by plants as part of the biological carbon cycle. Carbon dioxide remains in the atmosphere for centuries, meaning that each additional tonne of carbon dioxide emitted now will affect the well-being of people for decades and centuries from now. Concentrations in the atmosphere of other greenhouse gases (CH4, N2O, HFCs, PFCs, SF6, NF3) are also increasing steadily, exacerbating the problem.

As a consequence, the atmosphere traps more heat, and the global average surface temperature is increasing. This phenomenon is known as global warming. "Recent estimates indicate that the average surface temperature has increased by about 0.6 degrees Celsius (°C) with respect to 1951-1980, about 0.8 °C with respect to the pre-industrial average. Temperatures will continue to rise for decades because the climate system has a delayed response to the stock of GHG, and equilibrium temperature grows linearly with cumulative emissions of CO2" (Bosetti et al. 2014).

Back in 1972, the CO2 concentration was around 350 ppm and was increasing by around one part per million (ppm) per year (Sachs 2015). Today, the CO2 concentration in the atmosphere is increasing rather steadily at about 2 ppm per year. According to the IPCC (2014) "mitigation scenarios in which it is likely that the temperature change caused by anthropogenic GHG emissions can be kept to less than 2 °C relative to pre-industrial levels are characterized by atmospheric concentrations in 2100 of about 450 ppm CO2eq (equivalent)."

Unlike traditional pollutants, CO2 concentrations can only be stabilized if global emissions peak and in the long term decline toward zero. The lower the concentration at which CO2 is to be stabilized, the sooner and lower the peak should be. The stabilization of GHG concentrations requires fundamental changes in the global energy system relative to a baseline scenario. For example, according to the IPCC (2014) in mitigation scenarios reaching 450 ppm CO2eq concentrations in 2100, CO2 emissions from the energy supply sector decline over the next decades, reach 90% below 2010 levels between 2040 and 2070, and in many scenarios fall below zero thereafter. This concentration level is possible thanks to consistent energy efficiency improvements and almost quadrupling of the share of low and zero carbon energy technologies (from renewables, nuclear energy, and fossil energy with carbon dioxide capture and sequestration – CCS) and of technologies aimed at negative emissions such as bioenergy with CCS (BECCS) by 2050.

Climate Change Mitigation and Sustainable Development

Climate change has a clear inter-temporal and intergenerational dimension as it heavily affects the ability of each generation to satisfy its own needs. Climate change, therefore, is closely interlinked with the notion of sustainable development as originally defined by the Brundtland Commission (UN 1987), and its mitigation has an impact on the sustainability of the development process. Moreover, climate change has also remarkable intragenerational effects. In fact, climate change entails distributional impacts within each generation because the effects of global warming are spread unevenly across the globe, depending on the variation in regional and local climatic effects and on the differences in vulnerability of different societies.

Sustainable development is based on three dimensions, economic, social, and environmental, and it is conceived as development that preserves the interests of future generations, by preserving the ecosystem services, terrestrial or marine natural resources, and energy and water resources. First, climate change constrains possible development paths and could preclude any prospect for a sustainable future. Second, there are synergies and trade-offs between climate responses and Sustainable Development Goals (SDGs) because some climate responses generate co-benefits for human and economic development, while others can have adverse side effects and generate risks (IPCC 2014).

In 2015, the United Nations adopted the 2030 Agenda for Sustainable Development setting 17 SDGs, to be achieved worldwide by 2030. This represented a key step in the pathways toward a new global agenda that engages governments, businesses, scientists, academics, NGOs, and the civil society in a multi-stakeholder approach. Unlike the Millennium Development Goals (MDGs) which applied mainly to developing countries, the SDGs are universally applicable (Sachs 2015). As emerges from Table 1, the interlinkage between climate change mitigation objectives and SDGs is particularly evident in SDG 1, poors are more vulnerable to climate-related extreme events (Target 1.5); SDG 2, agricultural practices resilient to climate change are needed (Target 2.4); SDG 6, water scarcity needs to be addressed through sustainable withdrawals (Target 6.4); SDG 7, energy consumption needs to be reduced through energy efficiency (Target 7.3) and the mix of energy sources be in favor of renewables (Target 7.2); SDG 9, infrastructure and industry upgrade are needed for a greater adoption of clean technologies (Target 9.4); SDG 11, sustainable cities able to mitigate climate change need to be growing in number (Target 11.B); SDG 12, efficient use of natural resources has to be enhanced (Target 12.2); and SDG 13, climate change measures have to be integrated into national policies, strategies, and planning (Target 13.2), and awareness raising and capacity building on climate change mitigation need to be implemented (Target 13.3).

Climate Change Mitigation Options

According to the IPCC, to preserve a 50% chance of limiting global warming to 2 °C, the world can support a maximum carbon dioxide emission level, also known as carbon budget, of 3000 gigatonnes (Gt) (IPCC 2014), of which an estimated 1,970Gt had already been emitted before 2014. Accounting for CO2 emissions from industrial processes and land use, land-use change and forestry (LULUCF) over the rest of the twenty-first century leave the energy sector with a carbon budget of just 980Gt (IEA 2015).

Climate Change Mitigation, Table 1 Climate change mitigation and related sustainable development goals (own elaboration from UN 2015)

Goals	Targets
1 NO POVERTY	**1.5:** By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social, and environmental shocks and disasters
2 ZERO HUNGER	**2.4:** By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters, and that progressively improve land and soil quality
6 CLEAN WATER AND SANITATION	**6.4:** By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity **6.6:** By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers, and lakes
7 AFFORDABLE AND CLEAN ENERGY	**7.1:** By 2030, ensure universal access to affordable, reliable, and modern energy services **7.2:** By 2030, increase substantially the share of renewable energy in the global energy mix **7.3:** By 2030, double the global rate of improvement in energy efficiency
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	**9.4:** By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities
11 SUSTAINABLE CITIES AND COMMUNITIES	**11.B:** By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans toward inclusion, resource efficiency, mitigation, and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	**12.2:** By 2030, achieve the sustainable management and efficient use of natural resources **12.4:** By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water, and soil in order to minimize their adverse impacts on human health and the environment
13 CLIMATE ACTION	**13.2:** Integrate climate change measures into national policies, strategies, and planning **13.3:** Improve education, awareness raising, and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning **13A:** Implement the commitment undertaken by developed country parties to the UNFCCC to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions (. . .) and fully operationalize the Green Climate Fund (. . .)

The energy sector is the largest contributor to global GHG, representing roughly two-thirds of all anthropogenic GHG, and CO2 emissions from the sector have risen over the past century to ever higher levels. Climate change mitigation options in the energy supply sector should, therefore, be carefully planned as essential to tackling climate change. Options for climate change mitigation also exist in the energy demand sector, such as through demand side management and energy efficiency at household or business level, or in transport.

Energy supply sector comprises all energy extraction, conversion, storage, transmission, and distribution processes that deliver final energy to the end-use sectors. Options to reduce GHG emissions in the energy supply sector reduce the lifecycle GHG emissions intensity of a unit of final energy (electricity, heat, fuels) supplied to end users. Different available options for climate change mitigation in the energy sector exist. Some are aimed to replace unabated fossil fuel usage with technologies without direct GHG emissions, such as renewable and nuclear energy sources, whereas others aim to mitigate GHG emissions from the extraction, transport, and conversion of fossil fuels through increased efficiency, fuel switching (e.g., from coal to gas), and GHG capture (carbon capture and sequestration or CCS).

The Role of Electricity Sector in Climate Change Mitigation

Electrification of the energy system has been a major driver of the historical energy transformation from an originally biomass-dominated energy system in the nineteenth century to a modern system with high reliance on coal and gas. (IPCC 2014). Electricity generation is the largest single sector emitting fossil fuel CO2 at present and in baseline scenarios of the future. A variety of mitigation options exist in the electricity sector, including renewables (solar and wind energy, geothermal, hydro, bioenergy), nuclear, and the possibility of fossil or biomass with CCS. The electricity sector plays a major role in mitigation scenarios with deep cuts of GHG emissions. Mitigation in the electricity sector can be achieved by means of (1) decarbonize electricity generation, (2) substitute fossil fuels with electricity for end use in buildings and industry and as transportation fuel, and (3) reduce aggregate energy demands.

Renewable Energy for Electricity Generation

Renewable energy (RE) is one of the most important among climate mitigation options especially in the electricity sector. The lifecycle GHG emissions normalized per unit of electrical output (g CO2eq/kWh) from technologies powered by RE sources are less than from those powered by fossil fuel-based resources (IPCC 2012). Although consistent estimates for each RE source are not available, the technical potential for solar is shown to be the largest by magnitude, but sizable potential exists for many other forms of renewables. RE technical potentials are not always comparable to those for fossil fuels and nuclear energy due to differing methodologies. Nevertheless, the RE technical potential as a whole is at least 2.6 times as large as the 2007 total primary energy demand globally (IPCC 2012).

However, some constraints in RE sources development exist. The long-term contribution of some individual RE sources to climate change mitigation may be limited by the available technical potential if deep reductions in GHG emissions are sought (e.g., bioenergy), while even RE sources with seemingly higher technical potentials (e.g., solar, wind) will be constrained in certain regions due to changing weather patterns. In other cases, environmental concerns, issues related to public acceptance, and economic factors such as investment in infrastructure required for energy system integration are likely to limit the deployment of individual RE technologies before absolute technical resource potential limits are reached (IPCC 2012). Furthermore, aggregate technical potentials may be affected by competition for land and other resources among different RE sources, as well as by concerns about the carbon footprint and sustainability of the resource (e.g., biomass).

Solar Energy

Solar energy technologies for electricity generation can be divided in solar photovoltaics (PV) and concentrated solar power (CSP). PV and CSP are two considerably different technologies. Whereas CSP converts sunlight into electricity through the production of steam and the use of turbines and generators, PV produces its output thanks to special semiconductor materials that transform sunlight into electricity directly. Another important difference is that with CSP, the storage of electricity is possible through special fluids (molten salts), whereas in the case of

PV systems, the storage is more difficult and still very expensive. The energy from the sun is abundant although intermittent; therefore, PV solar power systems for generation of electricity need a backup system in order to ensure the continuity in the energy supply during nighttime or in cloudy or rainy days (Neuhoff 2005).

Moreover, CSP technology needs larger areas than PV. Thus, if combined with the need for long days of direct sunlight, CSP would perform better in certain geographical area. PV systems, on the contrary, are scalable and therefore adaptable to different solutions, either off-grid or on-grid, for distributed generation on rooftops of private households and businesses, as well as for concentrated generation in utility-scale PV plants for electricity generation (Alloisio 2012).

Although solar energy provides a relatively small fraction of global energy supply, namely, 18% at the end of 2017 (390,625 MW of capacity as of 2017) (IRENA 2018), it has the largest potential among all energy sources, and given continuous technological improvements and cost reductions, it could see a dramatic deployment in the near- and long-term future. However, the variability of the resource and the need for new transmission and distribution infrastructure will have an impact on the length, type, and cost of solar energy deployment.

Wind Energy

Wind energy offers the potential for significant near-term (2020) and long-term (2030 to 2050) GHG emissions reduction. In 2017, global wind energy capacity reaches 513,936 MW (23% of the global RE capacity) of which the greatest amount is from onshore wind applications (IRENA 2018). A number of different wind energy technologies are available on the market, but the primary use of wind energy which is relevant to climate change mitigation is the utility-scale, grid-connected wind turbines, deployed either onshore or offshore. Given its commercial maturity and the declining cost of onshore wind energy technology, wind energy has a large GHG mitigation potential. Although the wind energy potential is not dependent on technological breakthroughs, further incremental innovation is expected to increase the reliability and efficiency of wind energy. More technology challenges arise for offshore wind which have also the highest potential in terms of electricity output.

Like solar energy, wind energy has some barriers linked to the variability of the resource posing grid stability challenges to electric system operators and planners. Other barriers exist such as environmental and social acceptability issues. If the first – such as wind power plants impacts on wildlife – has been mostly overcome, the second represents the most important challenge in many countries. In Italy, for example, offshore wind power plant developers have met several obstacles from local communities. Other countries in the north of Europe, such as the UK and Denmark, instead, provide best practice examples of a rapid deployment of both onshore and offshore wind energy with no local opposition. In Scotland, for example, local communities have been involved in the ownership of wind energy farms.

Geothermal Energy

Considering its technical potential and likely deployment, geothermal could meet roughly only 3% of global electricity demand by 2050. As of 2017 a capacity of 12,894 MW of geothermal energy exist globally (IRENA 2018).

Geothermal resources consist of thermal energy from Earth's interior stored in rocks, steam, or liquid water. Technologies for geothermal utilization may be classified under categories for electricity generation, for direct use of the heat (heat pumps), or for combined heat and power in cogeneration plants. The technology for electricity generation from hydrothermal reservoir is mature and has been operating for more than 100 years. However, several prospects exist for technology innovation and improvement especially in enhanced geothermal system (EGS).

Geothermal energy is not dependent on climate conditions, and climate change is not expected to have a significant impact on the resource potential. However, on a local level, some effect of climate change on rainfall distribution may have a long-term impact on geothermal potential. With its natural thermal storage capacity, geothermal energy is suitable for supplying base load electricity and thus useful for the electricity system stability in the presence of intermittent renewable resources (wind and solar).

Hydroelectric Energy

In 2017, hydroelectric power accounted for the largest share of the global RE capacity (53%, with an installed capacity of 1152 GW (IRENA 2018). Although hydropower's share of the global electricity supply is foreseen to decrease by 2050 (in a range from 10% to 16%), this RE remains an attractive source within the context of global carbon mitigation scenarios.

Hydroelectric energy uses the energy of water moving from higher to lower elevations to generate electricity. Hydropower encompasses dam projects with reservoirs, run-of-river, and in-stream projects. Hydropower is a mature technology and in many regions is already overexploited. Hydropower projects exploit a resource that varies temporally across seasons and geographically among regions. Hydropower is highly dependent on the volume, variability, and seasonal distribution of the runoff and, therefore, is vulnerable to climate change effects. A shift in winter precipitation from snow to rain due to increased air temperature may lead to a temporal shift in peak flow and winter conditions (Stickler and Alfredsen 2009) in many continental and mountain regions. As glaciers retreat due to warming, river flows would be expected to increase in the short term but decline once the glaciers disappear (IPCC 2008). On the other hand, in sub-Saharan Africa, droughts have caused a reduced hydropower production (e.g., Ghana, Kenya).

Importantly, hydropower is becoming an important source of storage which could contribute to balance electricity systems that have large amounts of variable RE generation (IPCC 2012). As of 2017, up to 118,596 MW of pure pumped storage capacity is available globally (IRENA 2018).

Ocean Energy

The contribution of ocean energy to climate change mitigation is rather minor considering that – as of 2017 – it reaches, globally, 529 MW of capacity (IRENA 2018). Ocean energy comes from the kinetic, thermal, and chemical energy of seawater, which can be transformed into electricity and thermal energy. A large range of technologies exist depending on the different possible sources of ocean energy: waves, ocean currents, and tides. These range from barrages for tidal range, submarine turbines for tidal and ocean currents, heat exchangers for ocean thermal energy conversion, and a variety of devices to harness the energy of salinity gradient and waves. With the exception of tidal barrages, ocean energy technology is at the demonstration phase and requires additional R&D. Some of the technologies have variable energy output profiles with differing levels of predictability (e.g., wave, tidal range, and current), while others may be capable of near constant or even controllable operation (e.g., salinity gradient and ocean thermal) (IPCC 2012). To better understand the possible role of ocean energy in climate change mitigation, not only improvements in the various technologies will be necessary but also a clearer vision of when and if it will become commercially available at attractive costs.

Nuclear Energy

Nuclear energy has the potential to make an increasing contribution to low-carbon energy supply; it is a mature technology and a source of base load power. Its emissions are very low and below 100 g CO2eq per kWh on a lifecycle basis, and nuclear electricity represented 11% of the world's electricity generation in 2012 with a total generation of 2346 TWh (IAEA 2013). Nuclear energy is utilized for electricity generation in 30 countries around the world with more than 400 nuclear facilities and a total installed capacity of 371 GWp as of September 2013 (IAEA 2013). However, a variety of barriers and risks exist ranging from social acceptability issues to nuclear waste management concerns. Due to these reasons and on the wake of major nuclear accidents (Chernobyl Ukraine 1986 and Fukushima Japan, 2011) since 1993, nuclear energy share of global electricity generation has been declining (IPCC 2014).

Energy Efficiency

Energy efficiency is a fundamental option for climate change mitigation. According to the first law of efficiency, it can be defined as the ratio of the desired energy output for a specific task or service to the energy input for the given energy conversion process (Nakićenović et al. 1996). Other approaches often define energy efficiency in relative terms, such as the ratio of minimum energy required by the current best practice technology to actual energy use, everything else being constant (Stern 2012).

Economic studies often use energy intensity – the ratio of energy use per dollar of GDP – as an indicator of how effectively energy is used to produce goods and services. However, energy intensity depends on many factors other than technical efficiencies and is not an appropriate proxy of actual energy efficiency (Filippini and Hunt 2011; Stern 2012).

Finally, it is worth mentioning the European Union principle "energy efficiency first" raised within the communication on Energy Union in 2015 (COM (2015) 80 final) and now become a pillar of the EU energy policy. It means that where efficiency improvements prove to be the most cost-effective, taking full account of their co-benefits, energy efficiency should be prioritized over any other investment in new power generation and transmission.

Carbon Capture and Storage (CCS)

Carbon capture and storage or sequestration (CCS) technologies could reduce the lifecycle GHG emissions of fossil fuel power plants. CCS separates and captures CO2 from power and industrial sources and then transports the CO2 to a suitable site for injection into deep underground formations for permanent storage. CCS makes possible the strong reduction of net CO2 emissions from fossil-fueled power plants and industrial processes, providing a protection strategy for power plants that would otherwise be decommissioned or become stranded.

While all components of integrated CCS systems exist and are in use today by the fossil fuel industry, CCS has not yet been applied at large scale. A variety of pilot projects have led to critical advances in the CCS technology. CCS is an expensive technology and would need substantial cost reductions or economic incentives to become viable and contribute to GHG emission reduction. Beyond economic incentives, a well-framed regulation and coherent emission reduction policy scenarios are essential for a large-scale future deployment of CCS.

Furthermore, barriers exist for large-scale deployment of CCS including safety and environmental concerns, especially on uncertainty on long-term integrity of CO2 storage as well as transport risks. Also, there is a limited evidence of the potential consequences of a pressure buildup within a geologic formation caused by CO2 storage (such as induced seismicity) and on the potential human health impacts from CO2 that migrates out of the primary injection zone (IPCC 2014).

Bioenergy with Carbon Capture and Storage (BECCS)

As well as fossil fuels, CCS may also be used in combination with sustainable biomass, resulting in the so-called negative emissions. This technology is known as BECCS and plays an important role in many low stabilization scenarios. However, it entails some challenges and risks including those associated with the CCS technology and those linked to the upstream provision of the biomass that is used in the CCS facility. BECCS faces also large financial challenges, being still in a R&D phase and still not tested at scale.

Climate Change Mitigation Policies

The nature of climate change challenge requires that mitigation policies be pursued over long-term horizon, and this implies that they may change over time as a result of technological innovation and economic development. Long-term decisions are required in order to achieve levels of mitigation needed to limit its adverse effects.

Climate change mitigation outcomes depend on the extent to which explicit efforts are taken to implement climate change policies and measures (IPCC 2014). These efforts depend on the mitigation capacity of different countries which differ according to their economic development level. This is the main reason why the issue of burden sharing among countries is very relevant with respect to international cooperation on climate change (IPCC 2014).

Architectures for mitigation of international emissions can be distinguished according to the possible approaches (bottom-up versus top-down) and the different instruments (market-based instruments versus command-and-control regulations) being adopted (Aldy and Stavins 2007). The top-down approach is typical of international climate agreements (i.e., the Kyoto Protocol and the Paris Agreement), whereas an example of bottom-up approach is linking independent national and regional tradable permit systems (Jaffe and Stavins 2009). Market-based instruments are subsidies, taxes, and/or emission trading systems (e.g., cap-and-trade systems), whereas command-and-control regulations set specific limits for emissions and/or mandates on pollution control technologies to be used. The following paragraphs will focus on the international legal framework, as a top-down approach, and the cap-and trade system that has been increasingly used as a climate change mitigation instrument.

The International Legal Framework

The current top-down climate policy architecture has evolved since 1992 with the signature of the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC entered into force in 1994. Today, 197 countries have ratified it and are called Parties to the Convention. The UNFCCC recognized the long-term impacts of GHG emissions by setting long-term environmental goal and a near-term goal for industrialized countries (the so-called Annex I countries as opposed to non-Annex I countries). Annex I countries agreed to a non-binding quantitative emission target aimed at stabilizing their GHG emissions at 1990 levels starting in 2000 (Aldy and Stavins 2007).

The Kyoto Protocol

Every year a Conference of the Parties (COP) to the UNFCCC takes place to progress on the international negotiations on climate change mitigation and adaptation. In 1997, at the third COP in Kyoto, Japan, 192 parties agreed on the terms of the Kyoto Protocol (KP). The KP entered into force in 2005, although the United States – one of the countries with highest GHG emissions – did not ratify it. This agreement established emission commitments for 37 industrialized countries and the European Community. Within the first commitment period (2008–2012), they were required to reduce their collective GHG emissions to an average of 5% below 1990 levels. In the second commitment period (2013–2020), they committed to reduce GHG emissions by at least 18% below 1990 levels. The second commitment period bridges the gap between the end of the first period and the start of the implementation of the Paris Agreement in 2020.

The KP establishes that industrialized countries' emission reduction targets are legally binding and provide a compliance mechanism to ensure implementation. The Protocol recognizes the UNFCCC principle of "common but differentiated responsibilities" (articles 3 and 4 UNFCCC) calling on those countries responsible for most of the anthropogenic GHG emissions to adopt first emission commitments. However, emerging economies with growing emission pathways such as China and India, being non-Annex I countries to UNFCCC, do not have quantitative emission targets.

The KP created the tradable emission allowances for industrialized countries with quantitative emission targets that would have become the basis for an international emission trading system. The Clean Development Mechanism (CDM) was introduced allowing developed countries (Annex I Parties) to generate emission reductions in developing countries that could be used as credits (certified emission reductions, CERs) to satisfy their own targets. At the end of 2006, industrialized countries had financed nearly 500 CDM projects (Aldy and Stavins 2007). Similarly, joint implementation (JI) provides for Annex I Parties to implement projects in the territory of other Annex I Parties to generate emission reduction units (ERUs). Like all KP units, CERs and ERUs could be used by Annex I Parties to meet their Kyoto targets. They can also be traded on international carbon markets under the third flexibility mechanism, namely, international emissions trading. The KP and the UNFCCC served as milestones for future climate change mitigation policy and led the foundations on which the today climate policy regime is based.

The Paris Agreement

Adopted in Paris by the 21st Conference of the Parties (COP 21) to the UNFCCC in December 2015, the Paris Agreement (PA) entered into force, sooner than expected, on November 4, 2016. The PA calls on countries to contrast climate change and to accelerate and intensify actions and investments needed for a sustainable low-carbon future and to adapt to the increasing impacts of climate change. It represents a significantly more ambitious shift in the recognition that the long-term temperature goal should be to "hold [. . .] the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels" (UNFCCC 2015).

In the framework of the implementation of the Paris Agreement, 165 parties submitted their Nationally Determined Contributions (NDCs), which are national plans for GHG emissions reduction. The new approach characterized by the NDCs is particularly innovative for UN climate negotiations. These are voluntary-based pledges by which each country – based on its natural and financial resources, its technological know-how, and its economic and governance structure – commits to reduce GHG emissions through a national climate mitigation strategy.

However, it is acknowledged that current efforts as enshrined in the Nationally Determined Contributions (NDCs) fall far short of holding global warming below 2 °C, not to mention 1.5 °C. The Paris Agreement features a voluntary global stocktake of how national pledges are contributing to a long-term target in 2018 and a voluntary revisiting of pledges in 2020. However, a first binding stocktake is only foreseen for 2023, with a binding revisiting of pledges in 2025 toward a more stringent GHG emissions reduction.

The PA has set an institutional framework for engaging developing countries in climate change mitigation through the financial contributions from developed countries. Article 9 designates the Green Climate Fund (GCF) and the Global Environment Facility (GEF) as the operating entities that shall serve as the financial mechanism of the PA. Target 13.A of SDG 13 (Table 1) calls for developed countries to mobilize jointly USD 100 billion annually by 2020 to address the needs of developing countries in the context of mitigation actions. Another relevant aspect of the PA relates to Article 6 which encourages voluntary cooperation between countries with carbon pricing mechanisms by establishing the Internationally Transferred Mitigation Outcomes (ITMOs). They can be used to fulfill the NDC of another party (Marcu 2016), thus advancing key carbon offsetting mechanisms.

Cap-and-Trade Systems

In view of the KP first commitment period (2008–2012), some industrialized countries started to consider or to implement cap-and-trade systems to abate their GHG emissions. In 2005, the European Union (EU) launched its Emissions Trading Scheme (EU ETS); Japan promoted emission abatement in 1997 through the implementation of the Keidanren Voluntary Action Plans on the Environment, aimed to limit CO2 emissions to their 1990 levels by 2010.

To date, 21 distinct Emissions Trading Systems (ETS) exist worldwide, and other 16 are under consideration (ICAP 2018). China started its ETS in 2013 with pilot projects at the regional level and launched its nationwide emissions trading system in 2018, which is intended to cover one half of China's energy-related carbon emissions by 2025. Outside of the KP framework, it is worth mentioning the California-Québec joint cap-and-trade program, whose first joint auction was held in November 2014. Finally, the RGGI (Regional Greenhouse Gas Initiative) the first mandatory market-based program in the United States is operational since 2012. It aims to cap and reduce CO2 emissions from the power sector among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. All these instruments took inspiration from the EU ETS that is one of the most prominent examples of marked-based environmental regulation using cap-and-trade system as climate mitigation instrument.

The EU Emission Trading System (EU ETS)

In 2005, the EU launched the world's largest emission trading market (EU ETS) to cover about 45% of the EU's CO_2 emissions and around 11,000 installations in the energy-intensive industrial sectors. Aviation entered as a regulated sector only in 2012. The scope of the EU ETS has changed over time, as more countries have joined either by becoming EU members (Croatia, Bulgaria, and Romania) or by linking their national systems with the EU ETS (Norway, Liechtenstein, Iceland, and Switzerland).

The market currency is the EU allowance (EUA) which gives the holder the right to emit one ton of CO_2 or other GHGs (N_2O and PFCs) with an equivalent heating potential. The total number of allowances – the cap – is determined at the EU level. The institutional rules governing the market have been revised over time to address new emerging issues. Now the EU ETS has reached the third phase (2013–2020) and is preparing to enter its fourth phase (2021–2030). In phase III, the cap decreases each year by a linear factor of 1.74% compared to 2010 reaching in 2020 a level 21% below 2005 emissions. This trajectory is consistent with the 2020 target for the EU's overall GHG emissions reduction.

The market participants are regulated firms that "can trade allowances freely within the EU bilaterally, through brokers, or directly on a few commodity exchanges" (Gronwald and Hintermann 2015). CO_2 price has decreased from a maximum of 30€/tCO_2 at the beginning of phase I in 2005 to 7€/tCO_2 on the wake of the economic crisis and to as low as below 3€/tCO_2 in 2013. Today, carbon price has increased to above 20€/tCO_2 also as a result of the new ETS Directive (EU/2018/410) for the fourth phase (EEX 2018).

Future Perspectives

When originally conceived, the EU ETS was designed to comply with the KP targets. Now the KP has been replaced by a new global climate regime, which has radically changed the design and governance of global GHG emission reduction. The introduction of the NDCs has given the UNFCCC parties (both Annex I and non-Annex I countries) the possibility of voluntarily committing to GHG emission reduction targets. The PA is key not only for its innovative design, but also because it generated very high expectations in terms of climate change mitigation.

However, the voluntary nature of the commitment underlying NDCs brought to a trade-off between scope and ambition of the mitigation efforts under the PA. Voluntary commitments reduced the ambition of the targets but helped to largely increase the scope of the PA that includes countries accounting for 97% of global emissions – compared to the KP – which covered only 14% in the second commitment period. Within this framework and in the context of Article 6 of the PA, the EU ETS can play a potentially important role in fostering international climate cooperation (so as to further extending the scope of the PA) while raising climate mitigation ambition, thus contributing to reduce the trade-off described above.

Conclusions

The energy sector is the largest contributor to global GHG, representing roughly two-thirds of all anthropogenic GHG. Electricity generation is the largest single sector emitting fossil fuel CO_2 at present and in the future, and, therefore, the electricity sector plays a major role in mitigation scenarios with deep cuts of GHG emissions. A variety of mitigation options exist in the electricity sector, both at the demand and supply sides, for transitioning to a low-carbon energy system, through enhancing the use of new technologies, fostering renewable energies, reducing energy consumption, and making older energy systems more efficient. Climate change has an inter-temporal and intergenerational dimension and is closely interlinked with the notion of sustainable development. Synergies and trade-offs between climate responses and SDGs exist, and interlinkages between climate change mitigation objectives and most of SDGs are evident.

Climate change mitigation policies encompass bottom-up versus top-down approaches, market-based instruments, and command-and-control regulations. The top-down approach is typical of international climate agreements, namely, the Kyoto Protocol and the Paris Agreement, whereas the bottom-up approach is any climate initiative undertaken by a national or regional entity, such as linking independent national and regional tradable permit systems. Command-and-control regulations set specific limits for emissions and/or mandates on pollution control technologies, whereas market-based instruments are subsidies, taxes, and/or emission trading or cap-and-trade systems. The most prominent and world's largest emission trading market is the EU ETS launched in 2005 and soon become the reference for any cap-and-trade system. The EU ETS cover about 45% of the EU's CO2 emissions and around 11,000 installations in the energy-intensive industrial sectors. China started its ETS in 2013 at the regional level and in 2018 launched its nationwide emissions trading system aimed to cover one half of China's energy-related carbon emissions by 2025. Within the United States, the RGGI (Regional Greenhouse Gas Initiative) was the first mandatory market-based program, and it is operational since 2012, followed by the California-Québec joint cap-and-trade program in 2014.

Cross-References

▶ Climate Change Adaptation (CCA)
▶ Climate Change Agreement
▶ Green Climate Fund (GCF): Role, Capacity Building, and Directions as a Catalyst for Climate Finance
▶ Kyoto Protocol (KP)
▶ Role of Conferences on the Environment and Sustainable Development in Combating Climate Change

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Climate Change Mitigation and Adaptation: Role of Mangroves in Southeast Asia

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Definitions

*Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (*IPCC 2014*). Managing the risks of climate change involves mitigation and adaptation decisions with implications for future generations, economies, and environments.*

Climate change mitigation refers to actions to limit the magnitude or rate of long-term global climate change and its related effect. This mainly involves reducing the anthropogenic emissions of greenhouse gases and stabilizing the levels of these heat-trapping greenhouse gases in the atmosphere within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.

Climate change adaptation is the adjustment of natural or human systems to the changing climate, which reduces the vulnerability to the impacts of climate change. This involves taking practical actions to manage risks from climate impacts, to protect communities, and to strengthen the resilience of the economy.

*Ecosystem services are the goods or benefits derived, directly and indirectly, from natural ecosystems and the associated species to sustain and fulfill human well-being. The Millennium Ecosystem Assessment (*MA 2005*) categorized ecosystem services into four main types,* i.e., *provisioning, regulating, supporting, and cultural, while TEEB (*2010*) omitted supporting services for habitat services. The valuation of ecosystem services is a way of evaluating what society is willing to trade off to conserve a particular ecosystem service by either quantitatively or qualitatively assessing its value.*

*Mangroves are tropical maritime trees or shrubs that grow in coastal saline or brackish water, due to their ability to adapt to conditions of high salinity, low oxygen, and changing water levels. They play an important role in both climate change mitigation (*e.g., *through the sequestration of carbon) and adaptation (*e.g., *through stabilizing shoreline erosion, reducing storm surges, and preventing inland soil salinization).*

Introduction

Climate change (CC) affects Southeast Asia (SE Asia) coastal zones, particularly the mangrove habitats, in many ways. SE Asia coastal zones are vulnerable to CC due to poor socioeconomic conditions and large populations living near to low-lying coasts. Yet awareness among multi-stakeholders on the grave CC challenges confronting the region and its mangrove ecosystems is still weak. Likewise, collaborative deliberations are rare among the government, business, and civil society for incorporating climate change mitigation and adaptation (CCMA) measures into national coastal zone development policy and processes. With benefits that go beyond the borders of country, people, and generation, CCMA is a global public good that requires a global solution built on common but differentiated responsibility. With high coastal populations in Indonesia, the Philippines, Vietnam, and Thailand, SE Asia is highly vulnerable to CC and is in great need for adaptation to reduce the impact of changes already locked into the climate system (Weiss 2009). Nevertheless, SE Asia has great CCMA potential because of robust education and improving socioeconomic condition. Hence, SE Asia should play an important role in providing solutions to this global problem. As a good long-term neighbor and trading partner of China, SE Asia has the golden opportunity and unique obligation to collaborate with China to achieve CCMA goals. This is particularly the case for collaboration on conservation and restoration of mangroves since they are present in Guangdong and Southern China, which share similar climatic, socioeconomic, and geopolitical features with SE Asia.

This entry is organized as follows. Section “Introduction” lays the foundation for the deliberation of the remaining sections. Section “Global Distribution of Mangroves” describes the distribution of mangroves globally and within SE Asia. This highlights the important role of SE Asia, which harbors about thirty-five percent (Giri et al. 2011) of the global mangrove forests, in CCMA strategies. Mangroves link many associated sub-ecosystems, via their interdependence of each other. Hence, mangrove must be managed as an integrated coastal zone, comprising marine seagrass beds, coral reefs, terrestrial marshes, and wetlands. The failures in managing mangroves effectively over the past 50 years have resulted in the loss of more than 50% of mangrove coverage in SE Asia (Macintosh and Ashton 2002; Ilman et al. 2016; Feller et al. 2017). This failure stems from an undervaluation of the importance of mangrove ecosystem to the well-being of humans. The valuation of any ecosystem, including mangroves, is not a simple exercise of routine economic algebra. The ecosystem services (ES) rendered by mangroves consist of interlinked components. Accounting for ES and associated benefits is not straightforward (TEEB 2010) because different values can be attached to a particular service or benefit. Further, unlike components like fuel wood and timber, biodiversity and deforestation cannot be given readily acceptable prices because these services are not traded in the open market. However, it is beyond doubt that mangrove ecosystem serves many valuable functions to support human needs. Section “Ecosystem Services of Mangroves” elaborates on the various ES rendered by mangroves, from the abiotic to the biotic and from the physical to the cultural and spiritual. Ecosystem services economic valuation (ESEV) is the process of placing monetary value on goods and services provided by an ecosystem. The ESEV of a mangrove ecosystem is site-specific and can vary significantly on a per hectare per year basis from USD 33 ha^{-1} $year^{-1}$ to USD 57,000 ha^{-1} $year^{-1}$ (UNEP 2014) due to differences in economic activities, cultures, and lifestyles of the local community. Nevertheless, ESEV provides useful narratives about the social-economic-cultural and ecological benefits and costs associated with alternative coastal policies. Awareness of the importance of mangroves has prompted efforts to rehabilitate abandoned fishponds back to mangrove forests in SE Asia, including in Guangdong, Indonesia, the Philippines, Thailand, and Vietnam, with varying degree of success. Section “Rehabilitation of Abandoned Fishponds in SE Asia” examines the various issues related to the rehabilitation of abandoned fishponds in these SE Asian countries as a means of implementing CCMA strategies. Property ownership right is an important determinant of success in the rehabilitation of abandoned fishponds in Indonesia and Vietnam as they are in Guangdong, Thailand, and the Philippines. Section "Loss of Mangrove in SE Asia" suggests that the extensive loss of mangrove coverage in SE Asia is a direct consequence of giving very low ESEV to mangroves because of the attitude known as the "tragedy of open access" and the "tragedy of the commons." In resource-abundant countries in SE Asia, this pervasive and entrenched attitude turns these resource-abundant countries into resource-dependent, a phenomenon known as the resource-curse. However, improving regulatory institutions and robust education appear to have initiated a process of declining rate of mangrove loss in SE Asia, giving rise to emerging rays of hope for the future. Threats to mangroves long-term survival in SE Asia are aplenty, from traditional human over-exploitation to other major natural disturbances. Section "Threats to Mangroves in SE Asia" conveys the importance of implementing effective CCMA strategies to overcome this myriad of threats confronting mangroves in SE Asia. Section "Mangrove Restoration and Conservation in SE Asia" provides narratives to support the argument that socioeconomic prerogatives (e.g., community education and involvement), hydrological conditions (e.g., tidal inundation), and mangrove ecology (e.g., species to site matching) are major determinants for successful restoration of mangrove in SE Asia. Explosive growth in human populations in coastal regions in SE Asia over the coming decades may present conditions that are not conducive to mangrove conservation unless regulatory framework and supportive institution are put in place to facilitate mangrove conservation and restoration. Section "Two Examples of Successful Mangrove Conservation in SE Asia" introduces two successful examples of mangrove conservation in Malaysia and Vietnam. Section "Conclusion" concludes this entry, expressing hope for the future in which the Brundtland aspirations will be a reality. The Brundtland Report (Brundtland 1987) was published following the 1983 World Commission on Environment and Development (WCED). Embracing the aspiration for sustainable development, the Report introduced the concept of sustainable development and proposed long-term strategies for achieving it. The predicted environmental crisis (e.g., extreme climate events, debilitated habitats, and stressed ecosystems) and social crisis (e.g., widespread poverty, growing inequality, and pressures from migration) are proven accurate and relevant at present, more than three decades after its publication. Therefore, the key insights from the Report and suggested actions that can be taken to address these challenges should be earnestly implemented. The Brundtland Report inspired the United Nations Millennium Development Goals to be achieved by 2015, followed by the post-2015 agenda called "Transforming Our World: The 2030 Sustainable Development Agenda."

Global Distribution of Mangroves

Environmental factors, including temperature, salinity, and rainfall, are key determinants that have a strong influence over the growth, survival, and distribution of mangroves. Consisting of halophytic trees and shrub species, mangroves are intertidal wetland forests that live in the tropical and subtropical regions between latitude 30° north (e.g., Florida) and 30° south (e.g., southern Australia). A plethora of coastal and terrestrial fauna, including fish, crustaceans, snakes, and mammals, share the wetland habitats with some 70 vegetation species of mangroves. In the literature, mangrove also refers to the tidal forest that includes trees, shrubs, palms, epiphytes, and ferns (Tomlinson 1986). The distinctive community of plants and animals associated with mangroves is sometimes referred to as the "mangal." These forests grow around the mouths of rivers, in tidal swamps, and along coastlines. Mangroves are regularly inundated by saline or brackish water and subjected to constant salinity stresses due to vast variations in salinity over the diurnal and seasonal cycles. Mangroves must adapt to constant salinity stresses, in addition to high temperature and oxygen deprivation in waterlogged environment, at the expense of growth and development. This has resulted in the very low species diversity of the mangrove vegetation today, compared to the high biodiversity found in, e.g., coral reefs and tropical rainforests (Ricklefs and Latham 1993). For example, 223 tree species per hectare have been recorded in lowland tropical rainforest in Sarawak (Proctor et al. 1983). On the other hand, there may be only two or three mangrove species per hectare.

Although mangrove plant species themselves are not biodiverse, the mangrove ecosystem is. The abundance of fish is high in the creeks, pools, and inlets of mangrove forests. Many of the fish are juveniles suggesting that the mangrove habitat is a nursery area. The high abundance and productivity of mangrove plant and animal species make them an important fundamental ecological unit linking mangroves to other terrestrial and marine habitats. Therefore, management of this important coastal resource should be based upon an integrated approach, integrating the marine and the terrestrial habitats. Hence, the success in mangrove management "kills three birds with one stone," one on land (SDG 15) and the other below water (SDG 14), with good climate action (SDG 13). Integrated coastal zone management is a term used to describe a continuous and dynamic process that unites government and the community, science and management, and sectoral and public interests, in preparing and implementing an integrated plan for the protection and development of coastal systems and resources. Mangroves play an important role in the functioning of adjacent ecosystems, including terrestrial wetlands, peat swamps, saltmarshes, seagrass beds, and coral reef (Macintosh and Ashton 2002). Hence, integrated mangrove management must provide adequate assurance for mangrove to be functionally connected to other associated sub-ecosystems. Distributed unevenly over 118 countries (Tomlinson 1986), the center of diversity and development of mangroves occurs in a triangular area of tropical SE Asia, comprising the southern half of the South China Sea and the eastern half of the "Coral Triangle" (Giri et al. 2011). With four million hectare of mangrove cover, Indonesia alone hosts one fifth of the world's mangrove in 2001. Malaysia is a close second, with more than half million hectare under mangrove. Globally, frost frequency and severity as well as minimum temperature requirements limit poleward expansion of this tropic-adapted group of vegetation. Hence, global warming may give mangrove the window of opportunity to migrate poleward in the coming decades.

Ecosystem Services of Mangroves

These highly productive mangrove ecosystems provide a myriad of invaluable ES to human, wildlife, and the habitats they occupy. The ESEV of mangroves has not been adequately recognized nor properly assessed (Barbier et al. 2008). The provision as habitats for diverse fauna such as fish, birds, reptiles, and shellfish is probably the most acknowledged. Mangroves provide nursery habitats for juvenile coral reef fishes of many species. The prop roots of *Rhizophora* provide structural heterogeneity that is favorable to both fish prey attempting to avoid predators and to predatory fish searching for invertebrate prey hiding within the root structures. Mangroves also serve as sinks for carbon, through accumulation of living biomass and through litter and deadwood deposition, as well as the trapping of organic sediments delivered from the uplands. Carbon in mangrove sediments does not turn over in the same way it does in terrestrial soil, because it builds up vertically in response to SLR, offering a mechanism to combat SLR (McLeod et al. 2011). However, their recognition as carbon (C) sequestration and carbon burial, helping to regulate CC, is more recent (Donato et al. 2011). Mangrove forests serve as effective long-term C storages and as agents for mitigating urban C emissions in populous tropical SE Asian estuaries. Alongi (2009) reported a typical carbon burial rate for mangroves at 181.3 g C m^{-2} $year^{-1}$. Mangrove forests in tropical SE Asia are some of the most C-rich forests in the world (Donato et al. 2011), storing ~40% of their net C production underground as long-term C sinks. By comparison, agriculture, aquaculture, and urban settlement typically have extremely fast C throughput (e.g., through conversion of leached labile organic C into CO_2 via bacterial respiration) but negligible C storage capacity. Mangroves have been shown to provide protection to shorelines from persistent erosion caused by the ubiquitous tidal currents (Mazda et al. 1997). They reduce the damage inflicted by frequent storms and waves (Horstman et al. 2014). They provide some protection from lower intensity tsunamis, hurricanes, and cyclones (Alongi 2008). By dissipating incoming wave energy, they are particularly effective in flood defense against lower category hurricanes (Zhang et al. 2012).

By removing organic and inorganic nutrients from the water column, mangroves enhance water quality and inhibit eutrophication. Mangroves serve as a nutrient sink. Denitrification in the anaerobic environment and nitrogen fixation by certain bacteria and cyanobacteria associated with mangrove mud and with aboveground root systems can improve water quality from wastewater inputs. Their dense root-trunk systems slow down flow and enhance sediment deposition. The ESEV of mangroves needs to be adequately and systematically quantified for inclusion in policy decision beyond mere advocacy. ESEV has increasingly been developed and utilized in conservation management and policy decision. Consistent with the Millennium Ecosystem Assessment concept (MA 2005), ES is defined broadly as the well-being provided to humans by natural ecosystems. Therefore, ES must be evaluated through their linkage with human well-being and social-economic-cultural values. The process of placing monetary value on goods and services that do not have accepted market prices has always been a difficult process (Himes-Cornell et al. 2018). Many environmental goods and services, such as biodiversity, do not enter the traditional market and therefore have no commonly accepted market prices. ESEV provides useful narratives about the social-economic-cultural benefits and costs associated with alternative coastal policies. It facilitates the assessment of the trade-offs and synergies inherent in ecosystem-based management and policy. An estimated ESEV in the order of USD2000–9000 ha^{-1} $year^{-1}$ has been suggested (UNEP-WCMC 2006). The mean and median values of ESEV, in 2007 prices, for mangrove ecosystem services in SE Asia are estimated at USD4185 ha^{-1} $year^{-1}$ and USD239 ha^{-1} $year^{-1}$, respectively. This vast difference in ESEV reflects high variability across study sites due to vast variations in the biophysical characteristics of the site and the socioeconomic characteristics of the beneficiaries of ES including GDP (Brander et al. 2012).

Rehabilitation of Abandoned Fishponds in SE Asia

Vast tracks of mangroves in SE Asia have been lost in the past several decades, mostly to mangrove clearance to give way to shrimp cultivation. Many of these aquaculture ponds were abandoned when they were no longer commercially viable after several years of operation. Some of these abandoned former fishponds were subsequently converted back to mangrove areas. The pros and cons of these rehabilitations are constantly debated from various perspectives, including policy and community engagement. Duncan et al. (2016) evaluated the potential of carbon storage and coastal protection provided by rehabilitated fishponds in the Philippines. The study sites covered areas from the low-intertidal seafronts to the mid- and upper intertidal zones previously occupied by abandoned fishponds. For areas with large sizes and appropriate site conditions, reversion of abandoned fishponds back to mangrove was found to be favorable for enhancing ES. To combat mangrove losses, and to enhance CCMA efforts in SE Asia and elsewhere in the tropics, rehabilitation has become an essential CCMA management tool (Primavera et al. 2012). The blue carbon-based schemes of payments for ecosystem services (PES) projects related to rehabilitated mangroves are emerging (Wylie et al. 2016), and governments are increasingly recognizing the significance of mangrove ESEV in carbon stocks and coastal protection. There are two major potential sources of variation in the ability of rehabilitated mangroves to deliver high CCMA ES. Firstly, the low-intertidal seafront areas have sub-optimal hydrological conditions that limit survival and growth of replanted mangroves (Primavera and Esteban 2008). Rehabilitation in such areas may result in low mangrove biomass and low density, contributing to low associated carbon stocks and low coastal protection potential, particularly in areas where rehabilitation failure has historically been high. Secondly, rehabilitated mangrove carbon stocks are expected to increase linearly with site area, while coastal protection potential increases exponentially with mangrove greenbelt width (Koch et al. 2009). This is because wave energy reduction increases exponentially with the mangrove greenbelt protection width (Koh et al. 2009; Teh et al. 2009). Larger rehabilitation sites in the middle to upper intertidal zone may thus be expected to deliver much higher multiple CCMA ES benefits than narrow, low-intertidal rehabilitated mangroves. In short, C-rich sediments and large areal coverage of rehabilitated mangrove areas would enhance the overall carbon stocks and coastal protection potential of rehabilitated fishponds in the Philippines and throughout SE Asia (Duncan et al. 2016).

However, the area with available land suitable for mangrove rehabilitation is often constrained by land tenure conflicts in the coastal zone in the Philippines. Similarly, reversion of abandoned fishponds for mangrove replanting is difficult in Guangdong and in most of southern China, because of unresolved land tenure issues due to the ownership of massive ponds being held by numerous private stakeholders (Peng et al. 2016). Nevertheless, restoring mangroves and semi-mangroves in abandoned ponds is feasible in most nature reserves in Guangdong and southern China (Peng et al. 2013). To restore such abandoned fishponds successfully would require the restoration of the altered hydrological conditions back to the normal condition with suitable salinity and sedimentation regimes needed by mangroves. The mangrove plantations with introduced species currently account for approximately 16% of the total mangrove area in China. Their fast growth and high adaptability of introduced species ensure their continuing expansion in the future. But this "artificial" growth has aroused much criticism over the long-term ecological impacts on native mangroves. Further, such mangrove "plantations" tend to be dominated by low diversity, often with only one or two dominant species. From ecological perspective, mixed-cultured mangroves with higher diversity are preferred as they can deliver higher ES and higher carbon sequestration potential (Chen et al. 2012) in addition to improved nursery functions. Further, mixed mangrove cultures are also more resilient to human and natural perturbations due to their intrinsic "portfolio effects" of diversification.

Property rights have profound consequences for the patterns of resource use and management. Land tenure is a critical factor in how people manage and use the resources. The changes in land use over time and willingness to participate in rehabilitation efforts are related to these. In Vietnam and Thailand, the local people's interest in participating in mangrove reforestation was severely constrained by the lack of land ownership by the local people. Tenants with limited ownership rights and poor farmers were unwilling to invest in mangrove management and opted for short-term economic benefits from shrimp aquaculture. In South Sumatra, there has been some resistance among the local people to the replanting of mangroves because the status of the trees would revert the land back to the government once the trees become productive. This is unacceptable to the local community members that are currently making a living in these areas.

Loss of Mangrove in SE Asia

About 50% of the world's population now live within the coastal zone with most of the world's megacities (>10 million population) located near or in major estuaries (Martinez et al. 2007), where mangroves are mainly located. Because of intense anthropogenic activities around the estuaries, around half of total global mangrove coverage has been lost since pre-industrial times (Giri et al. 2011). Many SE Asian countries now support less than 50% of their original mangrove resources 50 years ago. The percentage loss of original mangrove areas in countries in SE Asia based upon data available in WRI (1996) are as follows in descending order: Thailand (87%), Singapore (76%), Vietnam (62%), Myanmar (58%), Indonesia (45%), Malaysia (32%), and Brunei (17%). This suggests that restoration of mangroves in SE Asia is an important contribution to worldwide effort in CCMA. The different quantities and qualities of organic carbon in the disturbed tropical estuaries may affect the remaining mangrove and could result in fundamental shifts in ecosystem dynamics and could impair their ability to sustainably provide beneficial ES. Large-scale extraction of water from catchments for domestic, agricultural, and industrial uses in virtually all countries in SE Asia affects habitat hydrological connectivity. Disruption of hydrological connectivity is a main factor causing mangrove forests to currently disappear at an alarming annual rate of 1% globally. The "blue carbon" source in the major estuaries in the tropical SE Asia would normally be dominated by mangrove-derived carbon, as the turbidity and low salinity due to riverine discharge would suppress contribution from seagrasses or the marine phytoplankton, the other major components of coastal blue carbon (Fourqurean et al. 2012). The loss of mangroves would therefore have severe impact on the blue carbon ES valuation in mangrove-disturbed areas and would therefore impair CCMA achievement.

Regulation of access to and use of natural resources such as mangroves, forests, fisheries, aquaculture, and agricultural lands in SE Asia have historically been weak. The pervasive regulatory and institutional weakness in managing mangrove utilization and exploitation in many countries in SE Asia is a contributing factor to this rapid loss of mangrove worldwide. In the recent past decades, many of these resource-abundant countries in SE Asia (e.g., Indonesia, Vietnam, Laos, Cambodia, and Myanmar) have become highly resource-dependent, heavily relying on aquaculture, agriculture, fisheries, timber, and other extractive industries that exploit natural resources. Several empirical studies of a cross section of developing countries suggest a negative relationship between measures of institutional quality and deforestation rates (Ferreira 2004). In countries where such institutions are stronger, the likelihood of resource overexploitation is lower. Malaysia and Thailand are countries making good progress toward robust governance institutions in governing resource exploitation. In Vietnam where the institution is weak, shrimp farming area alone has more than doubled since 1995 to more than 530,000 ha to support seafood exports accounting for 15% of the value of non-oil exports. The conversion of coastal mangrove forests, estuaries, and lagoons for intensive shrimp farming in Thailand, Indonesia, Vietnam, and elsewhere is aided by weakness in the "tragedy of open access" (Coxhead 2007), in countries with weak regulatory institution. Improving socioeconomic status in SE Asia should give a boost to strengthening regulation and institution in this region. This would upgrade the ES provided by mangroves overall and effectively contribute to CCMA in SE Asia.

Mangroves were reported to occupy 18 million ha worldwide (Spalding et al. 1997), but this was revised downward to 14 million ha (Giri et al. 2011), and then to 8 million ha (Hamilton and Casey 2016). Concurrently, the estimated area of tidal marshes associated with mangroves has decreased from 165 million ha in 1997 to 128 million ha in 2011. Indonesia had lost more than 200,000 ha of its mangroves by the 1960s, followed by another 800,000 ha being lost in the subsequent three decades, mainly in Java, Sumatra, Kalimantan, and Sulawesi. Over the following two decades, shrimp farming known as "tambak" in Indonesia and the timber industry cleared another 600,000 ha of mangroves (Ilman et al. 2016). The vast decline in mangrove coverage in Indonesia is another example of the consequence in weak regulatory institution and the curse of the "tragedy of open access." Following the global declining trend of mangrove loss (Alongi 2002), in part due to conservation and improving regulatory institution, the net loss of mangroves in Indonesia in the coming two decades is anticipated to be reduced to around 23,000 ha (Ilman et al. 2016). Promotion of sustainable mangrove conservation and its integration with human livelihoods is thought to lead to long-term sustainability of mangrove forests throughout Indonesia, Thailand, Vietnam, and the wider world. Improving policy framework and regulatory institution in SE Asia gives a ray of hope for sustainable mangrove conservation.

Threats to Mangroves in SE Asia

Mangrove forests in SE Asia and worldwide have been threatened by many forms of anthropogenic encroachments such as conversion of mangroves to agriculture (traditionally rice) and aquaculture (notably shrimps) and unsustainable harvesting of mangroves for timber, food, fuel, fibers, and medicine. Further, sustained environmental stresses due to CC and influx of sewage and industrial effluents containing high metals and organics contents will affect the health of the mangrove ecosystem. Where the mangrove sediment surface levels are not keeping pace with sea level rise (SLR), warming climate and its associated SLR will pose the greatest threat to mangroves. The greatest impact of SLR on mangroves will take place where the area for landward migration is limited. Most of coastal regions in SE Asia fall under this category with limited space for landward migration of mangrove due to very high human settlements. In such SE Asia coastal areas, there are speculation that mangrove may face collapse if confronted with SLR in the order of 1.0–2.0 mm per year over an extended period of decades. However, this speculation has not been duly substantiated by adequate data. On the other hand, mangroves may move inland if the pace of SLR and other environmental and hydrological conditions are suitable. Most coastal regions in SE Asia do not appear to have such benign endowment, with dire consequences under CC worst-case scenarios. On the other hand, mangroves in the Key West of Florida have shifted in land by 1.5 km since the mid-1940s under a SLR regime of 2.3–2.7 mm $year^{-1}$ (Ross et al. 2000). Globally, however, mangroves appear to keep pace with SLR, because average sedimentation rates are in equilibrium with mean SLR rates.

Underestimation of the total ESEV of mangroves and of the impacts of human activities is a major factor contributing to the widespread loss and degradation of mangrove ecosystems (Gilbert and Janssen 1998). Global warming could be a significant threat to mangrove cover and biodiversity. Rising seawater (because of melting ice caps and thermal expansion of seawater) could drown coastal mangrove. The presence of existing aquaculture, agricultural, and urban development and dikes would in many cases prevent the establishment of new mangrove areas. Projected CC could have other effects, such as changes in ocean currents, salinity, and surface temperatures. These would alter the species compositions and perhaps trigger local and global extinction. Many of the problems and causes for mangrove loss stem from failures in policy regarding land ownership. Reserved land should be allocated for the protection of mangroves. The usual requirement is a minimum of 100 m. But reserve belts of up to 500 m at the open coasts have been advocated for the Mekong Delta in Vietnam and elsewhere, which is subject to typhoons, and 50 m along riverbanks (Macintosh and Ashton 2002). The ecological links between habitats consisting of water catchment areas, mangroves, seagrasses, and coral reef connectivity should be maintained.

Mangrove Restoration and Conservation in SE Asia

The effect of unconstrained human intervention, poor socioeconomic conditions, and limited knowledge on mangrove ecology pose enormous challenges for mangrove restoration in SE Asia. The SE Asian coastal areas are highly populated with the poor and marginalized people, who depend heavily on mangroves for their subsistent livelihood. Because of this dependency, people and local community become a major determinant of the state of mangrove forests and its conservation or restoration. Historically, community participation in mangrove restoration in SE Asia has been weak, often leading to undesired consequences that pose detrimental impact on restoration progress down the road. With few exceptions, most mangrove restoration efforts in SE Asia have followed a trial and error method without any explicit and integrated framework. Lacking baseline ecological information and proper consideration of community involvement, most of the mangrove restoration efforts have met with limited success (Ellison 2000). Mangrove ecology, nature of disturbance, hydrology, and the local community well-being are the primary determinants for mangrove restoration success. Restoration of SE Asian mangroves demands special attention for social and economic issues (Bormthanarat et al. 2007). It is essential to incorporate science and traditional community ecological knowledge in management of natural resources, made possible by a thorough understanding of the driving forces behind community participation. Viability of a system will depend on sufficient economic returns to the community from the restoration. It is important to assign ownership rights to the community to encourage active participation in the restoration program (Biswas et al. 2008). The long-term ecological integrity of the mangrove forests depends on achieving and sustaining three criteria: (i) species diversity, (ii) vegetation structure, and (iii) ecological functions (Ruiz-Jaen and Aide 2005). First, the forests must harbor sufficient mangrove species diversity to improve resilience to human and natural disturbances due to the portfolio effects of species diversity. Second, the mangrove vegetation structure must be robust to enable the mangrove to function as a group. Third, the entire ecosystem comprising the mangroves and their associated sub-ecosystems comprising the seagrasses, the corals in the deeper water, as well as the marshes in the upland must possess complimentary ecological functions that allow them to support each other.

Mangrove systems are diverse at the ecosystem level, although the mangrove plant species themselves are not biodiverse. At the species and ecosystem levels, the following two conditions are critical to the success of mangrove biodiversity conservation: (a) protection of mangrove forest habitats, especially mixed species forests, and (b) preservation of the natural hydrological regime operating throughout the ecosystem. Most mangrove conversion in SE Asia usually leads to initial short-term economic gain but at the expense of greater and longer-term ecological benefits and off-site values. This undesirable situation is a consequence of not giving proper ESEV to the mangrove ecosystem, by either ignoring nonmarket valuation or awarding low valuation. The nonmarket values, for example, of species biodiversity, and off-site functions such as nutrient export and hydrology, are not easily quantified, although they have been shown qualitatively to be significant. In SE Asia, these valuations are conveniently ignored. Long-term ecological benefits and off-site values should be included in ESEV of mangroves, including the functioning of adjacent ecosystems, such as terrestrial wetlands, peat swamps, saltmarshes, seagrass beds, and coral reefs. Awarding proper recognition and designation to mangrove would help to create awareness, strengthen education, enhance community engagement, and justify government commitment on the importance of mangroves in CCMA strategies. Commitment to national parks, nature reserves and gazetted forests at national level, and commitment to Biosphere Reserves, Ramsar sites, or World Heritage Sites at the international level would enhance mangrove conservation and restoration achievements. As much as possible, mangrove restoration should actively involve the local communities who live in the mangroves and utilize the resources. They are in some sense the beneficial "owners" of these mangroves. Experience has shown that local communities have little prospect of improving mangrove management on their own efforts alone because of their limited scientific and technical knowledge and skills. But with support from NGO, government agencies, and local authorities, communities will develop a sense of unity and common purpose and can influence policy and management decisions to the common benefits. Macintosh and Ashton (2002) have suggested that the following activities should be planned and budgeted for in any mangrove restoration project: (1) site selection including detailed assessment of the hydrological conditions; (2) species selection and tree spacing, thinning, and maintenance criteria established; (3) a forest protection and monitoring system developed; and (4) a public information and awareness program incorporated in support of the restoration effort. Unfortunately, in most restoration projects undertaken in SE Asia including Malaysia and Thailand, in the past, some or most of these activities are not fulfilled, resulting in incomplete or failed restorations.

Two Examples of Successful Mangrove Conservation in SE Asia

In many SE Asian countries, federal and local governments have devoted significant resources to creating awareness, strengthening education, and enhancing community engagement for the restoration and conservation of mangroves. These successes contribute to the achievement of CCMA strategies in the region.

Matang Mangrove Forest Reserve (MMFR) in Malaysia

Sustainable management of mangrove has been achieved in the MMFR for the past 100 years. With an area of 40,000 ha, MMFR was created as a permanent forest reserve in 1902, to produce charcoal, firewood, and poles. The silvicultural operation runs on a 30-year rotation cycle with thinning at 15 and 20 years intervals. The forest is subdivided into blocks of a few hectares each and managed in such a manner that they are always surrounded by mature forests to facilitate repopulation with mangrove propagules. Local communities are contracted to cultivate suitable seedlings in small nurseries for this purpose. *Rhizophora apiculata* is the preferred species for charcoal and is planted at 1.2 m intervals. After 15 years the young trees are thinned to 1.2 m intervals to prevent overcrowding, with the timber so removed used for fishing poles. After 20 years the trees are again thinned to 1.8 m intervals and the removed timber used for the construction of village houses. Finally, after 30 years, the block is clear-felled for charcoal production (Gan 1995). Well known for its fireflies, MMFR rich and diverse flora and fauna attract nature lovers to visit and explore the wetlands.

Can Gio Biosphere Reserve in Vietnam

There are nine designated biosphere reserves in Vietnam. Designated in 2000, the Can Gio Mangrove Biosphere Reserve is in the coastal district southeast of Ho Chi Minh City. With an area of 75,740 ha, Can Gio encompasses diverse habitats including mangroves, wetlands, salt marshes, mud flats, and sea grasses. It functions as the “green lungs” of Ho Chi Minh City, absorbing carbon dioxide and other polluting agents and providing green space for recreation and relaxation. It hosts the highest biodiversity of mangrove floral and faunal in the subregion, consisting of plants, invertebrates, fish, and shellfish, as well as exotic creatures such as king cobra, saltwater crocodile, and fishing cats. Catering to a variety of activities such as hiking, bird watching, fishing and boat cruises, the mangrove ecosystems are a popular tourist attraction for locals and foreigners. It is easily accessible by road and ferry from Ho Chi Minh City.

Conclusion

The CCMA issues in SE Asia are examined in this entry with a focus on the role of mangrove. Rising temperature, elevating sea levels, and increasing frequency and intensity of extreme coastal storm events have cast severe consequences to coastal populations and ecosystems. Having large populations living near to low-lying coasts in addition to poor socioeconomic conditions, SE Asia is particularly vulnerable to these impacts of CC. Decreasing precipitation exacerbates water insecurity, adversely affects agriculture production, and accelerates forest degradation, particularly the mangroves. Mangroves provide numerous ES by supplying natural resources such as timber and fuel wood (provisioning services); by controlling erosion, flood, and storm (regulating services); by being dominant primary producers (supporting services) in tropical coastal marine environments; by providing aesthetic, recreational, and tourism value (cultural services); and by providing habitats for birds and various marine species (habitat services). Threats to mangroves’ long-term survival in SE Asia are aplenty, from traditional human overexploitation to other major natural disturbances. With around 50% of mangrove forests lost in the past 50 years, SE Asia should put priority on efforts to prevent further loss, encourage reforestation, and promote sustainable mangrove forest management. Mangroves play an important role in both CC mitigation (e.g., through the sequestration of carbon) and adaptation (e.g., through stabilizing shoreline erosion, reducing storm surges, and preventing inland soil salinization). Conservation of forests and mangroves will undoubtedly contribute to SDG 13 in reducing GHG and in helping to contain the "epidemic" of global warming.

Multi-stakeholders should remain wary of the grave CC challenges confronting SE Asia and its mangrove ecosystems. Deliberations for incorporating CCMA measures into national coastal zone development policy and processes must be characterized by collaborative engagement among government, business, and civil society. SE Asian countries must incorporate CCMA as an essential part of SDGs to minimize the costs already locked into the climate system and to build resilience against future climate shocks. Many countries are introducing green fiscal stimulus that creates jobs, shores up economies, and reduces poverty, all of which create opportunity for CCMA. In SE Asia, incidence of poverty remains very high and will continue to pose a daunting challenge to achieving CCMA and the broader SDGs, unless effective actions are taken to reduce poverty. Rapid economic growth in past decades has, however, lifted millions of people out of the extreme poverty in SE Asia. Robust education and improving socioeconomic conditions in SE Asia offer some comfort to the belief that CCMA and SDG in SE Asia would help to arrest the continuing decline in mangrove coverage in SE Asia. Endowed with improving socioeconomic capitals, SE Asia has the capability and responsibility to forge ahead a long-term program to achieve the goals of CCMA and SDGs. Key elements of CCMA and SDGs include (a) adapting water management to mitigate increase risk of floods and droughts, (b) adapting integrated coastal zone management to counter higher sea levels, and (c) protecting forests from fires and degradation. The fundamental principles of the SDGs can be traced to the Brundtland report that proclaimed that sustainable development is "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987). Let us look forward to a future in which our children will look back with appreciation for our foresight and actions.

Cross-References

- ▶ Adaptation and Mitigation Synergies and Trade-offs
- ▶ Climate Change Adaptation (CCA)
- ▶ Climate Change Effects on People's Livelihood
- ▶ Climate Change Impacts and Resilience: An Arctic Case Study
- ▶ Climate Change Mitigation
- ▶ Making Communities Resilient to Global Climate Change
- ▶ Vulnerable Communities: The Need for Local-scale Climate Change Adaptation Planning

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Climate Change Planning: Understanding Policy Frameworks and Financial Mechanisms for Disaster Relief

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Definitions

Climate Change has been broadly defined by the Intergovernmental Panel on Climate Change (IPCC) as "any change in climate over time, whether due to natural variability or as a result of human activity" (IPCC 2014). Consistent with this definition, the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (United Nations 1992).

Climate change **mitigation** refers to the efforts to prevent or reduce the emission of greenhouse gases into the atmosphere by incorporating the use of new technologies and renewable energies, increasing energy efficiency, or changing management practices or consumer behavior (IPCC 2018). Climate change **adaptation,** on the other hand, is the adjustment in natural or human systems (social or economic) in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC 2001). Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC 2018).

Introduction

The definition of climate change planning is important, especially in the context of government's policies and actions at the regional and local levels. Traditionally, the definition of climate change planning was largely influenced by the view that either changes in climate are due to natural climate variability or, in contrast, as a result of human activities. What is important, however, is the increasing recognition that the geographic location of a community alone is no longer an adequate indicator of a community's susceptibility to climate change impacts. For example, coastal communities were traditionally considered to be locations most vulnerable to climate change hazards due to sea-level rise and increased storm surges; however, some communities located inlands are facing an increased level of precipitation, which has led to an increase in frequency of overland flooding (Henstra and Thistlethwaite 2017).

While the discussion of what is the root causes of climate change may continue, what is becoming clear from a planning perspective is that government policies with respect to climate change planning must be better informed. Moreover, such policies must provide for the level and type of mitigation and adaptation measures necessary to address diverse community challenges.

National governments have traditionally provided the lion's share of funding for disaster relief, and therefore wielded significant influence over the direction of climate change policies. However, as funding levels are stressed in the face of increasing natural disasters, national governments are increasingly shunting responsibilities to regional and local governments (e.g., Kettle and Dow 2014), as well as nongovernment actors, such as the private sector. As climate becomes more variable, the importance of incorporating climate change into strategic planning increases in importance. Indeed, as evidenced in scholarship, governments are beginning to appreciate the value of programs that combine mitigation and adaptation approaches (e.g., Bulkeley and Tuts 2013).

To understand the mitigation and adaption planning measures taking shape at a range of scales, the following discussion presents a review of key global and national policy frameworks. The discussion highlights the importance of context and funding programs.

Frameworks on Climate Change

International Frameworks on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) was formed in 1992 as a framework for international cooperation to combat climate change. There are 197 Parties to the UNFCCC Convention. Since 1992, three significant international agreements on climate change have been entered into with the similar goal of reducing greenhouse gas emissions.

The first protocol linked to the UNFCC climate change initiative was the Kyoto Protocol, which was adopted in 1997 and entered into force in 2005. The Protocol has 192 Parties and their first set of commitments commenced in 2008 and ended in 2012. The second period commenced in 2013 and continues to 2020 (UNFCCC 2018b).

In November 2016, 174 countries signed on to the Paris Agreement, signaling a significant wave of international cooperation on climate change and marking the latest step in the evolution of the UNFCC. One of the key objectives of the Paris Agreement is to "strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change" (UNFCCC 2018a).

Canada's Framework on Climate Change

Canada is one of the 175 signatories to the Paris Agreement and has made the commitment to meeting or exceeding the 2030 target of a 30% reduction below 2005 levels of greenhouse gas (GHG) emissions (Canada 2017). The implementation of Canada's international commitments on climate, however, is fundamentally an exercise of cooperation among the federal, provincial, and territorial governments and in consultation with Indigenous peoples. This cooperation is necessary and in accordance with the division of powers between the federal government and the provincial governments as set out in the Canadian Constitution (Constitution Act 1982) and the agreements between the federal government and the territorial governments or Indigenous peoples.

In the context of Canada's division of powers, the Government of Canada sought cooperation with provinces and territories to develop and implement the Pan-Canadian Framework on Clean Growth on Climate Change. The development of this Framework was carried out in consultation with Indigenous peoples.

A key measure under the Framework is to implement a price on carbon pollution. The policy objective of the measure is to direct and guide individual businesses and households to seek out measures to increase efficiencies and to pollute less. It should be noted that energy production and use account for over 80% of Canada's GHG emissions (Canada 2016a). As a result, the transition to a low carbon future will likely require significant investments in clean energy to power households, transportation, and industries as well as policies to encourage more efficient use of energy.

To strengthen the cooperation at the national level, the Government of Canada bolstered the Framework with the promise of financial investments for public infrastructure at the regional and local levels. However, in order to access federal infrastructure funding, provincial and territorial government applicants are required to demonstrate that their proposed projects integrate specific emission-reduction opportunities and the adaptation of clean technologies.

Financing Disaster Relief

Financing Disaster Relief in Canada

The Government of Canada provides financial assistance to provincial and territorial governments through a program called the Disaster Financial Assistance Arrangements (DFAA). This assistance is provided to the province or territory when their individual responses and recovery costs exceed the established thresholds of the DFAA. When the DFAA is triggered, the amount of assistance available to the province or territory in question is assessed based on eligible expenses and is calculated by a predetermined formula (Public Safety Canada 2017).

Since the inception of the program in 1970, the Government of Canada has paid out more than $3.4 billion in postdisaster assistance to help provinces and territories with the costs of response and of infrastructure and personal property rehabilitation (Canada 2016b). The increase in demand for federal government assistance is notable in the change of the program's average of $118 million per year for the period of 1996–2011 to $280 million per year in the period of 2012–2015. The average far surpassed the program's initial $100 million budget.

As a response to the growing demands for funding under the DFAA, changes were made to the program with the overall effect of reducing the level of available federal assistance for disaster relief. One of such changes is to the expense thresholds at which federal funding is triggered: the threshold was raised from $2 per capita to $6 per capita. With costs estimates of flood losses projected to increase to more than $650 million annually over the next 5 years (Henstra and Thistlethwaite 2017), it is inevitable that the additional pressures will be placed more squarely on the provinces and territories as well as local governments.

Financing Disaster Relief in the United States

Equivalent to Canada's DFAA, the United States has the National Flood Insurance Program (NFIP), which was created in 1968. Administered by the Federal Emergency Management Agency (FEMA), the stated goal of the NFIP is to help people in flood-prone areas get insurance for their properties and reduce the impacts of flooding.

Historically, the NFIP was limited to using flood insurance premiums, available surplus, and borrowing capacity from the US Treasury; in limited circumstances, direct appropriations from Congress have been made to pay flood claims. However, the increase costs associated with natural disasters and subsequent increase in property insurance premiums have led to many individuals opting out of coverage. Consequently, many residents have been left vulnerable to responding to natural disasters and the aftermaths on their own (FEMA 2018).

Recent disasters, such as hurricanes Katrina, Rita and Wilma, resulted in the United States Congress increasing the level of borrowing to pay claims in the aftermath of the 2005 hurricane season (King 2008). Hurricane Sandy in 2012 resulted in a further increase in FEMA's borrowing limit to $30.425 billion and helped push the flood insurance program into significant deficit, namely, an approximate $24 billion debt (American Academy of Actuaries 2017). While costs associated with the 2017 hurricane season are not yet finalized, FEMA has already paid over $8.2 billion in claims for Hurricane Harvey alone (Horn 2018). As a result, there are growing pressures to curtail repeat claims under the program, while encouraging more private insurance involvement.

In face of the enlarging debt, without any immediate solutions to solve the growing pressure, discussion surrounding the program's fate suggests the possibility of ending the federal flood insurance program for new construction in areas most at risk of flooding (Flavelle 2017).

Increasing Financial Pressures on Relief Programs

National programs in Canada and the United States, such as the Disaster Financial Assistance Arrangements and the National Flood Insurance Program, are experiencing significant financial pressures due to the increase in size, and frequency of natural disasters attributable to climate change.

Programs and associated funding levels that were originally designed for disasters occurring once every hundred years are now being triggered at rates three to four times more frequently within the same period. Moreover, climate projections suggest increasing risk moving forward (e.g., Wu et al. 2018). Disasters that occurred typically every two or three hundred years are occurring in rapid succession and, as a consequent, imposing more stress on the already burdened programs.

Government's response, as in the case of Canada, has been to change program qualification thresholds. The result is a decrease in government's overall financial assistance for natural disasters, and increased costs that must be borne by the affected parties, including municipalities most vulnerable (Henstra and Thistlethwaite 2017).

National Influence in Climate Change Planning

In Canada, the provincial and territorial jurisdiction, except for the Territory of Nunavut, has autonomy over land-use planning, including the responsibility and legislative powers to direct planning actions. As a result, the ability of the federal government to influence municipal planning is generally tied to funding agreements.

An important example of federal funding agreement is the Federal Gas Tax Fund. Under this federal program, the Government of Canada is committed to providing a permanent source of funding to provinces and territories, which individual jurisdictions then transfer to their municipalities to support local infrastructure priorities.

The initial Gas Tax Funding Agreements required many provincial and territorial local governments to develop Integrated Community Sustainability Plans (ISCPs). The plan is required to be developed in consultation with community members and generally provides long-term direction for the communities to realize their sustainability objectives with respect to a broad range of environmental, cultural, social, and economic issues. Pickets et al. (2014) identified the general statements of objectives and the lack of a clear definitive policy as a potential weakness of the ICSPs.

Effectively, the communities decide how to spend the guarantee by selecting what programs or area of services to direct the funding. Under this approach, the communities can make investments across 18 different project categories, including public transit, wastewater infrastructure, brownfield redevelopment, disaster mitigation, and community energy systems (Infrastructure Canada 2018b).

In 2014, however, the Gas Tax Funding Agreements were renewed with an emphasis on cooperation between the jurisdictions. In particular, under the new Agreements, all signatories must agree that a priority of the funding must be directed to strengthening local governments' capacity to undertake asset management (Infrastructure Canada 2018a).

Impacts on Local Governments

Climate change will continue to occur as a result of the accumulation of greenhouse gases already in the atmosphere, regardless of mitigation measures currently underway; this has, as a result, emphasized adaptation as a necessary measure in the immediate and longer-term (e.g., Bosello et al. 2010). Although climate mitigation is the long-term solution to address the effects of climate change, and indeed has been the focus for many governments around the world (e.g., Birchall 2014, 2017), undertaking adaptation measures have become a necessity for local governments (Picketts et al. 2014; Birchall and Bonnett in review). To be sure, adaptation is particularly relevant at the local scale, where communities are at the forefront of climate impacts (e.g., Forino et al. 2017).

However, a policy choice to combat climate change that is heavily reliant on adaptation, without striking a balance with mitigation measures, may result in less effective adaptation strategies. Effectiveness in this context is in relation to the potential costs of the strategies, including social, environmental, and economic costs (Hamin and Gurran 2009).

Although climate change adaptation and mitigation planning are relatively new concerns to local governments, these measures have much in common with planning processes currently applied in the development of municipal land use plans. For example, planning for climate change actions are similar to local land use planning in that both exercises start with the collection of relevant environmental (including natural hazard mapping), cultural, social, and economic information.

In particular, climate change planning encompasses many activities that may be best viewed from the perspective of the responsibilities of, and associated actions, at the local or regional levels of government to plan for natural hazards (Berke and Stevens 2016; Stevens and Senbel 2017).

Generally, mitigation planning requires the creation of a local GHG emissions inventory, containing information and data on the quantity and source of local GHG emissions (Birchall 2014). The information would be reviewed and transmitted to form the baseline for projection of potential future emission levels. The emissions inventories also provide a baseline from which to measure progress on the implementation of local plans. Without access to this information, municipalities are limited in making informed decisions regarding how best to reduce their emissions in an effective way (Stevens and Senbel 2017).

Adaptation planning requires a proactive approach in order to better prepare a community in responding to an extreme weather event, which may include providing support for rapid recovery and helping reduce future risk. Planning for climate adaptation should benefit from the extensive collection of information and data used to plan for natural hazards, including information on local hazards, such as sea level rise, wildfires, overland flooding, and drought. It goes without saying that planning exercises should be based on the best and most current information available (Berke and Stevens 2016).

Despite the reality of increasing demands for climate change planning, many local governments working towards the adoption and implementation of adaptation measures are coming up against barriers, including the lack of adequate resources, and an increase of responsibilities being downloaded from senior levels of government (Birchall and Bonnett, in review). The barriers to local governments are further exacerbated by the competing political priorities and capacity related challenges (Picketts et al. 2014; Antonson et al. 2016). One way of addressing these barriers is to encourage an approach to climate change planning that incorporates adaptation and mitigation measures into existing plans and planning processes. Integrating climate change considerations into the decision-making process by including climate change adaptation and mitigation measures in local planning documents is not an overnight process (e.g., Kithiia and Dowking 2010). However, with the recognition that climate change planning is necessary and must inform local government's planning decisions, the process of updating the official community plans can quickly become an intuitive exercise for all local governments.

Land use planning has been identified as one the most effective processes to facilitate climate change adaptation efforts with preventative land use planning as the most promising long-term solution to mitigating the negative effects of climate change hazards. Local governments have used land use planning tools such as official plans, zoning, and development permits to minimize risks due to floods, wildfires, landslides, and other hazards. These tools are also critical to guide growth beyond the current and forecasted geographical areas vulnerable to natural hazards (Richardson and Otero 2012; Gerber 2015; Berke et al. 2015).

Smart Growth

Smart Growth has been identified as an important step towards achieving climate change mitigation goals by supporting denser housing and services near transit stations, taking advantage of compact building design, creating walkable neighborhoods, and preserving open spaces. Under smart growth strategies, local land use policies must limit sprawl and create denser forms to mitigate greenhouse gas emissions, while maintaining urban forests where possible (Hamin and Gurran 2009).

A growing number of local governments are incorporating smart growth principles into their climate change plans. Some of the principles developed by the Smart Growth Network, which are based on the experience of American communities that have used smart growth approaches to create and maintain neighborhoods, can support climate change adaptation planning. For example, principles supporting the preservation and enhancement of green spaces, the integration and harmonization of adjacent regions, and towns, effective community engagement, and implementation of planning strategies are principles that can support climate change planning and smart growth outcomes.

Smart Growth principles have been the hallmark of good planning practice. These principles are being considered by a growing number of local governments as they review and update their official community plans. Smart growth principles also offer local governments practical guidelines in addressing both climate change mitigation and climate change adaptation plans. As Hamin and Gurran (2009) note, one of the challenges of incorporating climate change planning is the potential conflict in land use policies that support both adaptation and mitigation measures. Local governments therefore need to ensure that any actions in support of adaptation do not detract from mitigation efforts.

Incorporating smart growth principles, community hazard mapping, and rebuilding in areas less prone to climate change impacts should be a priority. The resulting effect is often the recommendation that residents not rebuild in areas prone to natural hazards. Other smart growth principles can also be used to advance climate change planning with a focus on mitigation, such as smart building designs which incorporate the use of green building technologies, the use of green infrastructure to save money and protect the environment, and transportation options that support diverse transportation alternatives such as cycling and public transit options.

Tough Choices Ahead

The frequency and intensity of natural disasters are impacting every aspect of our lives, especially our societies, communities, and residents. At the local level, responding to natural disasters is a significant drain on municipal operations and finances. As a result, where and how communities can, or should, rebuild and grow is a necessary question in the discussions of local governments' climate change planning.

Typically, the questions relating to rebuilding efforts are most acute after a natural disaster has occurred and the community is faced with rebuilding. In particular, local governments must decide if they should permit rebuilding whilst knowing certain locations are vulnerable to severe climate events such as overland flooding, coastal erosion, or sea level rise and have a likely probability of reoccurring. From a climate mitigation and adaptation planning perspective, such questions should be addressed prior to any rebuilding.

As more local governments experience the impacts of climate change, it is becoming clear that there is insufficient financial assistance from the national and subnational disaster relief programs. Where there is a gap in government financial assistance, it is often the case that residents are left responsible for some rebuilding efforts while also facing increasing insurance premiums imposed by insurers to protect the industry against future losses.

More recently, local governments have undertaken risk management assessment to better identify and manage their exposure to the effects of climate change. This shift involves expanded role for government and nongovernment stakeholders involved in the design and implementation of climate change policies (Henstra and Thistlethwaite 2017; Stevens and Senbel 2017).

Future Directions

Insurance claims in Canada resulting from severe weather events averaged approximately $373 million a year between 1983 and 2004. In the decade from 2005 to 2015, the average amount has tripled to $1.2 billion a year (Demerse 2016). Estimates by the National Round Table on the Environment and the Economy suggest that by 2050, the costs of insurance claims as a result of climate change could range from $21 billion to $43 billion per year (Henstra and Thistlethwaite 2017). If these trends continue, climate change adaption planning initiatives will require a significant shift from the status quo to ensure vulnerable communities minimize risks.

As increasingly severe climate events take a toll on communities, local and regional governments must address their role in the rebuilding of communities, but also the climate change planning measures necessary to respond to future events. These policy decisions will largely be driven by the experience and/or awareness of local residents.

A key component of the policy discussion may relate to financial implications at the local government level, where officials will see a decrease in disaster relief funding from upper levels of government. From the perspective of the individual resident, property insurance premiums may become prohibitively high.

The increased financial demands on government programs and the growing role of private insurance providers may result in the need to modify the eligibility requirements to address elements such as where communities may rebuild after a climate event, or under what conditions. Accessing disaster relief funds may be limited if communities choose to rebuild in areas with known vulnerability, and private property insurance premiums will continue to rise. Ensuring vulnerable communities minimize risks associated with climate events may well require clearer direction on where and how communities rebuild.

Cross-References

► Climate Change Adaptation (CCA)
► Climate Change Impacts and Resilience: An Arctic Case Study
► Community Planning Opportunities
► Green Climate Fund (GCF): Role, Capacity Building, and Directions as a Catalyst for Climate Finance

▶ Immediate Climate Vulnerabilities: Climate Change and Planning Policy in Northern Communities
▶ Making Communities Resilient to Global Climate Change
▶ Vulnerability
▶ Vulnerable Communities: The Need for Local-Scale Climate Change Adaptation Planning

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Climate Change, Forest Policy, and Governance in Africa: Insights into the Congo Basin Forests

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Definition(s)

Climate change mitigation refers to the effort to control the human sources of climate change and their cumulative impacts, notably the emission of greenhouse gases (GHGs) and other pollutants, such as black carbon particles, which also affect the planet's energy balance (IPCC 2014).

Sustainable forest management refers to the process of managing forest to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment (ITTO 2015).

Introduction

Climate and forests are extrinsically linked. This relationship stems among others from the contribution of deforestation and forest degradation to greenhouse gas emissions, estimated at 12% globally in 2008 (van der Werf et al. 2009). This suggests that reducing emissions from deforestation and forest degradation should be factored into any initiative aiming to combat climate change. This is especially important, considering the mitigation potential of tropical forests now firmly established within the empirical literature.

Goodman and Herold (2014) argue that tropical forests have the highest carbon density than forests in any other biome and have removed 22–26% of all anthropogenic carbon emissions in the 2000s. Malhi and Grace (2000) suggest that tropical forests contain 40% of terrestrial vegetation carbon stocks, making this ecosystem an important source of carbon sequestration. Tropical forests are distributed across three main tropical landmasses, America, Africa, and Asia. The largest area of tropical forests is located in the America and represents approximately half of the world's total tropical forests (Thomas and Baltzer 2002). This is the domain of Amazon forests, the largest area of contiguous moist tropical forests spanning 670 million hectares. Second after the Amazon forests is the Congo Basin forests covering 300 million hectares of land spread across six countries, namely, Cameroon, Central African Republic (CAR), Democratic Republic of Congo (DRC), Republic of Congo (RoC), Equatorial Guinea (EG), and Gabon.

In comparison to the Amazon forests, the Congo Basin forests have been given a relatively lower importance due among others to a historical low deforestation and degradation rates, estimated at approximately 0.14% a year (de Wasseige et al. 2014). However, this trend is expected to be reversed over the next few decades as recent studies point out a 20% increase in deforestation rate in African tropical moist forests in 2012 (Hansen et al. 2013) and an average annual deforestation (forest degradation) increase from 0.09% to 0.17% (from 0.05% to 0.09%) between the periods 1990–2000 and 2000–2005 in the Congo Basin (de Wasseige et al. 2012). If this trend persists unabated, the Congo Basin forests may transition from a high potential carbon sink to an important source of carbon dioxide emissions.

In the face of this reality, this article seeks to shed the light on the urgency to further strengthen sustainable management of the Congo Basin forests. It takes stock of the current policy and governance challenges and elaborates on the central tenets in support of more effective climate action in forestry sector in the Congo Basin.

Socioeconomic Context of the Congo Basin Forests

The Congo Basin forests is home to more than 40 million people and fulfil social and cultural functions essential to more than 75 million people from approximately 150 ethnic groups – including indigenous populations – who live either inside or the vicinity of forests (Nasi et al. 2012; de Wasseige et al. 2014). This population relies largely on Congo Basin forest resources for income, food, fuel, medicines, and other non-timber forest products. For example, families living in and around the Congo Basin forests derive between one-fifth and one-fourth of their income from forest-based sources (Wollenberg et al. 2011). Many communities depend on forest watersheds and mangrove ecosystems for access to freshwater and fisheries.

Few decades ago, governments in the Congo Basin forests region relied heavily on revenues generated from the exploitation of natural resources in general and forest resources in particular. However, over the last decade, the contribution of the forestry sector to the GDP has decreased gradually and consistently with the booming development of the oil sector in several Congo Basin forests countries (e.g., Equatorial Guinea and Gabon). For example, the contribution of the forestry sector to GDP in Equatorial Guinea dropped from 17.9% in 1990 to 0.9% in 2006 (FAO 2011). The share of the forestry sector in the GDP is less than 10% in all Congo Basin countries, except for the CAR where it was 13% in 2009 (OFAC 2011; FAO 2011); the average for the six Congo Basin countries is 5%. Tax revenue from the forest sector in absolute terms is currently highest in Cameroon and Gabon, both of which are countries with well-developed commercial forestry sectors (Megevand 2013). The industrial logging sector remains one of the major contributors to the GDP for most Congo Basin countries and also a vital employer. The formal timber sector accounts for about 50,000 full-time employment in all six Congo Basin countries. For example, in Gabon, the forestry sector is the second largest employer after the government, providing more than 5000 indirect employments in the private sector, in addition to about 600 direct employment in the public forest service (FAO 2011). In Cameroon, recent statistics from the government indicates that indirect employment from the forestry sector could exceed 150,000 jobs (MINFOF-MINEP 2012).

Congo Basin Forests Characteristics and Mitigation Potential

The forests of the Congo Basin represent one of the most rich and diverse ecosystems in the world. These forests make up to 20% of the world's remaining tropical moist forests and nearly 91% of Africa's moist forests (Justice et al. 2001). The Congo Basin forests house an extraordinary biodiversity, including the world's largest population of tropical forest vertebrates, which represents an invaluable potential for socioeconomic development. There are some 10,000 plant species (of which 30% are endemic), 1000 bird species (of which 36% are endemic), 900 butterfly species, 280 reptile species, and 400 mammal species (CBD and COMIFAC 2009). According to the International Union for the Conservation of Nature (IUCN) Red List of Threatened Taxa (https://www.iucnredlist.org/), approximately 34% of these species are classified as vulnerable (VU), critically endangered (CE), or endangered (EN). Primary forests where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed represent 35% of total forest area. On the other hand, planted forests represent only 0.3% of the total forest area in 2010 (FAO 2011). In the Congo Basin, 99% of the forests are publicly owned. However, the legislation allocates forest management to private sector entities and most recently to community-based organizations, given that governments are ill-equipped to manage them on a daily basis given their large size and inaccessibility. The states rather play an oversight role by developing technical standards, monitoring the application of management decisions, and collecting tax revenues in the context of forest management activities (de Wasseige et al. 2012). These forests are managed or conserved for multiple uses and values. Nearly 52% of the total forest area is to be permanent forest estate, i.e., designated by law to remain under forest cover. The area of forest designated primarily for production purposes represents 20% of the total forest area, whereas forests designated for the conservation of biological diversity represent 12% of the total forest area. The lowest share is the area designated primarily to the protection of soil and water representing only 0.3% of the total forest area (FAO 2011). The portion of the forest area designated primarily for production purposes, and more specifically for industrial logging activities, is particularly high in the RoC (74%) and the CAR (44%). Notwithstanding, Gabon is the largest producer of timber in the Congo Basin region, followed by Cameroon and the RoC (de Wasseige et al. 2009). In respect to forest use for biodiversity conservation, a total of 341 protected areas were established in the six Congo Basin countries as of 2011, covering 14% of their territory and representing nearly 60 million hectares of land. Data from the Observatory of Central African Forests (*Observatoire des Forêts d'Afrique Centrale*, OFAC) suggests that the highest number of protected areas is found in Cameroon with 30 protected areas covering 8% of the national territory, whereas the largest proportion of national territory covered by protected area is represented by the CAR with nearly 11% of the national territory covered by 16 protected areas (Doumenge et al. 2015).

The Congo Basin forests are endowed with a significant mitigation potential. These forests contain between 25 and 30 billion tons of carbon in their vegetation, which represent approximately 4 years of current global anthropogenic emissions of CO_2. A report from the World Wildlife Fund for Nature suggests that protecting an additional 1% of forests in the Congo Basin would preserve 230 million tons of carbon, or about a third of UK's annual greenhouse emissions, which is worth more than 500 million US dollars in today's carbon market (Zhang and Justice 2001). Recently, researchers from the University of Leeds and University College London discovered the world's largest tropical peatland in the Congo Basin forests. Its area is larger than England, covering approximately 145,500 km^2. The carbon stock is estimated at 30 million tons, which represent one of the most carbon-rich ecosystems on Earth. The peatland covers 4% of the total area of the Congo Basin but stores as much carbon belowground as the trees aboveground that cover the remaining 96% (Dargie et al. 2017).

Current and Future Drivers of Deforestation and Forest Degradation

The forests of the Congo Basin are subject to complex web of threats that differ from one country to another. Following Geist and Lambin (2002), the drivers of deforestation and forest degradation in the Congo Basin can be classified into direct or proximate drivers and indirect or underlying factors. Concerning the direct drivers of deforestation, agricultural expansion – both commercial and slash-and-burn – is reported as the most important and the most common driver of deforestation among all Congo Basin countries. For example, using a geographic information system (GIS)-based assessment, Zhang et al. (2002) established that subsistence small-scale farming was the principal determinant of deforestation in the Congo Basin where forests are more accessible. Small-scale, nonmechanized forest clearing for agriculture – both rotational and semipermanent conversion of woody vegetation into cropland for subsistence or commercial crops – represents about 84% of the total forest disturbance area. Productivity for most commodities grown, either staples or cash crops, is particularly low in the Congo Basin due among others to reliance on mostly vegetative-propagated crops that slow down the dissemination of improved varieties and limited use of fertilizers and pesticides. For example, countries in the Congo Basin forests are at the bottom edge in respect to fertilizer use in Africa with an average of 2 kilograms per hectare, in exception of Cameroon and Gabon where it varies from 7 to 10 kilograms per hectare (FAO 2011). The annual deforestation rate from small-scale clearing for agriculture in primary forests and woodlands doubled between 2000 and 2014. The DRC accounts for nearly two-third of the total forest loss from smallholder clearing (Tyukavina et al. 2018). The expansion of infrastructure is also reported as an important proximate driver of deforestation in the Congo Basin (Duveiller et al. 2008). For example, Laurance et al. (2009) noted that the construction of the Douala-Bangui road going from Cameroon to CAR and that cuts across 1400 km in the northwestern section of the Congo Basin forests has led to massive forest loss.

In respect to forest degradation, logging is reported as the top first factor driving forest degradation in the Congo Basin. Selective logging contributes to nearly 10% of the Congo Basin forest total disturbance area. Out of nearly 100 species economically viable, fewer than 13 species are usually harvested, as timber companies tend to concentrate only on the most economically rewarding ones. de Wasseige et al. (2012) found that the three most harvested species (okoumé, sapelli, and ayous) combined represent about 59% of log production. The largest contributors to forest degradation from selective logging are the RoC (40%), Gabon (31%), and Cameroon (23%). Besides logging, fuelwood and particularly charcoal production is reported as one of the most important drivers of deforestation and forest degradation in the Congo Basin forests. Charcoal is mostly produced through traditional low efficient kiln techniques. In general, the production cost of charcoal is underpriced due to incomplete consideration of different costs along the value chain. For example, the primary resource for the production of charcoal that is wood is taken as free, which contributes to unsustainable forest management as far as access to forests is open and uncontrolled. To a lesser extent, other proximate factors of deforestation and forest degradation include mineral and oil extraction, forest fire, etc.

The underlying causes of deforestation and forest degradation in the Congo Basin forests are more difficult to quantify but present strong similarities across countries. Population growth, weak institutional capacity, regular conflicts and unstable political governments, limited financial resources, and access to finance are some of the underlying factors that impede on the sustainable management of the Congo Basin forests (Justice et al. 2001; Zhang and Justice 2001; Bele et al. 2015). For example, in respect to population growth, deforestation and forest degradation are mainly concentrated around fast-growing urban centers (3–5% population growth per year) and the most densely populated areas, such as Kinshasa and Kisangani in the DRC; Brazzaville and Pointe Noire in the RoC; Libreville, Franceville, and Port-Gentil in Gabon; Douala and Yaounde in Cameroon; and Bata in Equatorial Guinea, as they are chiefly associated with the growth of subsistence activities, notably agriculture and energy consumption (Megevand 2013).

Projections about future rate deforestation and degradation in the Congo Basin are worrisome. These projections are well illustrated by the Forest Transition Theory developed by Mather (1992). According to the theory, a country's forest cover generally declines as it develops socially and economically up to a certain point where the trend is reversed, and forest cover eventually expands. The result is an inverted "U-shaped curve" for forest cover as a function of time also known as the forest transition curve. The forest transition refers to the point at which forest decline halts and forest cover begins to rise (Barbier et al. 2010). There is a general agreement among forest stakeholders in the Congo Basin that countries in the region are at the early stage of the forest transition frontier characterized by high deforestation rate as most of Congo Basin countries are seeking to achieve economic emergence at different time horizons, namely, Cameroon and DRC by 2035, Gabon by 2025, and Equatorial Guinea by 2020.

It is expected that economic activities in the Congo Basin will expand significantly at the expense of the forests as a result of the development of large-scale infrastructure, further expansion of agriculture, and timber extraction. For example, the Government of Cameroon plans to construct many hydroelectric dams that will result in 42,000 ha loss of forests (Tchatchou et al. 2015). Similarly, the Government of Cameroon has planned to increase its agricultural area of more than 2.7 million hectares from 2005 to 2020. This increase will be achieved at the expense of nearly 1025 million hectares of forests by 2025. In the RoC, the government seeks to expand industrial agriculture and has recently granted 170,000 ha of forest areas to the Malaysian's multinational ATAMA Plantations for the production of biofuels. The Government of Gabon wants to multiply oil palm production by nearly 32 times and cocoa and coffee by 17 times by developing about 6000 ha of irrigated land and swamps. Bele et al. (2015) note that the emerging and lucrative logging market in China will further serve as incentive to increase commercial logging in the region over other interests and services provided by the ecosystem of the Congo Basin forests. Tyukavina et al. (2018) argue that maintaining natural forest cover in the Congo Basin into the future will be challenged by an expected fivefold population growth by 2100. This suggests that each country may have to produce five times as much food, either by increasing the area under cultivation or the agricultural yields.

Policy Responses to Deforestation and Forest Degradation

Three different policy approaches have been implemented by the countries of the Congo Basin to reduce pressure on forests and to mitigate climate change. These policies include the adoption of sustainable forest management measures, the improvement of forest governance, and the engagement into the REDD+ process (de Wasseige et al. 2015).

In respect to sustainable forest management, most countries of the Congo Basin did develop a Forest Code in the early 1990s, the most important legislation providing clear orientations on sustainable use of forest resources. Cameroon is the first country in the region to adopt a Forest Code in January 1994, followed by the RoC in 2000, Gabon in 2001, RDC in 2002, and CAR in 2008. Overall, each Forest Code lays out a new classification of the forest domain and forest titles, clarifies the allocation of logging rights, and defines the conditions and norms for the management of forests. The forest domain is divided into a permanent forest estate (lands designated to remain as either forest or wildlife habitat) and a nonpermanent forest estate (forested lands zoned as areas that may be converted into other land uses). The permanent forest estate consists among others of production forests which are forest concessions that comprise one or more Forest Management Unit (FMU) allocated through a competitive bidding process and only operated based on a forest management plan approved by the relevant administrative authority. The idea behind the sustainable management of forest concessions as a basis for climate change mitigation stems from the fact that properly managed concessions can be considered as avoided deforestation and forest degradation through reduced impact logging, the prevention of illegal logging, and agricultural encroachment to name only a few. De Wasseige et al. (2014) estimate the total area of forest concessions implementing forest management plans to be approximately 19 million ha, representing 40% of the total area under concession in the region. Forest certification has been promoted as a means to check that forest management is carried out in a manner that is environmentally appropriate, socially beneficial, and economically viable. As of 2013, there were 5.3 million ha of Forest Stewardship Council (FSC) certified production forests in the Congo Basin, the largest area of certified natural tropical forest in the world (Cerutti et al. 2014). In addition, there were more than three million ha of forest concessions operated under a legality certificate such as "Timber Origin and Legality" (OLB) issued by Bureau Veritas and "Timber Legality and Traceability Verification" (TLTV) issued by Société Générale de Surveillance (de Wasseige et al. 2014). Preliminary results of the mitigation potential of sustainable forest management in the Congo Basin suggest that the implementation of a forest management plan on a forest concession of 20 million ha has the potential to reduce CO_2 emissions by more than 35 million tCO_2eq over a period of 25 years (de Wasseige et al. 2015).

In respect to governance, interventions to strengthen forest governance have mainly resolved around improving both the supply and demand sides of forest products. The European Union and the United States of America, respectively, put in place the Forest Law Enforcement, Governance and Trade (FLEGT) initiative, and the Lacey Act as policy instruments to prevent illegal timber trade in Europe and the US markets through enforcement, monitoring, and trace technology. Over the last decade, the EU has been very active in the Congo Basin to implement the FLEGT Action plan. A key element of the FLEGT Action plan is the Voluntary Partnership Agreement (VPA), a bilateral trade agreement between the EU and a timber-exporting country outside the EU that aims to guarantee that any wood exported from a timber-producing country to the EU comes from legal sources. Under the VPA, the timber-producing country develops systems to verify that its timber exports are legal, and the EU agrees to accept only licensed imports from that country (Saunders 2009). As of 2018, only Cameroon, the RoC, and CAR are already implementing a VPA, whereas DRC and Gabon are still at the negotiation stage. The FLEGT initiative provides a unique opportunity to timber-exporting countries to improve forest governance and strengthen sustainable forest management. It fulfills the gaps from forest certification by taking a national supply level approach, while ensuring demand from an important consumer group (EU). Since the FLEGT Action plan was established in 2003, 124 FLEGT projects (6 ongoing projects as of December 2018) have been implemented in the Congo Basin in thematic areas such as information sharing, transparency, monitoring, timber legality assurance, legal reform, and domestic market. These projects bring together stakeholders from government agencies, civil society organizations, indigenous people, and the private sector to improve forest governance and achieve sustainable development goals.

Concerning the REDD+ mechanism, it is well established that it could spare the Congo Basin forests from large-scale deforestation and forest degradation (Mosnier et al. 2014). Four countries of the Congo Basin, namely, Cameroon, CAR, DRC, and the RoC, are actively engaged in the REDD+ process and benefit from priority financial and technical support from UN REDD, the Forest Carbon Partnership Facility (FCPF), and Investment Programme (FIP) of the World Bank, the African Development Bank, and to some extent the Government of Norway. The implementation of the REDD+ mechanism usually consists of three phases (Angelsen et al. 2009a):

phase 1, "early readiness phase," is the one whereby a country develops a national REDD+ strategy or action plan, national forest reference emission, national forest monitoring system, and safeguard information system through inclusive multi-stakeholder consultations and capacity building; phase 2, "advanced readiness stage," is characterized by the implementation of demonstration activities (e.g., pilot REDD+ projects) and capacity building to reduce emissions; and phase 3, "compensation phase," is the one whereby a country is compensated financially solely on the basis of reduced emissions and enhanced carbon stocks relative to agreed reference levels (Angelsen et al. 2009b). All four Congo Basin countries are at different levels in the REDD+ readiness process. They have all adopted and validated their Readiness Preparation Proposal (R-PP). DRC and Cameroon are the most advanced in the process and have nearly completed phase 1 of the REDD+ process. For example, DRC adopted the National REDD+ Framework Strategy in 2015 to stabilize forest cover to 63.5% from 2030 and maintain it thereafter. The National REDD+ Strategy for the RoC was validated in July 2016 concurrently with the development of an Emissions Reduction Program (ER-P) aiming to generate nearly 11.7 million tCO_2 in emission reductions by 2021. Alongside the implementation of the REDD+ mechanism, a new partnership referred to as the Central Africa Forest Initiative (CAFI) consisting of a coalition of dedicated donors and Congo Basin countries has come to a fruition. The objective of the CAFI is to recognize and preserve the value of the forests in the region to mitigating climate change, reducing poverty, and contributing to sustainable development through the implementation of country-led, holistic low-carbon emissions development investment frameworks that include national policy reforms and measures to address the drivers of deforestation and forest degradation. CAFI's support focuses on (i) the development and implementation of National Investment Frameworks (NIFs) endorsed at the highest level by national institutions with cross-sectoral mandates, (ii) the provision of funding based on the achievement of policy and programmatic milestones that are spelled out in letters of intent, (iii) the promotion of donor coordination and alignment of bilateral assistance to partner countries based on NIFs, and (iv) the promotion of inclusive participation of all stakeholders (CAFI Joint Declaration 2015). In DRC, the REDD+ Investment plan that includes sectoral approaches and integrated programs to address all direct and underlying drivers of deforestation and degradation was formally adopted by the Government of the DRC and presented to the CAFI Executive Board in December 2015. The Letter of Intent (47 milestones – 200 million US$) was signed with CAFI in April 2016, marking the beginning of the implementation of the Investment plan. As of December 2018, five milestones of the Letter of Intent were achieved, including the development of the first National Forest Reference Emission Level (FREL) submitted to the UNFCCC for technical review in January 2018. To implement the National REDD+ Strategy, the CAFI Executive Board approved a preparatory grant of 698,000 US$ and 1 million US$ for the RoC and Cameroon, respectively, to develop a comprehensive REDD+ National Investment Framework (REDD+ NIF). The final version of the REDD+ NIF for the RoC and the first draft for Cameroon were recently presented to CAFI Board and endorsed by the FIP subcommittee.

Persistent Challenges to the Sustainable Management of the Congo Basin Forests

The Congo Basin forests are subject to multiple and persistent challenges. Martius (2015) finds the epitome of the challenges preventing effective implementation of low-carbon climate change-resilient policies grounded into the political economy of deforestation and forest degradation characterized by weak forest governance, multilevel and multi-sectoral coordination challenges, and competitive national development objectives. In respect to the development policy, for example, Congo Basin countries – in exception of Gabon and DRC – have relatively failed to mainstream climate change and/or environmental sustainability in their vision of emergence documents, which constitutes an important risk for the future of the Congo Basin forests in the current context of mounting pressures. Despite tangible progress on sustainable forest management, much remains to be done, notably in respect of forest certification. As of 2014, the total area of forest concessions under FSC certification (5.3 million ha) is still low representing only 7–13% of all FMU in the region. Despite notable progress to improve forest governance, difficulties remain to control the informal forest sector in general and to halt illegal logging in particular. The FLEGT-VPA initiative has demonstrated great potential to promote good governance by setting up a framework to ensure legal timber sourcing from the Congo Basin forests to European countries. However, the FLEGT-VPA does not apply to China who represents 47% of timber trade on the demand side in the Congo Basin region (Pepke et al. 2016). The possibility for illegal timbers to flow to China for transformation before entering the global market as finished consumer goods keeps illegal logging as an attractive – low cost and high profit – business in the Congo Basin. For example, a report from Chatham House (Lawson 2014) estimates that nearly 90% of logging in DRC was illegal in 2011. Though it is well established that the REDD+ mechanism has a great potential to be a comprehensive land management and climate mitigation instrument, conceptual and implementation challenges are reported in the Congo Basin. For example, Trefon (2017) reports that most REDD+ conservation initiatives in the Congo Basin focus on landscape not at immediate risks of deforestation and forest degradation as it is supposed to be. Furthermore, the implementation of the REDD+ mechanism is mainly relying on under-equipped national administrations in respect to service delivery capacity and motivation. Moreover, the development of synergies between REDD+ and FLEGT-VPA is yet to happen in practice, hampered among others by REDD+ and VPAs being dealt with by different ministries and the lack of cross-sector coordination (Tegegne et al. 2014). Additionally, the CAFI has so far operated in a relatively top-down approach with limited participation of civil society organizations at the decision-making levels. Its intended role of donor coordination and alignment of bilateral assistance to partner countries is limited to only six donor countries: France, the Netherlands, Norway, Germany, United Kingdom, South Korea, and the European Union. Some strategic actors in the Congo Basin region such as the United States have been reluctant to become part of this initiative.

The Way Forward

Over the last few decades, the Congo Basin forests have benefited from passive protection due to economic stagnation, lack of infrastructure, and political instability, among others. Today, the socioeconomic context suggests that we are heading to a turning point characterized by increasing pressure on these forests. The rate of deforestation and forest degradation is now following an increasing trend, and this condition may exacerbate, aided and abated by the aspiration of the Congo Basin countries to become emerging economies in a near future. In the face of the dual challenge to promote economic growth and poverty alleviation, while also conserving forests, Megevand (2013) argues that opportunity exists for the Congo Basin countries to embark on development pathways that leapfrog severe deforestation, and proposes cross-cutting and sector-specific recommendations to reconcile economic growth with forest protection in an inclusive and sustainable way. Crosscutting recommendations include investing in participatory land use planning, improving land tenure systems, strengthening institutions to enforce rules, and building alliances within complex political economy. Sector-specific recommendations include increasing productivity and prioritizing non-forested land for agriculture, organizing the informal energy value chain, better planning and minimizing adverse impacts of transportation, expanding SFM to the informal sector, and setting high standard goals for environmental management in the mining sector. In a nutshell, Tchatchou et al. (2015) suggest mainstreaming low-carbon climate-resilient growth into Congo Basin countries' vision for emergence to prevent and eventually mitigate the adverse impacts of their development policies on forests. Today, Congo Basin's leaders are more receptive and inclined to embrace this approach. The time is now ripe to transform the political will into concrete climate action.

Cross-References

► Climate Change, Forest Policy, and Governance in Africa: Insights into the Congo Basin Forests
► Forest and Climate Change Governance

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Climate Change, Human Health, and Sustainable Development

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Definitions

The three most important approaches concerning human health include the "medical," the "holistic," and the "wellness" models.

1. The medical model understands the body as a machine, emphasizes treating specific diseases, does not accommodate mental or social problems and, therefore, de-emphasizes prevention. This has led to measuring health by its absence, by disease, or death rates (Stokes et al. 1982).
2. The holistic model is exemplified by the World Health Organization as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO 1946).

   Holistic health is a system of preventive care that takes into account the whole individual, one's own responsibility for one's well-being, and the total influences – social, psychological, environmental – that affect health, including nutrition, exercise, and mental relaxation (Heritage 1995).

   The holistic model expanded the medical perspective as well as introduced the idea of positive health. The WHO definition was long

considered unmeasurable; the terms were vague. Measuring "well-being" required subjective assessments that contrasted sharply with the objective indicators favored by the medical model.
3. The wellness model was developed through the WHO Health Promotion Initiative, which proposed moving away from viewing health as a state, toward a dynamic model that presented it as a process or force (WHO 1984).

The idea of health was amplified in the Ottawa Charter to "the extent to which an individual or group is able to realize aspirations and satisfy needs, and to change or cope with the environment. Health is a resource for everyday life, not the objective of living; it is a positive concept, emphasizing social and personal resources, as well as physical capacities" (WHO 1986).

Health is also measured in terms of resilience, "the capabilities of individuals, families, groups and communities to cope successfully in the face of significant adversity or risk" (Vingilis and Sarkella 1997). Applied to population health, the definition might include elements such as the success with which the population adapts to change such as shifting economic realities or natural disasters.

An ecological definition of health is: "A state in which humans and other living creatures with which they interact can coexist indefinitely" (Last 1995).

Human health is also defined by the impacts of climate change on health. Because of increased temperatures and more frequent and intense extreme weather events, the number of direct injuries and deaths will increase, along with infectious diseases, whether food, water, or vector-borne; respiratory and cardiovascular diseases are expected to rise due to worsened air pollution and extreme heat (Louis and Phalkey 2016).

The severe drought is associated with harm to human health. "With Earth observations indicating increasing variability in precipitation patterns around the globe, the need to understand the health effects of drought is as great as the need to understand the health effects of flooding and extreme precipitation" (Balbus 2017).

The climate change will increase the numbers of individuals exposed to extreme events and, therefore, to subsequent psychological problems such as worry, anxiety, depression, distress, loss, grief, trauma, and even suicide. It can also lead to mental health risks if they provoke migration, whether people are forcibly displaced, resettled, or choose to leave. Participating in group-based ventures that emphasize identity, citizenship, and the augmenting of social capital can change behavioral norms around mental health and climate change (Berry et al. 2018).

Pollutants like ozone and small particulates cause and exacerbate a range of health conditions, including heart disease, stroke, respiratory infections, lung cancer, and more. The progression of climate change is expected to increase the number of deaths and hospitalizations caused by air pollution (Ospina 2018).

The vector-borne disease outbreaks can increase around the world. A recent report noted that climate change would likely amplify the transmission of dengue, especially in Latin America (CDC 2016). In addition to taking climate mitigation measures, it will also be necessary to take adaptation measures, such as strengthening health systems, improving preparedness, and developing early warning systems (Louis and Phalkey 2016).

The goal of improving health in a context of climate change presents a potential paradox: on the one hand, efforts need to be made to mitigate climate change, but, at the same time, there is a clear need to encourage development in lower and middle income countries in order to reduce poverty and to improve health. The two objectives can be achieved, but, as emphasized by the Lancet Commission, the opportunities that they are offer are tempered by very serious challenges, and difficult decisions will need to be made at a political level (Watts et al. 2015; Louis and Phalkey 2016).

Introduction

The relationship between human beings and the environment throughout time has been crucial to establish the impact of disease on society.

When we look at the domestication of animals at the dawn of humanity, we see that the close contact between the two exposes people to a variety of diseases. Many human diseases are related or derived from animal diseases. Smallpox is very similar to cowpox, tuberculosis and diphtheria are originally from cattle, and there are also other diseases we share with cats and dogs (Ponting 1995).

Deforestation is another example of how human actions impact human health: for example, it creates new environments for mosquitos that carry malaria.

The growth of societies also exposes people to a new range of infectious diseases, given the greater population concentration. Diseases like dysentery and cholera are related to a lack or deficiency of sanitation systems or to contaminated water. Poor water quality and irregular waste disposal are responsible for diseases such as leptospirosis, diarrheal diseases, hemorrhagic dengue fever, hepatitis, and others. Air pollution is responsible for respiratory diseases and allergies, the predatory occupation of hills is the cause of landslides, deforestation, and the cutdown of riparian forests causes the sedimentation of bodies of water, etc.

Therefore, the health of human beings does not relate only to the opposition of currently not having any diagnosed disease. The state of natural elements is considered when assessing whether these elements are healthy and whether their use will produce health or disease in the future.

Evidently, the relationship between health and the environment cannot be considered exclusively in the biomedical perspective, although it is extremely relevant.

Consequently, according to Labonte (1996), health problems may fit into three categories: *biomedical*, based on disease and actions to treat symptoms and eradicate the disease; *disease prevention*, based on the promotion of healthy behaviors to prevent disease; and the *creation of physical and social environments that promote the health and the well-being of individuals* based on policies that seek social change through the development of healthy public policies.

Social Determinants of Health

All around the world, poverty and poor living conditions remain one of the most important causes of disease. Although mortality rates by infectious diseases have dropped, the number of diseases related to lifestyles and diet changes increased. Chronic malnutrition or hunger makes people much more vulnerable to infection. One example is child mortality rates. They keep dropping but not uniformly throughout all social classes (PNUD 2007).

Six million kids die each year before the age of 5 because of extreme poverty, which expresses the vulnerability of the poorer strata of the population (UNICEF 2015).

Such deficiencies in human development bring attention to the profound inequalities we've been witnessing around the world. Since 2015, the 1% richest in the world held more wealth than the rest of the planet (BCS 2016).

Therefore, social inclusion and exclusion can be understood as determining in the health-disease process and produces a significant impact on social equity.

With the decrease of mortality by infectious diseases, chronic noncommunicable diseases (CNCD) are currently the most important cause of death in the world, having caused 38 million deaths in 2012, more than 40% of which premature and avoidable, affecting people younger than 70. Approximately 80% of CNCD deaths take place in middle- to low-income countries, most related to the circulatory system, cancer, diabetes, or chronic diseases of the respiratory system (WHO 2014).

CNCDs have to do with complex, multivariable factors, and significantly change the quality of life of affected people, producing subjective and objective changes expressed by biological and behavioral changes. The most important risks of CNCDs are related to unbalanced diets, sedentarism, smoking, and psycho-emotional disorders (Ribeiro et al. 2012).

Although these factors are centered around the individual, strategies to tackle CNCDs must include both interventions to promote behavioral changes and individual changes and population-based interventions related to living and work conditions and education.

Social justice is a matter of life and death. It affects the way people live, their consequent chance of illness, and their risk of premature death.

Within countries, there are dramatic differences in health that are closely linked with degrees of social disadvantage. Differences of this magnitude, within and between countries, simply should never happen (WHO 2008).

The social determinants of health (SDH) are the "conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life which include economic policies and systems, systems shaping the conditions of daily life which include economic policies and systems, development agendas, social norms, social policies and political systems" (WHO 2017).

The idea that health is produced socially implies recognizing that health determinants are mediated by social systems and influenced by the excluding social relations that operate these systems.

Environmental Determinants of Health

The current economic system – in which the environment is conquered because not only of survival but also of the pursuit of profit and capital accumulation to maximize the power of the most important economic and political agents – aggravates and accelerates ecological imbalances, stimulates excessive growth, wastefulness, and the production of items that are not necessary to improve the quality of life and which are inaccessible to the majority of the population, thus, expanding social inequality.

The increase in production and the supply of material goods marks the environment with soil and air contamination, the amount and quality of water, etc., which demonstrates that the health risks of this model transcend the realm of production and affects not only workers but also the population in general.

Navarro et al. (2002) highlighted that environmental change, demographic increase, and the mobility allowed by international means of transportation and trade have been promoting the adaptation and the change of pathogens, which further dilutes the traditional separation between north and south and brings closer the epidemiological profile of developed and developing countries, the negative side of the so-called globalization.

Geography researches have been contributing greatly with studies on patterns of spatial and temporal distribution of health and disease conditions in each given population. The mapping of health and disease conditions has been an important tool to understand the spatial distribution, the incidence and prevalence of disease in a given territory, and the establishment of possible correlations with known or suspected factors that could be causing that distribution (Ribeiro 2005).

The first studies of medical geography were concerned, above all, with the global distribution of the most important diseases. It was observed that climate is a determining factor in the distribution of diseases, especially those communicated by vectors that depend on adequate conditions for survival and reproduction. Other studies show that socioeconomic disparities, the access to health services, and the quality of the environment also influence the health of specific populations and that, at the local level, there is a greater influence of environmental contamination on health (Ribeiro 2005; Newton and Bower 2005).

Therefore, the health of individuals is also associated with what humanity creates and does, to social interactions, to the policies adopted by the government, including healthcare mechanisms, the teaching of medicine, nursing, to education, and to environmental interventions.

Having a new perspective on health and disease also means being sure that we as a species need to be responsible to the planet, that is, survival is our central concern.

Sustainable Development

The critique to the consumer society, wastefulness, and to the limits of production started a discussion in the field of Economics that included the areas of Science and Ethics, as well as the Social Sciences and the debate on spirituality and political action.

In this context, nonanthropocentric ethical-legal preservationist models emerge.

(a) *Biocentrism* understands humans as part of nature and does not admit aggressions of any kind to life in any of its forms (Lanza and Berman 2010); (b) For *Ecocentrism* or *holism* biodiversity has value on itself, moving beyond the idea of ecology as a science, through deep evaluations of ecological awareness, questioning the capacity of the current society to fulfill basic human needs such as love, safety, and the access to nature (Devall and Sessions 1985; Naess 1986; Warwick 1986); and (c) *Gaianism* affirms that life and the global environment are part of the same self-regulating system (Lovelock 1998).

Thus, the perception of this fundamental unity of life – according to which humans are neither "separate from a reality that's been reduced to an object," nor "the measure of all things" – points to the essential elements of "deep ecology," which highlight values such as simplicity, self-sustained development, and nonviolence, and has been the most popular nonanthropocentric model among environmentalists (Santana 2002).

In this perspective, sustainable development consists in the possible and desirable conciliation between development, environmental preservation, and an improvement in the quality of life.

Climate Change and Health

There is abundant evidence showing that human activities are changing the climate and that climate change will produce significant impacts on health, both nationally and globally.

Climate change and health issues move beyond national borders, and impacts on health and climate change in some countries most probably will affect the health of other countries. "The influences of weather and climate on human health are significant and varied. Exposure to health hazards related to climate change affects different people and different communities to different degrees" (USGCRP 2016).

Some changes in the global environment affect human health cumulatively, such as the disposal of chemical pollutants in the water and soil, which bioaccumulate, and the destruction of multiple natural habitats, as well as the extinction of species, which reduce genetic resources and destroy natural landscapes (Confalonieri et al. 2002).

Other processes are also systemically important, such as the state of the climate and the ozone layer, which represent global risk factors for human health. Moreover, environmental degradation processes, such as the use of pesticides, produce a long-distance effect due to ocean and air currents (Confalonieri et al. 2002).

Human health may be harmed in the following ways: problems with reproduction and a decrease in the population of the species; changes in the immune system; behavioral anomalies; unusual thyroid function and other hormonal changes; tumors and cancer; male feminization and female masculinization; and congenital malformations (Confalonieri et al. 2002).

Besides the direct effects of global changes in health, there are indirect effects, which are often hard to quantify because the ecological mechanisms and social processes involved are complex (Confalonieri et al. 2002). For instance, multiple factors influence the dynamics of vector-borne diseases, as well as environmental factors (vegetation, climate, hydrology); socio-demographic factors (migrations and population density); biological factors (the life cycles of insects that are vectors for infectious agents); and medical-social factors (the immunological conditions of the population; the effectiveness of local health systems, etc.), which may potentialize their effects on human health (OPAS 2008).

Hunger, draught, extreme climate events, and regional conflicts – all probable consequences of climate change – are a few factors increasing the incidence and severity of diseases, as well as contributing to other adverse impacts on health. Therefore, it is imperative to address climate change as to the local, regional, national, and global decision-making process.

Climate can also affect the quality of water and food in specific areas, with implications in human health. Moreover, the effects of global climate change on mental health and well-being are part of the general impact of climate on human health.

Therefore, in order to promote health, we must identify the determinants of the health-disease process and act on them. Since they have to do with people's living conditions, these determinants are extremely significant especially at the local level, where the daily lives of individuals take place (Buss and Ferreira 2002).

Vulnerability, Impact, and Adaptation to Climate Change

Scientific studies from the most different areas warn us against various types of global problems: global warming, the hole in the ozone layer, water pollution, desertification, and the reduction in the amount of potable water, for instance. Biologists, chemists, forest engineers, and agronomists have been showing how important these issues are scientifically. Nations realized that the preservation of the species depends on environmental preservation. Even those who believe that new technologies could provide solutions to the environmental crisis ponder their costs, especially in developing countries (Penna 1999; Barnett et al. 2001).

The environmental consequences of climate change – both the observed and the foreseen, such as sea level rise, changes in precipitation causing floods and droughts, heat waves, hurricanes, more intense storms, and worsened air quality – will directly and indirectly affect health.

One useful approach for us to better understand how climate change affects health is considering specific exposure pathways and how they can lead to human diseases. Exposure pathways differ throughout time and space, and climate change exposure affects different people in different communities at different levels. Threats related to climate change can also accumulate throughout time, leading to long-term changes in the resilience of health.

The fact that someone is or is not exposed to health threats or sick or suffer with other adverse consequences of this exposure to health depends on a complex set of vulnerability factors. Vulnerability is understood as the aspects of a given population, system or set of assets that makes them more or less susceptive to the negative impacts of a threat. Such aspects or factors may be physical, demographic, socioeconomic, cultural, environmental, and institutional, depending on the approach used (Setti et al. 2015).

Climate vulnerability includes three different elements: exposure, sensibility, or susceptibility to harm and the capacity of adapting to or tackling such harm (IPCC 2014).

- Exposure is the contact of an individual with one or more biological, psychosocial, chemical, or physical stressors, including stressors affected by climate change. Contact can occur once or repeatedly throughout time, or only at one site or in a broader geographical area.
- Sensibility is the degree to which people or communities are affected by climate variability or change.
- The adaptative capacity is the capacity of communities, institutions, or people to adjust to potential risks, and resilience is their capacity to prepare, plan, absorb, recover, and adapt more successfully to adverse events.

All three elements can change throughout time and are specific of the site and system (IPCC 2014; NRC 2012; USGCRP 2016).

Vulnerability operates in various levels, from the individual to the community, and affects all people in some degree. For individuals, these factors include behavioral choices and the degree to which this person is vulnerable based on their level of exposure, sensibility, and adaptative capacity. Moreover, vulnerability is also influenced by the social determinants of health (USGCRP 2016).

In communities or the society as a whole, health results are strongly influenced by adaptative capacity factors, including those related to natural and human environments, governance, management, and social organization (USGCRP 2016).

Certain health-adverse effects can be avoided if decisions result from the identification of vulnerable populations and the assurance of the access to preventive measures.

A report developed by an ad hoc Interagency Working Group on Climate Change and Health identified 11 categories of human health consequences of climate change:

1. Asthma, respiratory allergies, and airway diseases
2. Cancer
3. Cardiovascular disease and stroke
4. Food-borne diseases and nutrition
5. Heat-related morbidity and mortality
6. Human developmental effects
7. Mental health and stress-related disorders
8. Neurological diseases and disorders
9. Vector-borne and zoonotic diseases
10. Water-borne diseases
11. Weather-related morbidity and mortality (IWGCCH 2010)

Climate change can, therefore, affect human health in two main ways: first, changing the severity or the frequency of health problems that are already affected by climate factors and second, generating unprecedented or unforeseen health problems or health threats where they did not happen before.

The areas that are already suffering with health-threatening climate events – such as heat waves or hurricanes – will probably suffer further, with even higher temperatures and increased rainfall and storms. Other areas will be introduced to new climate-related health threats, such as areas that were not affected by the proliferation of toxic algae or by water-borne diseases. These areas may face risks in the future because higher water temperatures allow the proliferation of health-threatening microorganisms (USGCRP 2016).

Intersectoral Policies for Sustainable Development and Health Promotion: Strategies Toward Improving the Quality of Life

The World Commission on Environment and Development (UN 1987) established sustainability as a new paradigm for development, that is, "that which satisfies the needs of current generations without compromising the capacity of future generations to satisfy their own needs."

What they are seeking is a form of development that is environmentally sustainable in the access and use of natural resources and the preservation of biodiversity; socially sustainable as to the reduction of poverty and social inequalities and a promoter of justice and equity; culturally sustainable in the conservation of the system of values, practices, and symbols of identity which, despite its constant evolution and change, determine national integration throughout time; politically sustainable as to strengthening democracy and assuring the access and the participation of all in public decisions.

The approach to these ideas allows the assertion that the health and environment sectors are interrelated, that is, they address cross-cutting issues whose amplitude extrapolates specific areas and, therefore, should be permanently encompassed by all areas.

According to the output document of the 3rd International Conference on Health Promotion, which took place in Sundsvall, Switzerland (1991), environment and health are interdependent and inseparable, and should be priorities to development and be given precedence in the everyday management of government policies (WHO 1991).

The UN Declaration on Human Environment, signed in Stockholm (1972), highlighted that "man has the fundamental right to freedom, equality and adequate conditions of life, in an environment of a quality that permits a life of dignity and well-being. . ." Similarly, with a focus on quality of life, the First International Conference on Health Promotion, carried out in Ottawa (1986), established that "Good health is a major resource for social, economic and personal development and an important dimension of the quality of life," an understanding that was later confirmed in other conferences (WHO 1986).

Human quality of life depends on the quality of the environment, which also drives balanced, sustainable forms of growth. However, quality of life is also linked to unprecedented forms of identity, cooperation, solidarity, and participation, as well as different forms of accomplishment – through work, creativity, recreation, etc. (Leff 2004).

Social Participation

Social participation and the involvement of local communities are crucial for the effectiveness of public policies.

Sustainable development must be based on people and their communities to conserve biodiversity and natural processes that maintain life, as well as on good planning and impact management.

The idea of ecodevelopment discussed by Sachs (2007) suggested a new style of development and a new (participatory) focus for planning and management strategies, guided by an interdependent set of ethical premises: meeting basic human needs, promoting the self-confidence of populations involved, and cultivating ecological prudence.

In terms of policy, participation refers to the goal of including as many social groups as possible in decision-making processes. The participation of more social groups increases the likelihood that civil society will deem government policy legitimate. However, certain participating groups have more power than others and may dominate policy-making processes to promote their own ends in ways that undermine social goals (Murphy 2012).

Decision-making processes need to incorporate mechanisms that require planning to meaningfully reflect the needs of future generations. Accordingly, policy approaches should be examined to assess the extent to which views and preferences of weaker groups, including future generations, are reflected in ultimate decisions (Murphy 2012).

Participation is a right and duty of all the people in society who value a positive coexistence based on the principles of freedom, morality, solidarity, and justice. Participation is an achievement, an endless process that is always being carried out. It assumes commitment, involvement, presence in actions, and an open dialogue with stakeholders, as well as the consideration of their contributions and potentials (Demo 1988).

The training of individuals and communities to take greater control over the factors that affect their lives, transferring the power over health from the professional domain and a biomedical paradigm to a social model (South 2014), is fundamental for the implementation of intersectoral policies to meet the SDGs.

Intersectorality

Intersectorality is an integrate solution for problems that cannot be addressed through sectoral – usually fragmented – policies.

It is a holistic perspective, represented by the idea of transdisciplinary awareness. Everything is interdependent and phenomena can only be truly comprehended by observing the context in which they occur (Capra 2004).

Therefore, for this holistic perspective, the world is an integrated whole, a network of interconnected phenomena, a self-organized organism (Capra 2004), and health is understood as a large system, a multidimensional phenomenon that affect physical, mental, social, and spiritual aspects which are constantly affected by interdependent biogenetic, environmental, socioeconomic, political, and cultural factors.

Intersectoral actions assumes openness to dialogue and negotiation toward the convergence of interest, such as the shared planning and evaluation between sectors. Intersectoral approaches must assure an active dialogue between forms of knowledge and practices.

More than access to high-quality medical/healthcare services, we need to address the entirety of the social determinants of health, which requires healthy public policies, actual intersectoral articulation of the public sphere, and popular mobilization.

Health promotion and quality of life are ideas can be brought together through healthy public policies that operationalize such interaction. Healthy public policies demand intersectoral action (Buss 2000), and the Sustainable Development Goals (SDGs) have been materializing this into a new social institution.

The goal of this agenda is to improve and protect the quality of life of the population based on a new development paradigm, based on changes not only in life styles, but also in the organization of the society and in governance for sustainable development, changes that would allow humanity to maintain a constant level of natural capital, that is, to keep the supply of raw materials for the human economy and the absorption of waste by ecosystems unaltered, while promoting social justice and inclusiveness.

Global Governance

Climate change has been a subject of serious international negotiations with a trend of broadening participation in those deliberations, but, for the most part, it continues to be led by environment departments and constituencies. Much of the reason the environment departments took such a predominant position in all matters relating to climate change – including mitigation and adaptation – is rooted in the establishment of the Intergovernmental Panel on Climate Change (IPCC) (Drexhage 2008).

In political and institutional terms, global governance means advancing intersectoral practices and promoting the relationship with the society. Criteria for preserving environmental health must increasingly be included in the decision-making process and in public policies that affect health.

According to Buss et al. (2012), global governance for sustainable development must assure policies and actions in various dimensions, such as:

- More democratic, participatory, inclusive, and efficient forms of government that place social, economic, environmental, and health equity at the center of its results
- Implementation of wealth distribution and social protection policies
- Better fiscal policies that incentivize sustainable policies and actions at different sectors for different social agents
- Greater energy efficiency in the use of natural resources, making use of adequate technological innovations
- Mitigation of greenhouse gas emissions to tackle climate change
- Profound changes in global trade, making it substantially fairer, establishing specific protections for the most fragile nations
- Assuring universal food and nutrition safety
- Assuring equitable access to water and sanitation services
- Creating decent jobs and labor, etc.

Final Considerations

As argued throughout the entry, human and environmental health are intimately linked. The complexity of problems that affect and determine the health of the population is a challenge for public health, given that health is not just biological (the absence of disease) but includes social, cultural, environmental, and economic aspects, as well as life styles.

Similarly, the environment does not include only natural aspects but also technological, social, economic, political, historic, cultural, technical, moral, ethical, and aesthetic ones. Moreover, several other factors determine the level of social vulnerability, including biological susceptibility, socioeconomic status, cultural competency, and constructed environment.

Therefore, implementing intersectoral policies that promote health and the environment is strategic and fundamental to reduce inequalities and promote sustainable development.

The development of partnerships between different sectors, the increase in participatory processes, and the implementation of multisectoral actions are strategies that should be adopted by political leaders, local organizations, and citizens committed to meeting the SDGs and with the continuous and progressive improvement of health conditions and the quality of life of the population, forming and strengthening a social pact between local authorities, community organizations, and public and private institutions.

While the SDGs propose an ample agenda of promotion of equity and sustainable development in the territories, in order for these changes to take place, the synergy between actors and structures of the government and the civil society will be necessary, not isolated or opposite actions. Collaboration must take place through dialogue and the development of a joint project. To do that, promoting the exercise of political participation and the governance of democratic societies – in which health and the environment are political priorities, expressed through the implementation of healthy public policies – is essential.

Cross-References

▶ Climate Change and Human Migration as Adaptation: Conceptual and Practical Challenges and Opportunities
▶ Climate Change Effects on Human Rights

- ► Climate Change Effects on People's Livelihood
- ► Gendered Impacts of Climate Change: The Zimbabwe Perspective
- ► Making Communities Resilient to Global Climate Change
- ► Sociocultural Impact of Climate Change on Women and the Girl Child in Domboshawa, Zimbabwe
- ► Vulnerability
- ► Vulnerable Communities: The Need for Local-Scale Climate Change Adaptation Planning

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Climate Change, Multiple Stressors, and Responses of Marine Biota

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Synonyms

Deleterious effects; Hypoxia; Impacts; Mortality; Ocean acidification; Ocean deoxygenation; Ocean warming; Physiology

Definition

Human-exacerbated emissions of greenhouse gases and nutrients are creating a multitude of chemical, physical, and biological stressors, disrupting the natural equilibrium within individual homeostasis, multi-species communities, and entire ecosystems.

Introduction

Climate change is ongoing and will be further aggravated if greenhouse gas emissions, and other anthropogenic pressures, remain unabated (IPCC 2013). Such scenario will imply a marked change on several abiotic parameters caused by said gases, with a special highlight for carbon dioxide (CO_2), which constitutes the majority of anthropogenic emissions. These abiotic alterations occur in all physical realms on the planet, with the oceans and the life they sustain being threatened by multiple fronts. Coined as "the deadly trio," climate change is expressed via three main stressors in the marine realm: increasing surface temperature (ocean warming), decreasing mean pH (ocean acidification), and decreasing mean oxygen content (ocean deoxygenation). These abiotic stressors impact biological responses and traits in a varied number of ways, displaying interactive effects on marine biota. In this entry, we will shortly explain the physicochemical changes associated with these stressors while providing an overview of their hampering effects on marine biota at different levels of biological organization – from molecules to ecosystems. Moreover, we will discuss HOW these stressors may potentially interact under realistic scenarios and the consequent impacts on marine life in the ocean of tomorrow.

Climate Change Stressors

Ocean Warming

During the last 30 years, sea surface temperature (SST) has averagely increased 0.18 ± 0.16 °C per decade, despite differential spatial and seasonal rates of change. Conversely, the global ocean (above 75 m) has suffered an increase of about 0.11 ± 0.02 per decade (Lima and Wethey 2012). Global mean temperatures are expected to continuously rise throughout the twenty-first century (IPCC 2013). Anthropogenic-related CO_2 and methane accumulates in the atmosphere, retaining the infrared radiation reflected from Earth's surface and warming the atmosphere. Concomitant to the increased temperature verified in the atmosphere, ocean temperature is also increasing, particularly at the surface level. According to IPCC (2013), model projections encompassing most plausible scenarios (e.g., decrease in emissions, "business-as-usual," and emissions increase) predict a further temperature increase averaging 1–3.5 °C for 2081–2100. Global warming is preeminently a feature of surface and lower atmosphere and is manifested more on land compared to water masses, by a factor of 1.4–1.7. Moreover, temperature change will not be uniform throughout global regions – global warming is projected to be stronger in Arctic latitudes, a phenomenon termed polar amplification. The less pronounced magnitude of this phenomenon in the South Pole appears to be linked to strong oceanic heat uptake and the persistence of the thick Antarctic ice sheet, as well as significantly higher deep ocean mixing, which allows for a better heat dispersion (Meehl et al. 2007). The phenomenon of global warming has received the most significant attention of climate change researchers (Fig. 1), with the largest number of studies trying to predict how marine organisms will cope with such warming trend.

At biological level, temperature expresses far-reaching effects across several levels of organization, from biochemical and molecular reaction dynamics to organism fitness, species distribution, and global biogeography (Angilletta 2009). The thermodynamic properties of biochemical kinetics and protein stability determine the thermal sensitivity of reactions (Kingsolver 2009). Consequently, according to basic metabolic theory, all organisms possess a survival thermal window, where increasing temperature increases reaction rates until an optimal level is reached, beyond which physiological stress (e.g., protein denaturation) is imposed and a steep decline is seen in metabolic and biochemical processes, such as growth, development, and feeding activity (Angilletta 2009; Mertens et al. 2015; Pörtner and Farrell 2008; Pörtner and Knust 2007; Rosa et al. 2012). Allied to this, organisms presenting higher optimal temperatures typically present a higher metabolic fitness, but that comes with the associated cost of a smaller thermal window, both for optimal and for basal levels (Kingsolver 2009). As such, predicted temperature increases will provoke larger negative fitness impacts on tropical than temperate species (particularly in ectotherms), since the first have already relatively small thermal margins and are generally living near their thermal maximum limits (Stillman 2003; Tewksbury et al. 2008).

Moreover, due to differential acclimation potential by autotrophic and heterotrophic metabolisms, the metabolic theory of ecology (MTE) predicts that less temperature-associated effects will be provoked on producers in comparison to consumer (O'Connor 2009). Thus, gradual increases in temperature will maximize consumer metabolism and strengthen top-down control on marine communities. However, in plant- and algae-dominated ecosystems, pronounced increases in temperature may result in an overdrive of consumer metabolism, leading to bottom-up dominated communities and increased primary producer biomass growth (Sampaio et al. 2017). Nevertheless, the width of organismal thermal range, optimal temperature, and temperature response varies across populations, which may lead to heterogenic effects on the same species depending on geography and other physicochemical properties (Stillman 2003). Regarding primary producers, for instance, in the temperate water of Australia, warming can lead to permanent shifts in kelp-dominated systems in favor of otherwise ephemeral algal mats and turfs (Wernberg et al. 2011). At the same time, in tropical waters, increases in temperature have been shown to elicit coral species to expel their symbiotic microalgae (zooxanthellae), a process known as bleaching (Kwiatkowski et al. 2015; Van Hooidonk et al. 2013). In the case that abiotic conditions do not return to favorable conditions in a specific time frame, these corals lose their nutrient source and perish, leaving huge inhabitable white "patches" across the ocean floor. Conversely, while warming has been shown to produce negative impacts on kelp and coral physiology and weaken their ecological fitness, this stressor increases algal turf productivity and spread, leading to a pronounced change on habitat-forming structures and potential for harboring species pertaining to higher trophic levels (Connell and Russell 2010).

Another important issue linked to temperature changes, with vast consequences on organism and ecosystem health, is the increase in frequency and magnitude of marine heat waves (IPCC 2013). These events have recently provoked pronounced negative effects on marine ecosystems across a disparity of areas such as the Southeastern, Northern, and Western Australia, the Northwest Atlantic, and the Northeast Pacific (Oliver et al. 2018). It is widely known that organisms are generally more impacted by rapid changes in abiotic conditions, than by gradual changes in mean conditions. Consequently, the sudden temperature increase coupled with extreme weather phenomenon, e.g., El Niño, led to sharp metabolic overdrive resulting in massive die-offs of fish, mollusks, crustaceans, corals, and even calcifying algae and seagrasses (Arias-Ortiz et al. 2018). Ecologically, beyond the mass mortalities of vertebrates and invertebrates, these events have caused marked losses on kelp forest, coral reef habitats, reduced primary productivity, species range limitations, phenological changes, communities' restructuring, and rupture of fishing stocks and respective quotas (Arias-Ortiz et al. 2018; Oliver et al. 2018).

Ocean Acidification

The ocean uptakes a third of the atmospheric CO_2 emissions, which causes profound changes in seawater carbonate chemistry. Specifically, the added CO_2 leads to the formation of bicarbonate and hydrogen ions, leading to an acidification of pH values and the sequestration of biological calcium (IPCC 2013). Since the Industrial Revolution, the initial CO_2 atmospheric concentrations of 280 ppm have amounted to over 400 ppm nowadays, with an associated drop in pH from approximately 8.2–8.1. Further increases are expected to happen, and CO_2 concentrations of 760–900 ppm (high confidence from several predictive models) will lead to a concomitant drop of 0.3–0.4 in pH, by the end of this century (IPCC 2013). As for ocean warming, ocean acidification will exhibit large regional and temporal variability, something that will be particularly true for coastal waters, in comparison to the open ocean. Such differential expression is explained by distinct upwelling intensities along the coasts, deposition of nitrogen and sulfur, freshwater input from rivers, as well as organic matter and nutrient runoffs (IPCC 2013; Melzner et al. 2013).

Ocean acidification is considered a major global threat for marine organisms and ecosystems alike (Kroeker et al. 2010, 2012; Rosa et al. 2017; Seibel et al. 2014). Many marine organisms across the trophic web are sensitive to alterations of carbon and hydrogen ion availability, and the ability to cope or not with the forecasted changes can lead to severe ecological shifts in the way ecosystems are organized (Kroeker et al. 2012; Sampaio et al. 2017). The UN and the scientific community have thus made ocean acidification a priority area for research, and the number of experimental projects contemplating its effects on marine life has increased exponentially (Fig. 1). A clearer understanding of what underpins differential biological responses to ocean acidification will allow policy makers and stakeholders to better deal with this problem and build more accurate models of future impacts, both organism and ecosystem wise.

In general, studies so far have shown a pronounced negative impact on marine organisms (Frommel et al. 2011; Kroeker et al. 2010; Rosa et al. 2017; Rosa and Seibel 2008); however, the strength of this effect varies with the vulnerability inherent to different sensitivity of specific taxonomical groups and ontogenetic life stages (Kroeker et al. 2010; Pimentel et al. 2015; Rosa et al. 2013; Wittmann and Pörtner 2013). In detail, ocean acidification is mostly known for the negative effects prompted on calcifying organisms. The augmented quantity of hydrogen ions in seawater leads to a concomitant decrease in available carbonates ions and to a potential dissolution of biological calcium carbonate, from a certain threshold on. The calcium carbonate of echinoderms and mollusks is chemically unprotected from the surrounding environment and thus particularly endangered by this chemical equilibrium imbalance (Kroeker et al. 2010). With comparatively higher repercussions on the ecosystem, the calcification rates of corals, calcifying algae, and coccolithophores are also severely affected, inducing profound changes to habitat structures and food web basis, respectively (Beaugrand et al. 2013; Kroeker et al. 2012). Moreover, impairments on calcification indirectly affect other metabolic and physiological processes, such as growth and reproduction, and can ultimately lead to organism death, especially if coupled with other sources of physiological stress. Nevertheless, some taxa, e.g., crustaceans and fish (particularly the latter), possess advanced mechanisms of acid-base regulation, actively removing excessive ions from the bloodstream (Frommel et al. 2011; Heuer and Grosell 2014). Moreover, both these taxonomical groups possess a biogenic protection over the calcium carbonate structures which likely infers further defense against acidic environments (Kroeker et al. 2010). However, even these taxa have shown ocean acidification-related impairments, particularly at the metabolic and behavioral levels (Munday et al. 2014; Pimentel et al. 2015; Rosa et al. 2017; Rosa and Seibel 2008). Metabolic depression or compensatory upregulation, in response to environmental acidification, is reported for several invertebrates (and even vertebrates,) and is thought to be at least partly caused by decreased extracellular pH, modulated by the inhibition of proton transport across the membrane (Rosa and Seibel 2008; Wittmann and Pörtner 2013). Most likely due to energy reallocation, multiple studies have concurrently suggested linked between lower or altered metabolic rates and upregulation of enzymatic and nonenzymatic CO_2-excretory machinery (Rosa et al. 2016; Sampaio et al. 2018; Wittmann and Pörtner 2013). Moreover, special behavioral impairments in fish and crustaceans have been shown to arise derived from excessive concentrations of H^+/HCO_3^- ions in the GABAergic neurotransmitter system (Nilsson et al. 2012). By increasing the ionic load on the synaptic cleft, the equilibrium necessary for the passage of electrical currents through ionic Cl^- and HCO_3^- concentrations is disrupted, and correct functioning of olfactive reception cues is impaired, increasing vulnerability to predation and difficulty to locate food (Munday et al. 2014).

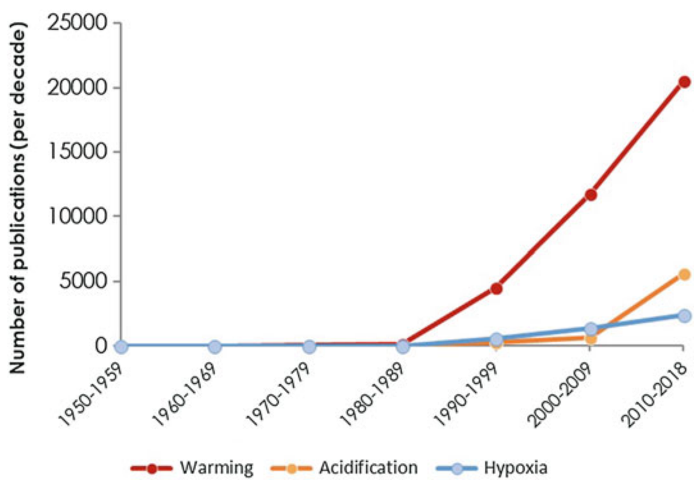
Moving to an ecosystem perspective, the end result at ecosystem levels depends on the role that affected species play in said ecosystem, as small changes to structural species physiology (e.g., corals or macroalgae) will be more visible than changes in consumer physiology, for instance (Fabricius et al. 2011; Hepburn et al. 2011; Kroeker et al. 2012). Thus, several nonlethal physiological effects registered and detailed until now may lead to pronounced changes in community assemblages and trophic interactions (Kroeker et al. 2012; Sampaio et al. 2017). One of the most worrying cases is the competition that tropical and subtropical coral reefs are suffering from algal turfs, worsened by climate changes (Connell and Russell 2010). Coral reefs shelter over a quarter of total marine biodiversity and provide several ecosystem services that are vital for human populations worldwide, such as coastal protection, fisheries, materials and biochemical composites used by industries, as well as ecotourism (Bell et al. 2013). Ocean acidification promotes the dissolution of calcified structures from hard corals, which will weaken its presence in the environment, thus providing a further competitive edge for algal turfs, which harbor significantly less biodiversity and provide a lower range of ecosystem services.

Ocean Deoxygenation

Since consistent time series data started being collected circa 1950, overall oxygen (O_2) concentrations, both in the open ocean and in coastal areas worldwide, has been decreasing at alarming rates, reaching 7 μmol kg^{-1} per decade in the North Pacific's mid-water depths (Keeling et al. 2010). The mean oceanic O_2 content is presently 162 μmol kg^{-1} (or roughly 5.05 mg L^{-1}), but dissolved oxygen concentration, as for temperature and ocean pH, displays high regional and temporal variation (Breitburg et al. 2018; IPCC 2013). At around 500 m of depth, naturally occurring oxygen minimum zones (OMZs) exist in the Atlantic, Indian, and Pacific oceans, close to the tropics, where oxygen regularly reach below 60 μmol kg^{-1} (i.e., hypoxia), resulting from poor water renewal and the input of anoxic water (Levin and Bris 2015). However, given anthropogenic pressures, total OMZs area is nowadays expanding, both horizontally and vertically, for thousands of miles more compared to what was registered in the middle of the twentieth century (Levin and Breitburg 2015). This rate of deoxygenation is faster in coastal areas than in the open ocean, and the number of coastal "dead zones" has increased over tenfold since the 1950s (Breitburg et al. 2018).

Ocean deoxygenation (OD) is caused by diverse chemical and biological processes, which have been exacerbated in recent years. Increasing temperatures are accelerating the spread of hypoxic zones worldwide, by accentuating established depth thermoclines and reducing the vertical mixing of water masses (Breitburg et al. 2018; Diaz and Rosenberg 2008). Water stratification is even more strengthened by salinity differences prompted by freshwater inputs, relating to the melting of polar ice caps and increased precipitation. Concomitantly, other sources of coastal hypoxia are sewage discharges and general runoffs from estuaries where anthropogenic pressure is high (Keeling et al. 2010). The excessive input of nutrients leads to an exacerbation of eutrophication phenomena, and as the superficial layer of water is covered by green algae, the subjacent marine fauna and flora die off, leading to organic matter decomposition, formation of nitrous oxide, and intensive microbial respiration, which depletes coastal waters of O_2 (Diaz and Rosenberg 2008). Not only that, the strengthening of wind-driven upwelling leads to the dispersion of these eutrophic waters into the open ocean. There, the sinking of senescent algae and phytoplankton (also known as "marine snow") increases organic matter decomposition over the water column and the ocean bottom. The seawater masses at these different depths are subsequently driven to coastal areas by the upwelling related outward movement of surface water masses, closing a continuous self-feeding cycle.

Although OD and hypoxia impacts have been somehow neglected by the scientific community in the past decades (Fig. 1), it is known that most life in the oceans is based on aerobic metabolism to catabolize biochemical compounds and produce energy, being thus highly dependent of O_2. Under low O_2 conditions, despite the existence of several hypoxia-tolerant species among metazoan meiofauna, its diversity is extremely reduced, while the selected few species that are usually less motile, i.e., have minor metabolic requirements, such as nematodes, start dominating benthic communities in abundance (Levin et al. 2009). Given their inherently higher motility, phenotypic responses to hypoxia by macro- and megafauna usually start to be detected at the behavioral level (Breitburg et al. 2018). To increase their body surface and O_2 sequestration, amphipods and polychaetes usually extend tubes or their bodies into the surrounding environment by shallowing, completely emerging from the sediment and forming stacks of individuals to move up in the water column (Levin et al. 2009). Continued exposition to hypoxic conditions leads to more pronounced physiological changes, particularly on body size and morphology. Under this scenario, reduced body sizes are particularly favored due to its higher ratio of surface area to body volume, as well as fast life cycles and mass spawning, such as polychaetes which are characterized by prolific respiratory morphological structures. Despite that meiofaunal organisms typically display high population turnover rates, the velocity and range of recolonization of sediments can vary greatly, and continuation of hypoxic events may hinder severely this recovery. Pelagic fish and invertebrates are also affected by these changes on the distribution and content of O_2 concentrations, particularly the ones with higher oxygen physiological demand, such as tunas and sharks (Prince et al. 2010; Prince and Goodyear 2006; Queiroz et al. 2016; Stramma et al. 2012). By diminishing suitable O_2 conditions, the habitat of these macropredators horizontally and vertically is compressed, which prompts shifts on their distribution, migratory potential (for diel movements), and routes, as well as in reallocation of their prey's distribution, which may lead to closer proximities or a decoupling of

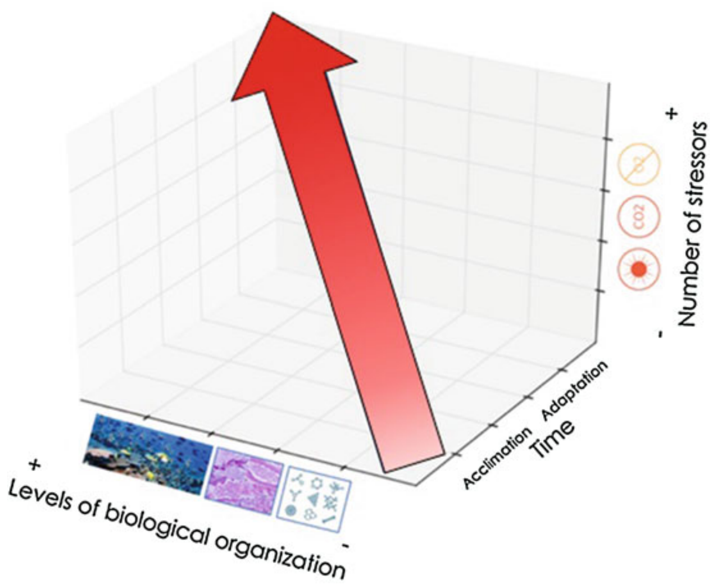


Climate Change, Multiple Stressors, and Responses of Marine Biota, Fig. 1 Publication trends of scientific studies (all fields of research) per decade, from 1950 to 2018, addressing ocean warming, ocean acidification, and hypoxia. Literature search was conducted via Web of Science and carried out with the three stressors (warming, acidification, and hypoxia) together with the words "ocean," "sea," "coastal," or "marine." (Data source: Web of Science, Clavirate Analytics) predator and prey frequented areas, as well as increasing fishing vulnerability (Rosa and Seibel 2008; Stramma et al. 2012). Conversely, pelagic cephalopods, such as the colossal squid (*Dosidicus gigas*), have the capacity to suppress their metabolism to extreme thresholds, allowing for the use of these habitats to escape predators, and also to hunt on OMZ-adapted taxa (Prince et al. 2010; Rosa and Seibel 2008).

Physiological changes driven by oxygen limitation will lead to fragmentation of existing communities, with the possibility of reassembling other communities with similar features (with different participants), which will always change the patterns of competition and interaction strength between trophic levels. At ecosystem level, and as referred before, hypoxic events usually have catastrophic outcomes across the world (Breitburg et al. 2018; Chan et al. 2008; Diaz and Rosenberg 2008). For instance, in temperate marine habitats that should supposedly already be accustomed to hypoxic conditions, the rise of anoxic waters in the Northwestern coast of America caused near-complete die-offs in the totality of trophic web (Grantham et al. 2004). Similar occurrences are known to happen in other coastal areas beneath OMZs which are getting further depleted from O_2. Also recently, Altieri et al. (2017) compiled 20 occasions where hypoxia was directly linked to massive mortalities of fish, mollusks, and corals in tropical waters, adding to the fact that, given the isolation of certain locations (e.g., some Pacific Islands) and rudimentary technology for monitoring, hypoxia events in these world regions are likely very underreported, perhaps by an order of magnitude.

Interactive Scenarios and Consequent Impacts on Marine Biota

Despite the scientific community's (by now well-grounded) understanding of the responses of marine biota to isolated climate change-related stressor scenarios, in the future ocean, all three stressors will interactively affect (e.g., additively, synergistically, or even antagonistically) marine life. The fact that most experiments have been performed using single stressor or single species scenarios hampers our ability to predict the responses of marine communities and ecosystems and sometimes even that of single organisms. Thus, a more integrative and holistic framework is warranted for climate change experimentation and modeling, to accurately portray the biological responses of the marine biota to the future conditions (Fig. 2). Attesting to this, current literature shows that the interactive effects provoked by climate stressors and respective physiological



Climate Change, Multiple Stressors, and Responses of Marine Biota, Fig. 2 Framework for future climate change-related experimental and modeling studies. (Adapted from Nature Publishing Group©, Riebesell, U., Gattuso, J.-P., 2015. Lessons learned from ocean acidification research. *Nat. Clim. Chang.* 5, 12–14. https://doi.org/10.1038/nclimate2456)) response from organisms and communities are many times nonlinear, depending highly on the degree of increase and consistency of each stressor, genetic potential, and phenotypical plasticity of individuals, among other factors (e.g., Riebesell and Gattuso 2015).

Starting with the most studied interaction, and taking the examples used above involving corals (predominantly from tropical areas), both ocean warming (through pushing thermal thresholds) and acidification (through biogenic calcium sequestration and ionic deregulation) will interactively affect marine species' physiology (Kwiatkowski et al. 2015). However, negative or counteracting effects are many times species dependent. In specific coral species, warming (prior to bleaching levels) has been shown to counteract acidification-prompted negative effects (such as decalcification and energy expenditure), by increasing the productivity of the algal symbiont and providing the coral with more energy to regulate carbonate chemistry through acid-base balance, at the sites of calcification (Anthony et al. 2011). However, the general predicted scenario is that the degree to which temperature is increasing (especially through more and more frequent marine heat waves) will indeed lead to bleaching, which will be further worsened by acidification-related energy consumption and decalcification of corals (Anthony et al. 2011). Such is in line with what is being recorded in the present day, wherein two recent mass bleaching occurrences on 2016 and 2017, across the northern area of the Great Barrier Reef, 90% of the corals bleached, and were unable to recover, following extreme weather events (Hughes et al. 2018).

The difficulty in predicting mixed effects of warming and acidification is not exclusive to specific coral species. Other literature has shown that basal activity and metabolic rates are lowered in fish and invertebrates in response to acidification, to allow allocation of energy expenditure to acid-base regulation (Gobler and Baumann 2016; Kroeker et al. 2010; Pimentel et al. 2015; Rosa and Seibel 2008). However, when temperature is added into the equation, metabolic levels can be returned to normal and sometimes raised over what was reported under normal circumstances (Kroeker et al. 2013; Sampaio et al. 2018). Even isolated stressor-elicited physiological responses to oxidative stress have been shown to be normalized under combined stressor presence, in some fish and crustacean species (Pimentel et al. 2015; Sampaio et al. 2018). Nevertheless, such is possible due to a prioritization of underlying basic cellular functions and repairing mechanisms, in detriment of non-vital functions (e.g., reproduction), which may cause further negative impacts on organism and population-wise further down the time line (Kroeker et al. 2013). Thus, responses to combined ocean warming and acidification seem to predominantly depend on species and sometimes individual-specific capacity for physiological trade-offs and the ability of organisms to maintain a significant energy allocation to all functions (vital and non-vital), which determine physiological (i.e., individual) and ecological (i.e., population) fitness (Lopes et al. 2018; Pimentel et al. 2015; Repolho et al. 2017; Rosa et al. 2013, 2017; Sampaio et al. 2016, 2017, 2018)

Ecosystem wise, while in the tropics, these combined stressors generally provoke negative effects; responses in temperate or algae-dominated habitats are potentially self-counteracting (Connell and Russell 2010; Goldenberg et al. 2018). Non-calcifying primary producers can use CO_2 as a nutrient which increases resources for the upper trophic levels. Thus, in these cases, warming-related increases in grazer metabolism are equilibrated by increases in algal biomass, which serves as support for predators, such as fish, to maintain healthy populational status. Conversely, predator-prey interactions and overall top-down pressure are strengthened by warming, which is met by higher resource availability prompted by acidification. However, it is important to highlight that several meta-analytical studies conducted, compiling a substantial amount of the available literature, have shown general negative (albeit differential) effects on both organism and ecosystem levels from the combined exposure to both warming and acidification (Kroeker et al. 2010, 2013). Moreover, the referred maintenance of trophic interactions will be supported by CO_2- and thermal-resilient species which will come with an associated cost to species and possibly functional diversity, since important calcifying species, such as mollusks and echinoderms, will still suffer grave consequences (Gobler and Baumann 2016; Levin and Breitburg 2015). Biodiversity loss is an issue that the general population, particularly managers and stakeholders, are able to comprehend the inherent consequences than of the physiological responses of biota, which may allow for a more "readable" assessment of climate change impacts on socioeconomic context, focusing on ecosystem goods and services.

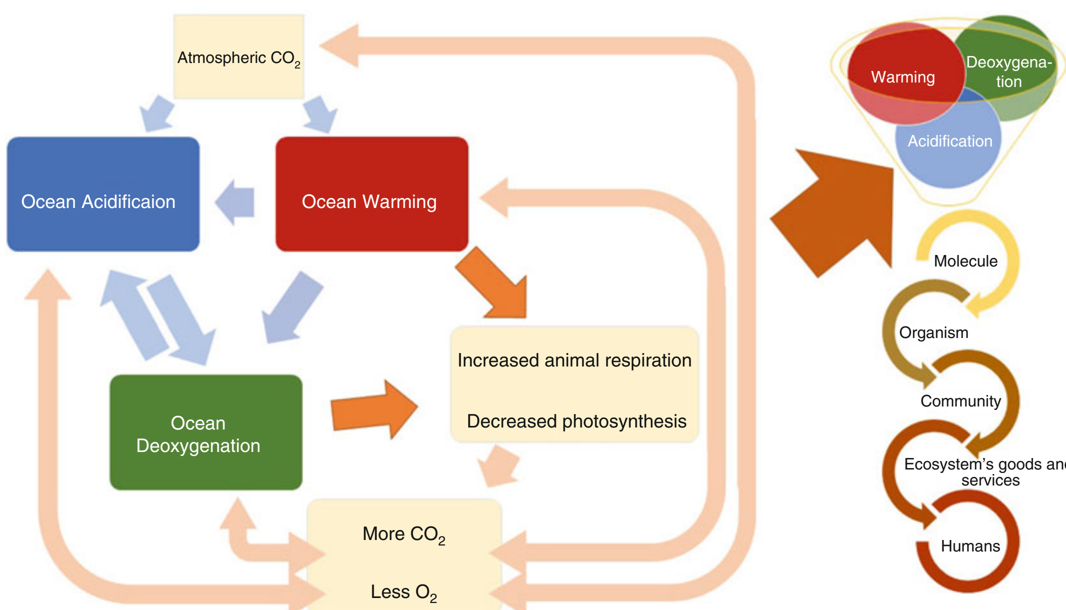
In complete contrast to what is observed for ocean warming and acidification, interactions with ocean deoxygenation appear to present a dreadful linear trend of additive or even synergistic negative effects on marine biota. Not only that, the physico-chemical underpinnings prompting each stressor are themselves synergistic and will, in all likelihood, further stimulate the impacts registered for isolated stressors (Breitburg et al. 2018; Levin and Breitburg 2015). Increasing temperature reduces O_2 solubility, increases water stratification (lowering mixing rates), and increases animal respiration and O_2 consumption, among other effects which reduce mean oceanic O_2 content. Accordingly, albeit taxonomical-specific differences must be considered; low O_2 conditions and warming synergistically increase the vulnerability of marine biota, by impacting virtually all biological responses, including survival, metabolism, abundance, and reproductive outputs. The higher metabolic cost demanded by increasing temperature lowers oxygen threshold concentrations for marine fauna (Rosa et al. 2013), which taxonomically decrease from fishes to crustaceans, and mollusks, with meiofauna following, i.e., polychaetes, echinoderms, and cnidarians (Vaquer-Sunyer and Duarte 2008, 2011). The extent of these impacts will also depend on species-specific physiological strategies, life stages, and motility, as well as populational adaptations to the gradual abiotic changes (Vaquer-Sunyer and Duarte 2008). Nevertheless, it is consensual that these interactive effects will reduce both the quality and the range of suitable habitats for aerobic organisms to live, leading to constrictions on both organism development, population health status, and marine biodiversity.

Concomitantly, hypoxic and acidified areas are linked by the process of heterotrophic and autotrophic respiration, given the removal of O_2 and adding CO_2 to the surrounding environment (IPCC 2013; Levin and Bris 2015). Thus, it is not uncommon to have daily occurrences of this interaction on, e.g., eutrophic ecosystems, where nutrient inputs drive communities to grow and respirate more on nocturnal hours. Accordingly, OMZs are also low pH locations, and their shoaling is tightly associated with additional acidity, which can create corrosive conditions during upwelling events on coastal ecosystems (Levin et al. 2009). Furthermore, this increase in CO_2 can decrease the oxygen affinity of respiratory proteins, while the required increased metabolic costs for maintaining acid-base balance are further worsened by lower capacity in meeting aerobic demands, stemming from lower O_2 concentrations (Pörtner and Knust 2007). Despite the paucity of studies analyzing the interaction between ocean deoxygenation and acidification, the first is confirmed as the strongest detrimental impactor, being additively, or in some cases synergistically, worsened by the co-occurrence of the latter (Gobler and Baumann 2016). These effects are most prominent in early ontogenetic life stages and are logically dependent of the current conditions the organisms face nowadays, e.g., despite still exhibiting negative effects, mollusks with a strong anaerobic capacity residing in areas of diurnal acidification/hypoxia are more resilient compared to organisms from low productivity/oxygenated areas (Breitburg et al. 2018; Vaquer-Sunyer and Duarte 2008). Also, echinoderms and other calcifying taxa struggle to cope with hypoxic conditions, which has been linked to the increased energetic demand for acid-base balancing provoked by an acidified environment (Breitburg et al. 2018). Although it is still early to accurately predict the impacts of this interaction on communities and ecosystems, all evidence hints to a strong decline in several traits, which will have profound implications for fisheries and other ecosystem services, particularly in industrialized coastal ecosystems.

"The Deadly Trio" Scenario

As made clear by the previous sections, ocean deoxygenation is connected to both warming and acidification, and this triple interaction will shape much of ecosystems' fitness in the future years to come (IPCC 2013) (Fig. 3). Given the virtual nonexistence of experimental evidence for this multi-stressor scenario (albeit the most realistic one), current bioenergetic frameworks can be useful in helping determine organism fitness in future oceans. Beyond the already weighted physico-chemical and biological synergetic mechanistics, while temperature increases metabolic demands, deoxygenation cuts off O_2 supply and lowers metabolic potential (Breitburg et al. 2018; Pörtner and Knust 2007; Vaquer-Sunyer and Duarte 2011). Simultaneously, lower pH can require further energetic costs on ventilation and acid-base balance and activation of antioxidant and protein repair mechanisms, which will require energy reallocation from an increased basal metabolism (Gobler and Baumann 2016; Levin and Bris 2015). Parallelly, both lower O_2 and pH are expected to reduce organism thermal windows, by pressing on their respective physiological thresholds (Kroeker et al. 2013; Vaquer-Sunyer and Duarte 2011). These physiological constraints cascade into ecological pitfalls, with ecosystem and community level changes predicted to be drastic, given massive mortalities (at all trophic levels), registered on several naturally occurring phenomena, such as prolonged exposure to eutrophic conditions and upwelling of hypoxic/acidic seawater masses (Breitburg et al. 2018; Chan et al. 2008; Keeling et al. 2010). Even the few antagonistic effects between ocean warming and ocean acidification contributing to organism and community resilience will likely be unbalanced toward negative impacts, when coupled with ocean deoxygenation (Altieri et al. 2017; Breitburg et al. 2018).

Thus, overall organisms, populations, communities, and entire ecosystems are predicted to have their physiological and ecological potential reduced across multiple abiotic (and consequently biotic) dimensions and traits, which will lead to pronounced impacts on both non-vital and vital functions, severely compromising organism, population, community, and ecosystem viability. It is important to retain that these alterations are ongoing and that field data already reveals significant alterations in community dynamics and species distribution (Breitburg et al. 2018; Queirós et al. 2015; Queiroz et al. 2016; Stramma et al. 2012). Ocean



Climate Change, Multiple Stressors, and Responses of Marine Biota, Fig. 3 Underlying links, impacts, and consequences of the "deadly trio" deoxygenation, warming, and acidification alter biogeochemical cycles, climate-regulating processes, heat distribution, wind regimes, and ecosystem services for the human population (Breitburg et al. 2018; IPCC 2013; Kroeker et al. 2012). Beyond the negative biological impacts on marine biota described along this entry, one should keep in mind the sharp repercussions at socioeconomic levels. Climate change will also imply severe losses of ecosystem's goods and services, leading to strainings in human activities and even diplomatic relations between countries (Breitburg et al. 2018; Frazão-Santos et al. 2016). Ocean management should rely on holistic frameworks combining modeling, observations, and experiments under multi-stressor environments to raise awareness within stakeholders and governments. This should ideally lead to halting or slowing the currently in effect rates of climate change-related gas emissions, in the hopes of thwarting a somber future for both marine life and human populations.

Cross-References

▶ Anthropocene and Climate Change
▶ Extreme Weather Events: Definition, Classification, and Guidelines towards Vulnerability Reduction and Adaptation Management

Acknowledgments The authors, and the work for producing this entry, were funded by PTDC/BIA-BMA/28317/2017, PTDC/AAG-GLO/1926/2014, and MAR-01.04.02-FEAMP-0007.

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Climate Change-Induced Mobility

► Climate Change and Human Migration as Adaptation: Conceptual and Practical Challenges and Opportunities
► Climate Refugees: Why Measuring the Immeasurable Makes Sense Beyond Measure

Climate Finance: Unlocking Funds Toward Achievement of Climate Targets Under the Paris Agreement

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Introduction: Understanding the Current Climate Financial Landscape

There is an undeniable urgency on the need to finance climate change activities with high greenhouse gas (GHG) emission reduction impact. The 2018 Intergovernmental Panel on Climate Change (IPCC) special report on *the impacts of global warming of 1.5 °C above pre-industrial levels and related global GHG emission pathways* confirms that warming greater than the global annual average is already being experienced in many regions (IPCC 2018). Additionally, the 2018 Emission Gap Report by the UN Environment reiterates the unlikeliness of holding global warming below 2 °C if current GHG emission trends prevail. The emission reduction efforts described in current national actions plans submitted by countries under the Paris Agreement on Climate Change would need to be tripled by 2030 to avoid a 2 °C warming scenario and increased fivefold for the 1.5 °C warming threshold (UNEP 2018).

Without a doubt, reducing GHG emissions will require massive new and additional investments. The importance of aligning financial flows to provide developing countries with low-emission technologies and climate-resilient development pathways is now more critical than ever to deliver on the 2030 Agenda for Sustainable Development and meet the Paris Agreement on Climate Change. But out of all the challenging conversations at the core of negotiations under the United Nations Framework Convention on Climate Change (UNFCCC), dealing with money is arguably one of the most persistent and difficult.

Based on the common but differentiated responsibilities and fair principles, the Convention requires developed countries to assume historical responsibility by providing new and additional financial resources to Parties from developing states in support of climate action implementation (Zhang and Pan 2016). However, developed and developing countries known under the convention as Annex 1 and non-Annex 1 countries interpreted this entry differently. Over the years, this misunderstanding between parties created a rift in expectations, delivery, accountability, use, and access of funds. Consequently, this misinterpretation created gaps in the execution and disbursement of funds where it is most needed.

For example, it has been argued that one of the more controversial estimates on climate finance flows is the US$ 100 billion figure that was introduced as part of the Copenhagen Accord in 2009. For a background, at the 15th Conference of Parties (COP15), Annex 1 countries committed to providing 30$US billions of fast-track finance between 2010 and 2012, promising to mobilize US$ 100 billion per year of long-term climate finance starting in 2020 (Weikman and Roberts 2019). Following the Copenhagen Accord in 2009 was the Cancun Agreement in 2010, which defined the US$ 100 billion to include public contribution as well as mobilized private sector funds. It was, however, never decided how different public sector instruments will be accounted for nor which criteria will be applied to define the private sector contribution. Furthermore, this figure does not refer to needed global investment but rather represents only the funding to be provided to developing countries by developed countries. It has also been argued that the US$ 100 billion amount was derived without much justification and evidence for the chosen amount from concrete assumptions on financing requirements for climate action (Sterk et al. 2011). Additionally, many developing countries on the one hand have highlighted the need for scaled-up international support (including finance) in implementing the Paris Agreement and the difficulties countries face to access the existing funds under the various financial mechanisms (Hedger and Nakhooda 2015). On the other hand, the real absorptive capacity by some developing countries to handle relatively large volume of climate funds, in the absence of robust fiduciary framework, has been raised by some developed countries. Additionally, there is growing expectation from developed countries for emerging economies such as China and India to contribute to global climate finance in the future based on their capacities.

Ensuring that sufficient finance and investment is available, accessible, trackable, and used for purpose will be the major challenge going forward. It is essential to bridge the gaps and barriers to unlock funds, in order to maintain temperature below 1.5 C under the Paris Agreement rulebook, hence the rationale for this entry.

Gaps in Identifying Climate Finance Contributions

There is an ongoing debate about the types of funding to be considered as climate finance. A report released by the Organization for Economic Co-operation and Development and Climate Policy Initiative (OECD-CPI), ahead of the Paris Agreement negotiations in 2015, indicated how much funds developed countries are delivering to developing countries as part of the US$ 100 billion pledge (OECD 2015).

The OECD-CPI report put forward the following figures, that is, US$ 52 and 62 billion in years 2013 and 2014, respectively, and argued its relevance for the US$ 100 billion goal. While the report attempted to illustrate how developed countries are achieving their collective pledge, it did not have the desired effect for developing countries. Non-Annex 1 countries questioned the report's methodology in calculating the contributions. For example, speaking on behalf of the G77 + China, a chief negotiator at the United Nations climate talks in Bonn was quoted as saying: "I am not able to comment on or judge the report because we don't know the veracity, credibility and the methodology of the report or who was consulted. Developing countries were not. It has no status in the UN negotiations. It was not commissioned under the mandate of the UNFCCC" (Quoted in Sethi 2015; Weikman and Roberts 2019).

Another developing country negotiator was quoted as saying "The OECD calculations include non-concessional loans and existing overseas development assistance provided to developing countries. How can these be regarded as climate finance flows when the climate convention clearly states the flows are to be new and additional?" (Quoted in Sethi 2015; Weikman and Roberts 2019).

Non-Annex 1 countries seem to have questioned the legitimacy of the report stating that since the report was not commissioned under the mandate of the UNFCCC, it held no legality under the convention. They also rejected the report's conclusions (Indian Ministry of Finance 2015). After the release of the report, a senior advisor in a Ministry of Finance from a developing country who is also a climate finance negotiator was quoted as saying: "The most fundamental assessment should have been that the total flows (of climate finance) provided by the developed countries should be matched to the total flows received by the developing countries. The report is silent on this" (Quoted in Sethi 2015; Weikman and Roberts 2019).

Since national plans vary greatly in content from one country to another and a number of countries focus on both adaptation and mitigation actions, it is important to determine the types of funding to be considered as climate finance. However, the Paris agreement does not seem to provide enough clarity in this area.

Gaps in Tracking Climate Finance Flows

There is no commonly agreed format to report on the financial support received, nor is there a common methodology for evaluating the financial support received. Determining how to account resources mobilized through the private sector is still a lingering challenge (Caruso and Ellis 2013). In addition, the UNFCCC guidelines do not require information on the underlying assumptions, definitions, and methodologies used to generate the information on climate finance received or methodologies for performance evaluations in the mobilization of private climate finance.

The Standing Committee on Finance (SCF) which assists the COP in measuring, reporting, and verification of financial mechanisms support provided to developing country Parties delivered a progress report on the matter at the COP24 (UNFCCC 2018). The 2018 Biennial Assessment (BA) and Overview of Climate Finance Flows included, for the first time, information relevant to Article 2, paragraph 1(c), of the Paris Agreement, including methods and metrics and data sets on flows, stocks, and considerations for integration (UNFCCC 2018).

While continued efforts to make climate finance information more accessible and transparent have been made, not only by governments from recipient countries and donors but also by nongovernmental (international, regional, and local) organizations, issues around the transparency of financial contributions persist. Under the Paris Agreement, provisions regulating climate finance contributions and its reporting obligations are not legally binding (Ferreira 2018). As demand for international climate finance flows is set to rise, transparency is an important tool for building trust between developed and developing country partners. Methodological issues relating to measurement, reporting, and verification of public and private climate finance flows persist, making identifying and quantifying the financial contributions challenging. Improving the effectiveness of climate finance accounting, reporting, and overall transparency is imperative.

Gap in Raising Public Funds for Climate Finance

Another gap is the apparent inability by developed countries to raise the promised amount via public finance mechanism. The amount of investment needed to address climate change is projected to surpass the US$ 100 billion per year target. To prevent the worst impacts of climate change, net additional investment of around US$ 4 trillion (about US$ 270 billion per year) will be needed (Global Commission on the Economy and Climate 2014). This cost represents only a 5% increase over the business-as-usual scenario and is likely to be offset in the longer term by fuel cost savings (Global Commission on the Economy and Climate 2014).

Article 9 of the Paris Agreement stipulates that Annex 1 Parties shall provide financial resources to assist developing country Parties as well as lead in mobilizing climate finance from a wide variety of sources, instruments, and channels, noting the significant role of public funds, through a variety of actions, including supporting country-driven strategies, and taking into account the needs and priorities of developing country Parties (UNFCCC 2015).

In general, public climate finance supports projects and aims to address market failures. In that regard, public funds have the ability to close funding gaps which would exist if only the private sector could provide financing (Clark et al. 2018). On one hand, developed countries have contributed through grants. However, studies have shown that reaching the US$ 100 billion goals is unlikely unless a major part of the funds stemming from public funds are disbursed as concessional loans (Westphal et al. 2015).

Part of these public funds finance multilateral climate finance mechanisms. More precisely, the Convention established a financial mechanism with operating entities that are accountable to the COP. The Global Environment Facility (GEF) was established in 1994 and the Green Climate Fund (GCF) in 2011 as an operating entity of the financial mechanism. The GEF also manages the Special Climate Change Fund (SCCF) and the Least Developed Countries Fund (LDCF). In addition to these funds, the Adaptation Fund (AF) was established under the Kyoto Protocol in 2001.

These funds are replenished through contributions from developed countries. The latest assessment report from the SCF indicates that multilateral climate fund total amounts channelled through UNFCCC funds and multilateral climate funds in 2016 were US$ 2.4 billion (UNFCCC 2018). That same year, climate finance from multilateral development banks provided US$ 25.5 billion in climate finance from their own resources to eligible recipient countries (UNFCCC 2018) (Fig. 1).

The summary and recommendations of the 2018 Biennial Assessment and Overview of Climate Finance flows of the Standing Committee on Finance presented at the COP24 highlighted that financial flows increased by 17% in 2015–2016 from 2013–2014 levels. It was indicated that part of this increase was due to high levels of new private investment in renewable energy (UNFCCC 2018). The total finance reported in 2016 was of US$ 38 billion, out of which US$ 34 billion was reported as climate-specific finance and channelled through bilateral, regional, and other channels; the remainder flowed through multilateral channels (UNFCCC 2018).

Furthermore, the World Economic Forum (WEF) Green Investment Report stipulates that additional, incremental investment in the order of US$ 700 billion per year would be needed to meet the global climate change challenge with regard to clean energy infrastructure, low-carbon transport, energy efficiency, and forestry (Green Growth Action Alliance 2013).

The WEF estimate reiterates that new kinds of investments are needed to achieve sustainability goals. Although the annual US$ 100 billion target is set for 2020 on, the 2016 figures clearly indicate the gap in raising the promised amount by developed country through public finance mechanisms.

Challenges in Tracking New and Additional Climate Finance

New and additional funds refer to resources being mobilized that are beyond existing development cooperation budgets, but funders have yet to define what constitute additional funds (Stadelmann et al. 2011). In the absence of an internationally agreed definition of the terms "new and additional" climate finance in the UNFCCC, each country has its own definition of these terms. As a result, each member state can decide what is considered climate finance and why is that climate financing option "new and additional." For example, some developed countries account all financial instruments toward climate action at nominal cash value (OECD 2015). This means that developed countries could possibly opt to count loans they grant to developing countries as climate finance.

	Annual average USD billion	Area of support				Financial instrument		
		Adaptation	Mitigation	REDD-plus[a]	Cross-cutting	Grants	Concessional loans	Other
Multilateral climate funds[b]	1.9	25%	53%	5%	17%	51%	44%	5%
Bilateral climate finance[c]	31.7	29%	50%	–	21%	47%	52%	<1%
MDB climate finance[d]	24.4	21%	79%	–	–	9%	74%	17%

Climate Finance: Unlocking Funds Toward Achievement of Climate Targets Under the Paris Agreement, Fig. 1 Characteristics of international public climate finance flows in the period 2015–2016. (Source: UNFCCC 2018)

This loose definition creates overlaps between development assistance and climate financing. The table below was prepared by the United Nations Conference on Trade and Development (UNCTAD) and illustrates a number of interpretations of what additional official flows for climate change mean for different developed countries (UNCTAD 2015).

Under the first option showcased, climate finance is considered additional if it is over and above the 0.7% official development assistance (ODA) or gross national income target. This percentage was established in 1970 by the Development Assistance Committee (DAC) of OECD to measure aid. It was prepared before climate change was recognized and therefore did not factor in the additional finance needed to tackle climate change. The second optional definition for climate finance sets a reference year as the baseline for expenditures relevant to climate finance. The reference year is determined at the discretion of the country, and the additional climate investments can be set on a random amount or percentage, i.e., 2018 climate finance contribution for country A would be of one million USD above 2009 investments or as another example, country B would, for 2018, dedicate funds 3% above 2017 climate finance flows. The third option suggests that finance for climate change should be included in the country's development aid funding but limited to 10% of ODA. Depending on the country's pledges to the various financial mechanism and bilateral development aid, additional funding might be needed. Under the fourth option, new source considered additional stem from other alternative sources of finance such as international air transport levies, currency trading levies, or auctioning of emission allowances (Knoke and Duwe 2012) (Table 1).

It is understood from the table above that budgets of multi-sectorial development programs with a climate action component are reported and counted as climate finance. This reporting method results in double accounting of financing for development environmental aid and climate finance.

While criteria for ODA have been defined quite clearly, there is no such clear-cut definition for climate finance. At the same time, there are considerable overlaps, both geographical and sectoral, between development and climate change issues that add a level of complexity when tracking climate-specific funding.

Challenges for Developing Countries to Access Funding

Stringent Rule

Provisions were added under the Paris Agreement to allow non-Annex 1 countries most vulnerable to climate change to access funds. Notably, it is understood that relevant operating financial entities of the convention are required to ensure efficient access to financial resources through simplified approval procedures and enhanced readiness support for Least Developed Countries and Small Island Developing States, in the context of their national climate strategies and plans (UNFCCC 2018). However, the various rules and regulations to the funds complicate direct access to the funds, especially by some of the most vulnerable countries. Taking the example of the Green Climate Fund (GCF), the extensive rules surpass capacities of a number of countries. For instance, if a country would want any of its national departments to become an official entity and direct recipient of GCF funds, then that institution needs to undergo the GCF's accreditation. This rigorous process would lead the nominated national entity to demonstrate the compliance with the funds fiduciary and gender policy standards and environmental and social safeguards as well as have a track record of delivering mitigation and adaptation projects and show functional independent audit committee over the past 3 years, various procurement committees, relevant guidelines and data on complaints handled in the past 2 years, examples of conflicts of interest in the past 2 years and how they were dealt with, and so on (Green Climate Fund 2017). The GCF also has a special readiness program to support developing countries' institutions through the accreditation process.

While due diligence is a vital exercise, the current process meant to accelerate access might not in actuality enable the desired result for reasons beyond the fund's mechanism. As an

Climate Finance: Unlocking Funds Toward Achievement of Climate Targets Under the Paris Agreement, Table 1 Summary of climate finance definitions

Options	Definitions	Member States currently in support of options
Option 1	Funding above the 0.7% ODA target	Denmark, developing countries, Luxembourg, the Netherlands, Norway, Sweden
Option 2	Increase in current levels of climate finance (reference year, 2009)	Austria, Estonia, Finland, Germany, Slovenia, Spain
Option 3	Funding additional to the level of ODA spending in nominal terms	Belgium, European Commission, Hungary, Latvia, Portugal, Slovak Republic, United Kingdom
Option 4	Increase in climate finance from new sources	Germany, Poland

Source: UNCTAD (2015)

example, Africa holds 33 out of 47 Least Developed Countries, and these countries are also in need of the readiness program. Unfortunately, these countries happen to be ranked high in Transparency International's perceived corruption report, adding a level of difficulty in compliance to some transparency requirements of the GCF to obtain accreditation (Fig. 2).

Alternatively, some countries opt to access the funds through multilateral institutions that are already GCF accredited or that have the means to become accredited quickly. As designated entities, the multilateral institutions also have greater input in allocation of funds to the country to support national processes in the GCF Readiness activities. This substitute approach then puts into question the level of immediate ownership, control, and accountability of GCF projects by countries taking this route until after a period of time when capacity in the recipient country has been built by the multilateral institution providing GCF support. The question therefore is how to, in a concerted manner, improve the system to facilitate an expedited capacity building initiatives in developing countries to enable them access directly the GCF.

Lack of National Coordination and Fragmentation of Climate Financing Sources

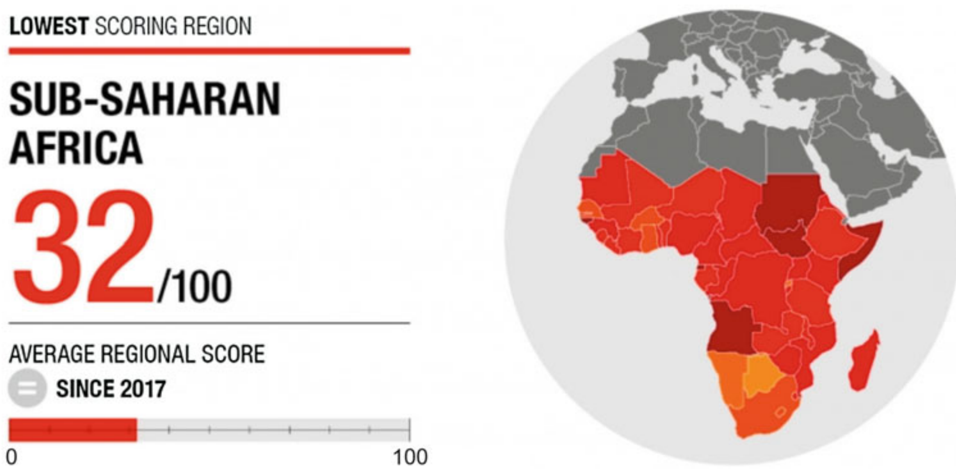
The fragmentation of financing sources and funding priorities presents accessibility challenges. Recent reports on development aid in general have indicated that increased coordination of development and climate-related activities among various donors operating in a country increases the transparency of resource commitments and delivery (Lundsgaarde et al. 2018). Other reports have highlighted the fact that a number of developing countries show deficiency in their ability to successfully coordinate, at national level, donor programs and funding. This lack of organization ultimately makes it more challenging to identify financial needs at national level and to attract further financing (Halonen et al. 2017).

With regard to climate finance flows, a recent study by the World Resource Institute (WRI) concluded that the multiplicity of bilateral and multilateral climate funds creates in the end and overlaps in work programs as well as inconsistencies in procedures for accessing and managing funding (Amerasinghe et al. 2017).

Opportunities to improve practices did arise from these findings. For example, it has been concluded that a development aid project's success rate is greater when donors pay due diligence to recipient country's national priorities and the use of country systems for implementation of the activities (Abdel-Malek 2015). As climate finance funding opportunities increases, the need to ensure effective national coordination with regard to disbursement of funds, objectives of climate-related programs, and expenditures is paramount going forward.

The Scale of Needed Investment

Currently a reported US$ 360 billion is invested annually in public and private climate investments, comprising of about US$ 10–20 billion



Climate Finance: Unlocking Funds Toward Achievement of Climate Targets Under the Paris Agreement, Fig. 2 Sub-Saharan Africa *Corruption Perceptions Index*. (Source*:* Transparency International 2018)

per year from developed countries governments, according to their fast-start finance reports and OECD estimates (OECD 2015). However, the amount that would be needed according to The Green Growth Action Alliance is US$ 5.7 trillion (WEF 2018). This will however need to be invested annually in green infrastructure, especially in developing countries (Green Growth Action Alliance 2013). This will require shifting the world's US$ 5 trillion in business-as-usual investments into green investments.

An estimate by the World Economic Forum indicates that the world will have to invest an estimated US$90 trillion just in infrastructure over the next one and half decade. This translates to an increased in today's US$3.4 trillion a year spending to US$6 trillion. This kind of money will be needed to be able to invest in the needed ideas, businesses, and technologies that would yield GHG emission reductions (WEF 2018).

Options to Alleviate the Barriers and Challenges to Unlocking Funds

Rethinking Public Source of Financing

Historically, climate finance commitments under the climate change convention have been agreed through a top-down approach where developed countries committed a certain amount to the developing countries. Indeed, it has been agreed that developed countries have emitted over 75% of cumulative global GHG emissions since the mid-nineteenth century. Scientists have been able to illustrate that the occurring anthropogenic climate change is largely the result of these past emissions (IPCC 2018). Consequently, under the climate change convention, developed countries are responsible for transferring technologies and providing financial contributions for climate mitigation and adaptation investment in developing countries. However, as discussed above, a number of challenges and barriers in the current climate public financial mechanism prevent effective fund transfer to the developing countries.

One possible option would be to strengthen individual countries' capacity to absorb and manage climate funding through national initiatives. This approach could allow countries to get direct access to multilateral funds and consequently gain more ownership of climate actions being taken within their borders. For example, governments could set up a national financial entity dedicated to coordinate national climate strategies and be used as the official channel through which financing from international sources would transit by. The Brazilian Development Bank (BNDES), Corporación Financiera de Desarrollo (Cofide), Peru, South Africa's Development Bank of Southern Africa (DBSA), and Uganda Development Bank are all example of National

Development Banks (NDB) that could, for example, be possibly considered for nationwide coordination of climate-related activities. The process for setting up such institutions is less stringent than acquiring accreditation as such local institutions, in addition to being largely government-led, are also dependent on domestic budgets and other macro- and microeconomic factors in-country (Inter-American Development Bank 2013). While national funding sources for climate adaptation and mitigation projects in developing countries are not as well established as the multilateral or bilateral financing agencies globally, the NDB could, for example, be used to provide a greater oversight of climate finance expenditures in a given country.

Innovative Private Source of Financing

Although efforts have been made to estimate private climate finance mobilized through multilateral and bilateral institutions, data on private finance sources and destinations are still lacking. The various private sector source of climate financing include debt investments and private equity investment management services, exchange, insurance companies, and pension funds and microfinance (Ruppel and Luedemann 2013). One way to better track private financing would be to create financial products specific to climate investments.

Microfinance, for example, is a form of financial services for small businesses and entrepreneurs but also households to access finance when they lack access to banking and related services. The main role for microfinance institutions (MFI) is to enhance financial inclusion at affordable costs to disadvantaged and low-income communities (Singh and Yadav 2012). A growing number of MFIs are also diversifying their products and services toward dedicated climate finance products. This shift can be seen in promoting clean energy products. Renewable energy solutions such as solar home systems and anaerobic digesters (biogas) are important to low-income families as they provide affordable access to clean energy and sometimes even new income-generating opportunities (Rippey 2009). MFI can help in accessing energy-efficient options for energy-intensive activities such as home cooking and lighting. MFI provide an opportunity for customers to leapfrog to energy-efficient intermediaries technologies at a reduced cost.

Reducing Climate Finance Risk Through Financial Regulation

Financial regulation supporting climate change action is currently uncommon but could be an option comparable to regulation targeting other secondary financial markets. Clear regulation is required to force the financial sector to drive global transformation toward a green economy. Standardized carbon accounting and reporting will contribute in elevating climate risks when considering financial investments. It is important that appropriate carbon metrics are used to ensure carbon performance is adequately assessed (Folger-Laronde and Weber 2018).

Traditionally, investors are only willing to invest on a short-term basis, while, on the other side, many climate-related projects (energy-efficient cooking and lighting, cooling systems, resilient infrastructure, etc.) projects require financial commitments for long-term investments. The Basel Committee on Banking Supervision (BCBS) is the primary global standard setter for the prudential regulation of banks (Basel Committee on Banking Supervision 2017). As such, the Basel's series, its International regulatory accord which seeks to improve the banking sector's ability to deal with financial stress, improve risk management, and strengthen the banks' transparency should be considerate of climate risks as well.

Recent revisions of the Basel III banking regulation resulted in higher capital requirements for banks when providing long-term loans (Basel Committee on Banking Supervision 2017). This updated requirement consequently discourages banks from long-term lending. Considering that climate finance investments are considered long-term, current international banking regulations do not entice investments in climate projects.

Establishing a Monitoring, Verifying, and Reporting Framework for Climate Finance

To achieve a more independent and sustainable development process, developing countries should be able to build up national capacities to monitor, report, and verify the various climate finance sources.

It is important for countries to identify the climate finance proportion included in the envelopes received for development assistance. Conducting a national mapping exercise of relevant multilateral and bilateral funds as well as private sector actors will provide clarity in terms of knowing the actual amount invested in climate actions. Establishing clear MRV modalities for accounting each financial assistance is key. Another key point to consider would be to create procedures and methodologies to isolate climate finance components in projects with multiple development objectives. For example, separate accounting of the nominal value of climate finance provided against the concessional components of the finance provided would be identified in the project's financial reporting.

Conclusions

A reported US$ 5.7 trillion will need to be invested annually in green infrastructure, much of which will be in today's developing world (Green Growth Action Alliance 2013). This will require shifting the world's US$ 5 trillion in business-as-usual investments into green investments. We are currently at US$ 360 billion annually in public and private climate investments, with developed country governments providing somewhere between US$ 10 and 20 billion per year, according to their fast-start finance reports and OECD estimates (OECD 2015). When one considers these figures, the US$ 100 billion annual goal that is often referenced, though it is something to start with, is only a small piece of the US$ 5.7 trillion puzzle. Both public and private levels of funding need sustained injection of funds and disbursements to ensure that the world get on a pathway to meeting investment needs in 2020 and beyond such as to help limit the global average temperature increase to 2 °C above pre-industrial levels. Green investment can be scaled up to deliver sustained global growth through the implementation of the Paris Agreement. However, it is imperative to address the current urgent challenges and barriers that hinder access to needed climate finance funds.

Definitions

Climate finance: refers to local, national, or transnational financing – drawn from public, private, and alternative sources of financing – that seeks to support mitigation and adaptation actions that will address climate change (UNFCCC 2019).

Concessional loan: loans that are extended on terms substantially more generous than market loans. The concessionality is achieved either through interest rates below those available on the market or by grace periods or a combination of these. Concessional loans typically have long grace periods (IMF 2003).

Nationally determined contributions (NDCs): The Paris Agreement establishes binding commitments by all Parties to prepare, communicate, and maintain a nationally determined contribution (NDC) and to pursue domestic measures to achieve them. It also prescribes that Parties shall communicate their NDCs every 5 years and provide information necessary for clarity and transparency (UNFCCC 2019).

Paris Agreement Article 2, paragraph 1(c): (c) Making finance flows consistent with a pathway toward low greenhouse gas emissions and climate-resilient development.

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Climate Induced

▶ Sociocultural Impact of Climate Change on Women and the Girl Child in Domboshawa, Zimbabwe

Climate Literacy

▶ Climate Change Literacy to Combat Climate Change and Its Impacts

Climate Migrants

▶ Climate Change and Human Migration as Adaptation: Conceptual and Practical Challenges and Opportunities

▶ Climate Refugees: Why Measuring the Immeasurable Makes Sense Beyond Measure

Climate Perturbations

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Climate Refugees: Why Measuring the Immeasurable Makes Sense Beyond Measure

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Synonyms

Climate change-induced mobility; Climate migrants; Climate refugees; Climate-related human displacement; Environmentally displaced people

Definition

Climate change-related human movement typically occurs within a complex web of commingled contributory causative factors. Hence the multicausality inherent in human movement makes attribution or disaggregation of causality an almost intractable problem. Nevertheless, climate change is now widely recognized as a key contributing migration push factor. Moreover, there is agreement among experts that its contribution to migration, relative to other causes, is growing. This suggests a possible, if not probable, influx in "climate refugees" (Reeves and Jouzel 2010), although this term is contested in the literature (cf. Zetter 2017; Ahmed 2018; see Box 1). Adopting a posture of "preparedness" emerges as an important priority for effective adaptation to climate change, where "migration" is seen not as a "failure to adapt" but rather as a "strategy to survive". This discourse argues that quantitative scenarios of "climate refugees" are an essential prerequisite for anticipatory adaption to climate change.

Introduction

This chapter explores the topic of climate change and human migration (CCHM) within the broader framework of the United Nations Sustainable Development Goal (SDG) 13: Climate Action: Take urgent action to combat climate change and its impacts (UN 2019). More specifically, Targets 1 and 3 explicitly emphasize the need for anticipatory adaptation to climate change, envisaging progress as follows:

- “Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries” (Target 1).
- “Improve education, awareness-raising, and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning” (Target 3).

Situated within this context, discourses about CCHM typically comprise theoretical, practical, empirical, analytical, and computational challenges, among others. Importantly, adaptation to climate change in the global migration arena is a strategic human development and policy concern, which typically envisages a forward-thinking posture of “preparedness.” In short, safeguarding equitable sustainable development (Luetz and Walid 2019) makes the proactive engagement in the CCHM space a strategic and fertile undertaking (EC 2019).

In terms of content arrangement, this chapter is divided into three sections and organized as follows. Section “Multicausality and Disaggregational Difficulties” introduces the multicausality inherent in climate change-related human migration and discusses arising attribution challenges and disaggregational difficulties. Thereafter, section “Numerical Projections, Predictions, and Predicaments” outlines prediction problems in respect of making, proving, or disproving numerical projections of future CCHM. Finally, section “Concluding Synthesis: Catalyzing Anticipatory Climate Change Adaptation” provides a synthesis of the state of the art, concluding that in terms of promoting preparedness and anticipatory adaptation to climate change, measuring the immeasurable makes sense beyond measure.

Multicausality and Disaggregational Difficulties

C

The nexus between climate change and human migration is intricate, since cause-and-effect relationships can be difficult to establish. Any migrant’s decision to move is invariably influenced by numerous and often interrelated factors. Attempts to dissect a migrant’s resolve to leave, and disaggregating the mix of factors that underlie that decision into “environmental” and “non-environmental,” “climate related” and “non-climate related,” or “forced” and “voluntary” categories, can be daunting, if not outright impossible. To what extent is a migrant “pushed” out of his or her human habitat by environmental degradation – or “pulled” away from it by the promise of a better life elsewhere? And to what extent is climate change implicated, identifiable, and quantifiable as a driver in the environmental degradation that precedes the migration? And, how might the mixture of perceived causal factors be disentangled, proven, and substantiated (Myers and Kent 1995; Renaud et al. 2007; Brown 2008a, b; Laczko and Aghazarm 2009; McAdam 2010; Luetz and Havea 2018)? Moreover, the classifications are interconnected and interrelated: environmental degradation may trigger migration, but migration may also trigger environmental degradation (Myers and Kent 1995; Laczko and Aghazarm 2009). Goffman (2006) aptly articulates that “[o]ne classification may cause the other or, more likely, each drives the other in a vicious cycle of reinforcing degradations” (p. 6; cf. Brown 2007, p. 29). Expressed in simple language, it is very difficult to draw a clear dividing line between “forced” and “voluntary” migration in relation to environmental degradation or slow-onset climatic changes. While this may be possible theoretically or conceptually (e.g., “migration, [is] voluntary, and displacement . . . is forced” [ADB 2012, p. 9; linked to Foresight 2011]), it appears to be impossible, practically. Instead, in the view of the International Organization for Migration (Laczko and Aghazarm 2009), it is more expedient to imagine the issue of climate-related migration on a continuum, "ranging from clear cases of forced to clear cases of voluntary movement, with a grey zone in between" (IOM 2018, para 10).

Seeing that it is difficult to establish a "direct causal link" of linear nature between environmental degradation and population displacement, demonstrating "relative causal attributions" seems to be an even more vexing challenge (Foresight 2011). Moreover, causality may be further obscured by statistical "noise" as all people movements take place within the wider context of global trends, including population growth, urbanization, sprawl of slums, and globalization, among others (Foresight 2011; Hugo 2011; WBGU 2011; Ehrlich and Ehrlich 2013; UN 2017). Ascribing the entire urban drift to climate change-derived environmental degradation would be untenable, but dismissing climate change as a causal factor seems equally absurd. On the contrary, while commingled contributory causes cannot be uncoupled or neatly divided asunder, there is a clear sense that the "evidence for a distinctively anthropogenic 'climate change signal' in forced migration [. . .] is mounting" (Brown 2007, p. 18). Hence there is widespread agreement among experts that climate change will increasingly emerge as a driver of environmental degradation, compounding existing pressures, exacerbating vulnerabilities, and leading to potentially fast-swelling numbers of displaced people (e.g., Brown 2007, 2008a, b; UN-OCHA 2009; Foresight 2011, p. 9). Even so, accepting climate change as one migration cause among numerous others should not be seen as problematic, given that most migration literature argues for multiple causes (e.g., Hugo 1996, 2010; Luetz and Havea 2018).

In summary, while aggregated migration causality is not easily disaggregated, the role of climate change in inducing or enhancing human migration – relative to other contributing causes – is both perceptible and growing, and the fallout in numerical terms may be both significant and unprecedented (WBGU 2007; Schellnhuber 2008; IPCC 2018). Relatedly and importantly, adaptation to climate change is predicated on an anticipatory posture of "preparedness," which in turn implies the need for a state of "readiness" *before* ultimate certainties can be empirically proven "beyond doubt" (Luetz 2018). Hence, there is an argument that "conceiving the inconceivable," "estimating the inestimable," and "quantifying the unquantifiable" are invaluable for promulgating a more robust and future-oriented agenda for anticipatory adaptation to climate change. This seems to be of far greater benefit to migration-affected individuals and communities than debating whether "climate refugees" exist (Box 1). Possible quantitative scenarios are sketched next (section "Numerical Projections, Predictions, and Predicaments").

Box 1 Do Climate Refugees Exist?

The concept of "climate refugees" is contested in the literature (cf. Zetter 2017; Ahmed 2018). In point of fact, climate-related human displacement is subject to well-known conceptual and practical challenges, scholarly debates, and terminological contestations, which are elaborated in the chapter entitled "▶ Climate Change and Human Migration as Adaptation: Conceptual and Practical Challenges and Opportunities." Relatedly, debates surrounding the definitional or associational appropriateness of different terminologies appear to have broadly divided academics into two camps (Brown 2008a, pp. 13–15), namely, those favoring the term "refugee" (e.g., Docherty and Giannini 2009) and those favoring the term "migrant" (e.g., IOM 2018). Importantly, the words "refugees" and "migrants" conjure up vastly different mental images and associations which seem to be, more often than not, indicative of the writers' normative preferences, institutional or ideological allegiances, or underlying agendas (Zetter

(*continued*)

Box 1 Do Climate Refugees Exist? (continued)
2007; Cournil 2011, pp. 359–360). Hence, there is no consensus definition on people who are displaced (in full or in part) by the adverse environmental effects brought on by progressive climate change (ADB 2012), leaving a situation that has been described as "confusing" and "unhelpful" (Dun and Gemenne 2008, p. 10). Instead, different normative approaches and agendas have led scholars to propose a vast array of competing conceptualizations and dissimilar definitions.

Even so, pilot research on atoll islands in Bougainville/Papua New Guinea (Luetz and Havea 2018) has proposed a shift away from treating climate migrants (however they are to be conceptually classified) as passive consignees of "scholarly labels," to placing them more firmly at the center of the definitional debate. There seem to be at least two reasons for a stronger local-level involvement of individuals and communities who migrate for reasons that may implicate climate change. First, there is a sense that some islanders may resist the categorization of "climate refugees" (McNamara and Gibson 2009; Luetz and Havea 2018). Second, there are suggestions that "local contexts, dialects and expressions (e.g., 'Turangu') have much to contribute terminologically with respect to more appropriately informing the definitional and conceptual constructs of policy and research discourses" (Luetz and Havea 2018, p. 23). Inclusivity in coining conceptualizations has already made advances in discourses about disability, and there is the hope that "inclusion" may be similarly normalized in the climate migration domain: "The 'nothing about us, without us' (Charlton 2000) cry within the disability discourse, calling for representation in a bureaucratic system of oppression and disempowerment, is hauntingly relevant" (Luetz et al. 2019, p. 120). Furthermore,

Box 1 Do Climate Refugees Exist? (continued)
inclusivity seems to be all the more pivotal as "consulting the unconsulted" is increasingly identified in the international development arena as a key concern and success factor for global poverty reduction, social justice, and environmental sustainability education (cf. Chambers 1997; Luetz et al. 2018, 2019; Luetz and Walid 2019).

NB: Pertinent conceptual and practical challenges and opportunities arising from CCHM are elaborated in the chapter entitled ► "Climate Change and Human Migration as Adaptation: Conceptual and Practical Challenges and Opportunities."

Numerical Projections, Predictions, and Predicaments

Several researchers have published projections about possible numbers of people who may migrate on account of climate-related environmental changes. Estimates vary significantly, ranging from dozens to hundreds of millions of people. This section is limited in scope to 12 selected numerical prognoses and/or studies.

First, Myers and Kent (1995) posited:

> [A]s increasing numbers of impoverished people press ever harder on over-loaded environments [and] if predictions of global warming are borne out . . . as many as 200 million people [could be] put at risk of displacement. (p. 1)

Subsequently, Myers (2006) increased his projection to 250 million (cited in Walker 2007, p. 14; Christian Aid 2007, p. 48, endnote 10; cf. Biermann and Boas 2010, p. 68).

Second, a World Bank Report (Dasgupta et al. 2007) estimated that:

> [. . .] global warming could well promote SLR [sea level rises] of 1 m–3 m in this century, and unexpectedly rapid breakup of the Greenland and West Antarctic ice sheets might produce a 5 m SLR. [. . .] [T]he overall magnitudes for the developing world are sobering: Within this century, hundreds of millions of people are likely to be

displaced by SLR; accompanying economic and ecological damage will be severe for many. The world has not previously faced a crisis on this scale, and planning for adaptation should begin immediately. (pp. 2, 44)

Third, Rajan (2008) cautioned that:

as many as 120 million people could be rendered homeless by 2100 in both countries of India and Bangladesh. Given the proximity of Bangladesh to India and the large land area that would be inundated, it is also likely that the bulk of these people will end up being migrants in India, particularly in large cities in the interior that are already likely to face resource stress due to climate change and over-exploitation of groundwater and other ecosystem services. (p. 10)

Two snapshots (2050 and 2100) are excerpted from Rajan's (2008) tabular presentation of potential future forced migrants (Fig. 1). In the event of sea level rises of 1 m, 3 m, or 5 m, 65.6 million, 91.9 million, or 118.2 million people, respectively, could be rendered homeless in Bangladesh and India by 2100 (Rajan 2008, p. 10; cf. Byravan and Rajan 2008, pp. 13–20).

Fourth, UNDP (2007) stated:

Sea levels could rise rapidly with accelerated ice sheet disintegration. Global temperature increases of 3–4 °C could result in 330 million people being permanently or temporarily displaced through flooding. Over 70 million people in Bangladesh, 6 million in Lower Egypt and 22 million in Viet Nam could be affected. [. . .] The 1 billion people currently living in urban slums on fragile hillsides or flood-prone river banks face acute vulnerabilities. (p. 9)

Fifth, Sachs (2007) cautioned:

As global warming tightens the availability of water, prepare for a torrent of forced migrations. Human-induced climate and hydrological change is likely to make many parts of the world uninhabitable, or at least uneconomic. Over the course of a few decades, if not sooner, hundreds of millions of people may be compelled to relocate because of environmental pressures. [. . .] We are just beginning to understand these phenomena in quantitative terms. Economists, hydrologists, agronomists and climatologists will have to join forces to take the next steps in scientific understanding of this human crisis. (p. 43)

Sixth, Schellnhuber (2009) speculated:

When we talk about a one metre rise in global sea level we are also talking about 500 million people who are going to have to look for new homes. And so far we do not have any instruments to manage this. (p. 77; cited in Luetz 2013, p. 42)

Seventh, the Stern Review surmised:

By the middle of the century, 200 million more people may become permanently displaced due to rising sea levels, heavier floods, and more intense droughts, according to one estimate. (Stern 2006, p. 56; attributed to Myers and Kent 1995)

Eighth, the Intergovernmental Panel on Climate Change (IPCC) also repeated Myers' quantitative assessment:

If such projections [of extreme vulnerabilities] prove true, climatic change will create 'environmental refugees.' Even without the worst projected impacts, problems of both domestic and

India			
Time	**1m SLR**	**3m SLR**	**5m SLR**
2050	4.4 million	6.1 million	7.9 million
2100	24 million	33.6 million	43.3 million

Bangladesh			
Time	**1m SLR**	**3m SLR**	**5m SLR**
2050	5.7 million	8.0 million	10.3 million
2100	41.6 million	58.3 million	74.9 million

Source:data excerpted from Rajan 2008, p.10

Climate Refugees: Why Measuring the Immeasurable Makes Sense Beyond Measure, Fig. 1 Estimates of migrants displaced by sea level rise from Bangladesh and India

> international migration are likely to be exacerbated. Myers (1993, 1994) cites estimates that there are about 10 million environmental refugees at present, and on the basis of a survey of projected impacts in vulnerable regions, estimates that this figure could rise to 150 million by the middle of the next century as a result of climate change. He sketches the immense social, economic, and political costs implicit in such movements, 'pushing the overall cost far beyond what we can realistically envisage in the light of our experience to date . . . it requires a leap of imagination to envisage 150 million destitutes abandoning their homelands, many of them crossing international borders.' Again, the poor seem most likely to suffer, though clearly such movements might also trigger broader ethnic or even international conflicts that could envelop whole societies. (IPCC 1995, p. 98; cf. p. 199)

Furthermore, in AR4, the IPCC (2007) concedes that:

> [c]limate change may contribute to destabilising unregulated population movements in the Asia-Pacific region, providing an additional challenge to national security (Dupont and Pearman 2006; Preston et al. 2006). Population growth and a one metre rise in sea-level are likely to affect 200–450 million people in the Asia-Pacific region (Mimura 2006). An increase in migrations from the Asia-Pacific region to surrounding nations such as New Zealand and Australia is possible (Woodward et al. 2001). Displacement of Torres Strait Islanders to mainland Australia is also likely. (attributed to Green 2006; in Hennessy et al. 2007, p. 522)

Ninth, the NGO Christian Aid offered a prediction on the high end of the scale:

> We estimate that, unless strong preventative action is taken, between now and 2050 climate change will push the number of displaced people globally to at least 1 billion. (Christian Aid 2007, p. 22, cf. pp. 1, 5)

Tenth, in 2010 the Global Forum on Migration and Development duly noted that:

> exact impacts of climate change on migration and development are difficult to predict because of the wide variation in estimates of global numbers of people that could potentially be affected, and because of terminological differences. For example, estimates of people affected by climate-induced disasters between 2000 and 2004 mention some 240 million or 62 million a year. Another prediction suggests that up to 1 billion people may be forced to move between 2007 and 2050, which sounds a lot but, at some 23 million a year, is fewer than the estimates of 62 million a year for the period 2000–2004. (GFMD 2010, p. 38)

Eleventh, according to Brown (2011):

> The most vulnerable country is China, with 144 million potential climate refugees. India and Bangladesh are next, with 63 million and 62 million respectively. Viet Nam has 43 million vulnerable people, and Indonesia 42 million. Also in the top 10 are Japan with 30 million, Egypt with 26 million, and the United States with 23 million. Some of the refugees could simply retreat to higher ground within their own country. Others—facing extreme crowding in the interior regions of their homeland—would seek refuge elsewhere. (p. 75; attributed to McGranahan et al. 2007).

Twelfth, the Foresight report criticized numerical projections of future climate migrants, cautioning that:

> [e]xisting estimates of 'numbers of environmental migrants' tend to be based on one or two sources [referring to Jacobsen (1988; 10 million) and Myers and Kent (1995; 150 million)]. [. . .] Furthermore, the methodology used in Myers [and Kent] (1995) has been criticised [Castles 2002; Castles 2011; Gemenne 2011] [because] it seems to negate the ability of those in low-income countries to cope with environmental events, presenting a relatively deterministic connection between risk and migration. [. . .] By trying to count those who move, those who stay behind or are trapped in the context of environmental change may be overlooked [. . .]. (Foresight 2011, p. 28)

The above discussion of selected numerical projections is admittedly incomplete (Luetz 2013, pp. 39–48). Even so, two observations emerge. First, numbers, authorities, methodologies, typologies, and conditionalities are divergent. Second, the numbers are all rather large (Fig. 2). In a paper for the United Nations High Commissioner for Refugees (UNHCR), migration researcher Richard Black (2001) observed: "At first glance, the data available on environmental refugees appears quite impressive, [. . .but] the strength of the academic case put forward is often depressingly weak" (p. 2). Other scholars make similar observations: "[e]stimates [. . .] are divergent and controversial" (Warner et al. 2009, p. 2; cf. Gemenne 2011).

There seem to be at least four reasons why predictions of future climate change-related human movements are fraught with problems. First, human mobility takes place within the wider context of global megatrends, including

Source	Displaced People	Timeframe
IPCC (1995, p. 98; attributed to Myers 1993, 1994)	150 million	2050
Myers and Kent (1995, p. 1)	200 million	2050
Christian Aid (2007, p. 48; attributed to Myers)	250 million	2050
Nicholls (2004, pp. 69–86)	50–200 million	2080
IOM (Laczko & Aghazarm 2009; attributed to Myers)	200 million	2050
Stern Review (2006, p. 77; attributed to Myers)	150–200 million	2050
Christian Aid (2007, pp. 1, 5, 22–23)	"at least" 1 billion	2050

Sources: Selected figures quoted from Walker (2007, p. 14), Walker (2009, pp. 176–177), and contested, e.g., by Gemenne (2011, p. 45) and Foresight (2011, p. 28)

Climate Refugees: Why Measuring the Immeasurable Makes Sense Beyond Measure, Fig. 2 Selected commonly quoted projections

population growth, urbanization, coastward migration, and sprawl of slums (McGranahan et al. 2007; Hugo 2011; WBGU 2011), which makes it virtually impossible to isolate the "climate-change-only" contribution to consequent human movement. With rapid urbanization continuing unabated, the United Nations Human Settlements Programme projects that by 2030 five billion people could be living in cities, with slum populations expected to double from one billion to two billion (UN Habitat 2006). Much of this growth takes place within the context of coastward migration (Cohen et al. 1997; UN 2016), which sees more and more people being concentrated in coastal megacities (e.g., Nicholls and Small 2002; WBGU 2006; UN 2017). According to the United Nations (2016), "[e]ight of the top ten largest cities in the world are located by the coast" (para 1), and according to Gommes et al. (1998), "21 per cent of the world's human population live less than 30km from the sea" (cited in WBGU 2006, p. 40). According to the UN (2017), coastal communities "represent 37 per cent of the global population in 2017" (p. 1). With coastal population growth rates given at approximately "twice the global average" (WBGU 2006, p. 40; attributed to Bijlsma et al. 1996; cf. UN 2016), researchers synthesize that by the year 2030, about half of the world's population could be living within 100 km of the sea (Small and Nicholls 2003; cited in WBGU 2006, p. 40; cf. UN 2016, 2017). In short, ascribing the entire urban and/or coastal drift to climate change would be absurd, but arguing that climate change is therefore not implicated as a major contributory migration enhancing determinant seems similarly untenable.

Second, demographic data are often old, poor, or incomplete, and most census data in developing country contexts are rarely detailed enough to provide nuanced insights into population displacements, especially those that are internal and/or induced by slow-onset causes (Myers and Kent 1995; Brown 2008a, b; Luetz 2017, 2018). Relatedly, the views and local realities of people affected by CCHM are often not sufficiently solicited and reflected in research studies even though "local contexts, dialects and expressions . . . have much to contribute [to] policy and research discourses" (Luetz and Havea 2018, p. 23). "There is therefore an argument that better data are urgently needed. This must include an unequivocal focus on "consulting the unconsulted" (Luetz et al. 2019, p. 115).

Third, dealing with future scenarios invariably involves elements of speculation and uncertainty. Brown (2007, 2008a, b) asserts that computer modelling techniques may not conclusively account for the combined impact of individual choice, variable future emissions, meteorological scenarios, and international climate change action. Stated differently, the multiplicity of issues involved creates a challenge for quantitative data collection and modelling, including data management, analysis, and synthesis. Precisely, how is multidimensional human vulnerability (or resilience) to be measured, quantified, compared, and computed across vastly divergent developing country contexts? How are computer models to manage the massive compound mix of data and variables, comprising climates, local communities, economies, inequalities, cultural customs, religious traditions, social classes, colonial legacies, gender relations, changeable adaptive capacities (e.g., ongoing learning), and evolving policy formulations, to name just a few (Piguet 2013, p. 157; attributed to Tacoli 2009)? Moreover, how are their interdependent relationships to one another to be understood or computed?

Fourth and, finally, the scope and scale of future climate change-related migration depends largely on actions taken today (e.g., mitigation), wherefore estimates of future climate migrants would necessarily be subject to caveats, conditionalities, and evolutionary changes. Since the future is hard to foresee and non-static, the question arises whether time-bounded numerical predictions are useful, especially if scenarios involve more distant futures which are naturally subject to greater uncertainty (Brown 2008a, p. 25). In short, and as the Danish physicist Niels Bohr (1885–1962) famously said, "[p]rediction is very difficult, especially about the future" (cited in Brown 2008a, p. 21). Notwithstanding, infinite possible future scenarios and infinitesimal certainties seem to converge around the following lowest common denominator consensus, namely, that:

> [t]he avalanche of statistics above translates into a simple fact—that on current trends the 'carrying capacity' of large parts of the world, i.e. the ability of different ecosystems to provide food, water and shelter for human populations, will be compromised by climate change [and] that the international community has to face up to the prospect of large-scale displacement caused by climate change. (Brown 2008a, pp. 17, 41)

Or to synthesize the situation in the understated words of the United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA 2009), "[c]limate change is likely to lead to increasing rates of displacement" (p. 15). Given the apparent prediction problems discussed above, it seems to be essentially impossible to make, defend, prove, or disprove any accurate, verifiable, and robust projections of future climate change-related people movements. Notwithstanding, the figures nevertheless seem to serve an important purpose as they demonstrate that, concurrent with global megatrends (Hugo 2011; WBGU 2011), climate-related human migration may progressively evolve and manifest as a significant challenge in this century (Brown 2008a, pp. 17, 41; Schellnhuber 2008, 2009; IPCC 2018). Furthermore, the overall problem analysis does not imply that best "guesstimates" are superfluous or do not have an important role to play in alerting policymakers to prepare for potentially extraordinary and unprecedented impending sociodemographic changes. Relatedly and importantly, promoting "preparedness" should not be confused with encouraging or accommodating "alarmism," as advocated in a study on migration in Bangladesh (Luetz 2018, pp. 73–74):

> While accurate prognoses of future migrations are inherently difficult, if not impossible to make, this researcher measuredly rejects the use of the term "alarmist" on the grounds that its use seems to [incorrectly] insinuate exaggeration, a point corroborated by dictionary definitions of this word: "alarmist [. . .] someone who is considered to be exaggerating a danger and so causing needless worry or panic" (McKean 2005, p. 36). In light of the growing body of evidence linking climate change to the erosion of livelihoods the notion of "exaggeration" appears not only scientifically ill-informed but also runs counter to the premise of preparedness which seeks to pre-empt problems before they materialise beyond reasonable hopes of resolution. Therefore, the mere possibility (not probability or certainty) of humanitarian scale displacements and resultant human suffering is seen here to be reason enough to invoke a response of preparation, irrespective of whether or not large displacements will ultimately materialise. While gargantuan challenges can lead to torpidity, inaction or so-called "paralysis of analysis", the point bears repeating that the very notion of preparedness implies readiness *before* both need and certainty arise. As the United Nations has advocated regarding climate change adaptation: "Hoping—and working—for the best while preparing for the worst, serves as a useful first principle for adaptation planning." (UNDP 2007, p. 198; in Luetz 2018, pp. 73–74)

Hence it is argued here that in terms of activating or maximizing anticipatory adaptation to climate change, measuring what seems to be essentially immeasurable still makes immeasurably more sense than running the risk that laissez-faire non-engagement may spawn unforeseen situations of violence and chaos. The "climate change-collective violence" nexus is well established in the literature, and there are indications that recent humanitarian-scale refugee movements have been, at least in part, fuelled by climate change-related causality (Breisinger et al. 2013; Wendle 2016; Levy et al. 2017; cf. Ahmed 2018). Hence the case to assist early, proactively, and preemptively remains clear and compelling.

Concluding Synthesis: Catalyzing Anticipatory Climate Change Adaptation

Climate change and human migration (CCHM) typically takes place within a complex context of commingled contributory causative factors. Hence the multicausality inherent in human movement makes attribution or disaggregation of causality an almost intractable problem. Discourses about CCHM are therefore commonly characterized by theoretical, practical, empirical, analytical, and computational challenges, among others. The challenges are well known (Brown 2008a, b; Gemenne 2009; Luetz 2013) and include deterministic constraints, compound cause-and-effect interrelationships, entanglement of "push" and "pull" factors, overlapping "forced" and "voluntary" categories, and intransigent difficulties involved in determining direct causal links of linear nature between environmental degradation and population displacement. Even so, the challenges also point to untapped opportunities for adaptation to climate change. As Myers and Kent (1995) have pointed out, if a migrant is:

> putatively driven 60 percent by environmental factors and 40 percent by economic factors, or the other way round, this issue is not nearly so important as the fact that he or she is impelled to migrate and to seek refuge elsewhere—whereupon society at large should feel inclined if not obliged to do something about his or her plight rather than to debate the precise factors in the underlying motivation. (p. 29)

In synthesis, while the manifold and unsearchable motivations of a migrant's decision to move will invariably remain impossible to discern, dissect, and/or compute, the question what to do about it is clearly of far greater consequence to the global climate change adaptation agenda than misguidedly expecting to first meet quasi-perfect scientific conditions for research that simply do not exist outside of hermetically sealed laboratories.

In respect of preparing for future scenarios of CCHM, section "Numerical Projections, Predictions, and Predicaments" discussed 12 selected quantitative prognoses. Further, the section also outlined pertinent prediction problems inherent in making, proving, or disproving numerical projections of future climate change-related human movement. To summarize, there is very little agreement among scholars on how to collate, analyze, and synthesize data into widely acceptable numerical model projections of future CCHM. Even so, this limitation needs to be kept in perspective of what can and cannot be conclusively established, both in terms of epistemological considerations and available empirical evidence. As Myers and Kent (1995) have pointed out:

> In a situation of uncertainty where not all factors can be quantified to conventional satisfaction, let us not become preoccupied with what can be precisely counted if that is to the detriment of what ultimately counts [. . .] absence of evidence about a problem does not imply evidence of absence of a problem. (p. 33)

Finally, there are indications that the preparedness paradigm long embraced by the disaster management community, which values proaction over reaction and preparing over repairing (Luetz 2008, 2013; IPCC 2012; UNISDR 2011, 2015), is also increasingly gaining currency in CCHM discourse, as evidenced by case study research in the Maldives (Luetz 2017) and Bangladesh (Luetz 2018; Luetz and Sultana 2019) and a "toolbox" for planned relocations (UNHCR 2017). Given that Targets 1 and 3 of SDG 13 explicitly envisage anticipatory adaptation to climate change (see section "Introduction") corroborates the point that proactive engagement in the CCHM space is a fertile albeit underappreciated climate change adaptation priority. This opportunity offers development actors clear benefits in respect of supporting climate change-related migration as a favorable, underrated and comparatively benign form of adaptation to climate change (IOM 2010; Luetz 2013, 2017).

To recapitulate and to conclude, there are no agreed mechanisms to attribute or disaggregate conglomerate causality and no agreed projections in terms of future fallout. Even so, the adaptation potential remains clear, compelling, and underutilized. Expressed in simple preparedness prose, action or proaction is inherently preferable to inaction or reaction. Hence to catalyze anticipatory adaption to climate change, measuring the immeasurable indeed makes sense beyond measure. Or stated differently, preparedness presumes informedness, and informedness presupposes that accommodating approximation may be necessary where exactness is impossible. As the ancient philosopher wisely said, "It is the mark of an educated mind to rest satisfied with the degree of precision which the nature of the subject admits and not to seek exactness where only an approximation is possible" (Aristotle, Greek philosopher and scientist; 384–322 BC). Or to put it in the words of the well-known physicist and Nobel Prize winner, "Not everything that counts can be counted, and not everything that can be counted counts" (Attributed to Albert Einstein; cited in Garfield 1986, pp. 156, 311).

Postscript

Climate Migration: Bangladesh on the Move (Case Study)

A video documentary on case study field research conducted in Bangladesh (communities of origin and destination) was published by UNSW Sydney on 18 February 2015 and illustrates sociocultural and environmental issues and complexities. It is publicly available at https://youtu.be/PBJeelgnadU.

Cross-References

▶ Climate Change and Human Migration as Adaptation: Conceptual and Practical Challenges and Opportunities

Acknowledgments Grateful acknowledgment for essential support is made to the University of New South Wales (UNSW) and the development organization World Vision International (WVI).

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Climate Resilient

► Sociocultural Impact of Climate Change on Women and the Girl Child in Domboshawa, Zimbabwe

Climate Risks and Adaptation to Crop Yield in Pakistan: Toward Water Stress Tolerance for Food Security

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Introduction

The conservation of fresh water and water resources around the world is seriously threatened by climate change. The effects are manifested in the systemic patterns of origin of the global environment, which are gradually disintegrating (Lesk et al. 2016). The sustainability of modern agriculture and human life on Earth is in danger.

During the twentieth century, the world's population grew from about 1.6 to 6.0 billion people. During the same period, many countries recorded a significant increase in yields through the introduction of improved cultivars. In many cases, this has been accompanied by improved management of soils, plants, water, and nutrients, although environmental problems have also arisen (Wheeler and Von Braun 2013). As we will see later, rates of acquisition of more intensive and productive agricultural practices in developed countries were much higher than in developing countries, where a number of constraints still limit the widespread acceptance of such practices. Despite this success, it was estimated until 2017 that more than 820 million people worldwide were malnourished (FAO 2018).

In the twenty-first century, the challenges for achieving global food security will be immense. As said by Alexandratos and Bruinsma (2012) by 2050, the world will have to respond to rising demand due to population growth and income. As a result, agricultural production must increase by at least 60%, taking into account both food and non-food products compared to 2005–2007. This challenge is compounded by the fact that this population growth is inevitably and directly linked to the increasing restrictions on the availability of land and water for crops and livestock and the decline in wild fish stocks (Musser and Patrick 2002; Wheeler and Von Braun 2013; Kirby et al. 2016).

The latest report by the Intergovernmental Panel on Climate Change (IPCC) concludes that agriculture and thus food security are already affected by climate change ((Porter et al. 2014). At the same time, the value chains of agriculture and the food industry, as the main emitters of CO_2 and other greenhouse gases (CO_2) as CO_2, play an important role in climate change. It is estimated that 2.5 billion people around the world depend on smallholder agriculture, which is vulnerable to climate change, and that food systems cause 19–29% of global greenhouse gas (GHG) emissions (Niles et al. 2017). The challenge of agriculture and climate change in the twenty-first century is urgent and diverse. It is imperative not only to take a major initiative to meet the rapidly growing food needs but also to invest heavily in adaptation and mitigation initiatives as part of global agriculture itself and in the context of larger food systems.

Many environmental conditions, such as drought, heat, rain, flood, wind, cooling, and frost, affect crop yields and quality worldwide (Ullah et al. 2016). Among them, water stress is the most detrimental factor to cereal production and seriously compromises food security (Ali and Erenstein 2017). Water scarcity is a major disaster for irrigated and arid agriculture in the world and is considered to be the most important environmental factor limiting plant growth and development, thus reducing yields (Alcamo et al. 2007). There is abundant literature on the different types of water stress. An overview of the occurrence of water stress and its actions is described in this document.

Drought Perceptive

Drought, generally defined as lack of moisture in the soil, is considered an important environmental factor that reduces wheat yield in the affected areas.

Drought Flee

Plants react differently to drought conditions. Many adaptations allow plants to survive in extreme conditions of water stress. Drought is one of the simplest mechanisms for plants to cope with drought through developmental plasticity such as early maturity. Significant developmental plasticity is also evident in the manufacture of a large number of milling tools. The numbers of tillers that survive and produce spikes are reduced by water stress at the beginning of flowering and at the maximum of the pan.

Drought Averting

Drought prevention is another mechanism to deal with drought. This can be achieved by maintaining soil water uptake through a deep root system that facilitates continuous contact of the plant with soil moisture to withstand periods of water stress. Alfalfa produces a relatively high feed yield, even in times of drought due to its deep root system, while the growth of cereal crops and shallow root grasses is much delayed (Fahad et al. 2017).

Reductions in Water Loss

Another mechanism to prevent drought is to reduce water loss. While most of the water that plants extract from the soil is lost through transpiration, leaf modification also affects dryness resistance (Brisson et al. 2010). Some plants have leaves that curl or curve during periods of drought, reducing surface exposure directly to wind and sun. This mechanism does not stop sweat, but slows it down considerably (Barnett et al. 2005; Blum 2005). The water status of plants can also be influenced by morphological features such as leaf size and shape, angle, cuticle, shimmer, and reflection (de Dorlodot et al. 2007).

Drought Indulgence

When plants are exposed to stress due to drought, a series of physiological reactions have been observed. In some cultured cereal products, osmotic adaptation has been shown to be one of the most effective physiological mechanisms underlying plant resistance to water deficiency (Condon et al. 2004).

Breeding for Drought Resistance

Half of the wheat area in developing countries and approximately 70% of the area in industrialized countries are periodically affected by drought (Misra 2014). During the harvesting cycle, drought can occur at any time in a rainy environment. Stress on or after flowering is typical of many Mediterranean environments. The phenotype is the result of the interaction of the genotype with the environment. The environment of a plant therefore influences the expression of its physiological and morphological responses. The yield potential under favorable moisture conditions is important for production under water stress conditions.

Water Stress

Water pollution is considered to be a moderate loss of water, resulting in the closure of the stomata and the restriction of gas exchange. Desiccation is a much greater loss of water leading to severe metabolic and cellular disorders (Oliver et al. 2005; Farrant 2000; Noorka and Khaliq 2007; Wahid et al. 2007). Sufficient water absorption is essential for plant growth because stress of water leads to a reduction of plant growth. It has been shown that the tolerance to water stress in all wheat genotypes has a direct impact on the yield and yield properties. Chowdhary et al. (1999) found that under water stress, the number of fertile tillers, the number of grains per ear, the weight of the core per ear, the weight of 1000 grains, and finally the grain yield per plant are reduced. It has been suggested that the selection of these yield-related traits could lead to the development of dryness resistance in wheat, while reported that water stress played an essential role in reducing plant height and the number of cores per ear. Crop yield and biomass as stomatal frequency increased under water stress. In this context, Angus and Van Herwaarden (2001) compared 13 experiments on water consumption and yield of wheat and pointed out that the amount of water used during the final drought was strongly influenced by plant management. According to, "the water stress tolerance is just like difference between life and death."

Effect of Water Stress on Seedling Traits

Water shortages can affect plant health at any stage of development (Bandara and Cai 2014). The seed trait is an important aspect of a growing program because the final crop depends mainly on the characteristics of the seedlings. Several factors, such as seed germination, seedling vitality, growth rate, average emergence time, and tolerance to dehydration, influence the yield of a crop (Basra et al. 2003). Poor germination, resulting in uneven crops, is the main obstacle to a good crop. Survival was the main characteristic of seedlings (Farooq et al. 2006). Survival after desiccation was the most important and appropriate method for screening a large population (Noorka and Khaliq 2007).

Effect of Water Stress on Physiological Traits

The physiological understanding of dryness of plants is very important for variety improvement as a determinant of crop yield in an environment under water stress. The physiological approach can complement the empirical selection and accelerate yield improvement. Stomata are the main routes of transpiration and gas exchange. Stomata respond to a variety of internal and external stimuli (Nabipour et al. 2002).

Insufficient moisture brought by transpiration during any growth period can weaken the plants and their susceptibility to disease and insect, hence reducing the grain yield and even causing plant death. The reduction in crop yield depends not only on the level of pollution but also on the level of development of the plant (Janjua et al. 2010; Vatén and Bergmann 2012).

Effect of Water Stress on Plant Growth, Development, and Yield

Water stress has a very negative impact on cellular processes, plant growth, development, and economic performance. Many droughts adversely affect the root growth and development. A continuous deficiency of moisture in soil causes in stunted growth of stem and reduces the expansion in the volume of the roots (Banziger et al. 2000). Agriculture depends mainly on the success of the reproductive phase of the plant because this phase is crucial for high grain and fruit production. The world is focusing on the abundance of harvesting techniques. Optimizing plant resources can maximize both biomass and economic performance (Pandey et al. 2000).

Hassaan (2003) found that different water stress level results contrasting behavior for traits, days to heading, days to maturity, and yield components. Water stress reduced grain yield by an average of 34%. Oweis et al. (2000) reported that supplemental irrigation increased grain yield from 0.77 to 0.92 $kg/m^{3.}$

Water stress during anthesis affects the development of gynoecium in different ways. Kazmi et al. (2003) investigated the influence of water stress on yield and yield components with variable irrigation treatments. He concluded that wheat can withstand or tolerate water stress at the flowering stage.

In sugar beets (Ober and Luterbacher 2002) and barley (Rizza et al. 2004), most of the genotypes tested have shown high yield potential and minimal environmental interaction between genotype and environment under water stress conditions.

Effect of Water Stress on Genetics of Wheat Plant

In conventional farms, breeders rely on their experienced eyes when selecting the first generations and on yield tests for subsequent generations. Recent advances in genetic improvement are due to improved mechanization and statistical analysis, which allows more lines to be evaluated and errors to be reduced. A breeder creates a new gene combination and variability between genotypes by disrupting parents with desirable characteristics or by introducing new genetic material from other breeding programs. This variability is then limited by selecting the few best performing genotypes in the target environment.

Studies have shown that both additive and nonadditive gene actions determine the phenotypic responses of various agronomic and physiological properties of the wheat plant with additive effects. Subhani and Chowdhry (2000) reported that the environment plays a crucial role in the expression of all characteristics under drought conditions. Additive types of genetic effects were found for plant height, ear length, number of days at head, and weight of 1000 grains under normal conditions and drought conditions; characteristics such as leaf area, tillers per plant, grains per spike, and grain yield per plant were not controlled by additive gene action.

Plants react differently to drought. Many adaptations allow the plant to survive in extreme conditions of water stress. A change of environment, i.e., from normal irrigation to water stress, can alter the pathways of expression of a gene. While additive genetic effects were important for plant size and number of seeds per peak under normal irrigation conditions, nonadditive genetic effects were assumed under conditions of water stress (Arshad and Chowdhry 2003).

In addition, Chowdhry et al. (1999) showed the presence of partial dominance with additive genetic effects on features such as flag leaf area, number of fertile tillers, and spike length, but in the case of crop yield and 1000 grains, partial dominance was replaced partial dominance. The mode of action of genes has changed in some characteristics when exposed to an environment ranging from normal irrigation to a state of water stress.

Genetics and Plant Breeding for Water Stress Tolerance

Breeder generally used a step-by-step selection process to identify the best genotypes with the given resources. With each selection, the breeder reduces both the number of genotypes and the variation between genotypes, mainly by eliminating the bad genetic material (Banziger et al. 2000). Plant breeding by phenotypic selection led to the improvement of the most important crops (Banziger et al. 2000). The unpredictability of drought conditions (intensity and timing) and the difficulty of correctly managing the terrain characteristics for a desired level of stress clearly limit the improvement of the facilities.

Troubleshooting includes selection of pest resistance, modification of morphology to reduce scale, and selection of better grain quality. This is a strategic approach to conventional plant breeding called “smart crossing.” This approach systematically increases the likelihood of an accumulation of gene that adapts to stress. Banziger et al. (2000) points out that the key to tackling water stress tolerance is dealing with stress and all that is achieved through a series of dry-period and irrigation-stress experiments. To deal with stress, intensity and consistency are the main factors to consider.

Choice of Parents for Breeding Program

Hybridization is the most widely used breeding technique for overcoming yield barriers and developing stress-tolerant varieties with the highest yield potential. Selection of an appropriate parent for hybridization is of paramount importance in the hybridization process. There are several techniques for evaluating varieties or strains.

Combining Ability and Gene Action

Crop breeders are primarily interested in information about genetic systems that control the morphophysiological traits they manage through appropriate statistical methods to obtain accurate estimates of the additive and dominant components of genetic variance. In addition to these estimates, former scientists (Sheikh et al. 2000; Subhani and Chowdhry 2000; Nazeer et al. 2004) have also reported estimates of additive genetic effects on traits such as plant height, number of tillers per plant, spike length, grain per spike, and 1000 grain weight. Types of nonadditive genetic effects were observed for grain yield, stem length, number of grain per plant, the number of tillers per plant, and the weight of 1,000 kernel (Sheikh et al. 2000 and Siddique et al. 2004). However, to represent the quadratic ratios, the average squares of the overall combining ability were higher than the specific combining ability allowing to combine the traits like plant height, number of grains per spike, weight of 1000 grain, and spike length (Siddique et al. 2004), relative to ease; shows the breeding of a homozygous strain with the desirable characteristics and ensuring stable performance.

A stomatal closing mechanism under water stress to reduce water loss is a natural phenomenon in crops. Reported high levels of overall effect on the ability to combine features such as venation, stomatal frequency, and flag leaf surface, indicating that these features were controlled by additive type/or an accessory type of gene action. While, Subhani and Chowdhry (2000) reported high levels of impact on the specific ability to combine plant height, spike length, number of grains per spike and number of spikelets per spike, and grain yield, indicating nonadditive genetic effects.

Flag leaf area has prime importance and positive correlation with grain yield controlled by nonadditive type of gene action (Bakhsh et al. 2004; Inamullah et al. 2005), while Kashif and Khaliq (2003) reported that for flag leaf area, additive genetic effects are important. It was also shown that a change in environment correspondingly changed the expression of a gene leading to an altered genetic behavior in a given production situation (Chowdhry et al. 1999 and Subhani and Chowdhry 2000).

Genetic architecture of valuable traits can be improved by utilization of proper breeding methodology (Thirunani et al. 2000). Combining ability is an effective tool which gives useful genetic information for choice of a parent (Chezhian et al. 2000). The value of any population depends on its potential and combining ability in crosses (Vacaro et al. 2002).

Heritability

In crop improvement, only genetic variation is important, as only this component is passed on to the next generation and ensures its performance over several years. The extent to which a phenotype is determined by its genetic make-up (genotype) is referred to as heritability in the broader sense. Heritability in the broader sense is the proportion of total variance due to average gene effects.

Heredity does not just depend on genetic factors, but environmental conditions are also important (Kumar et al. 2002; Patil and Jain 2002). Memon et al. (2007) reported high values of heritability for traits such as plant height, number of tillers per plant, grain yield but moderate for flag leaf area, and weight per spike. The study of gene activity, combining ability, and heredity is a prerequisite for the synthesis of biologically superior and physiologically and agronomically efficient genotypes.

Wheat Quality

The term wheat quality is a complex phenomenon that involves many factors and cannot be expressed as a unique property. Wheat quality is the sum of the effects of soil, climate, and seed on wheat plants and core constituents. The flour mills need good quality wheat that is storable and can produce a maximum amount of flour.

The consumer needs palatability and a healthy look in baked goods, which have a higher nutritional value for a reasonable price.

Wheat is one of the cereal products used in many parts of the world for the preparation of bread and baked goods. The bakery industry is concerned about the deterioration of the final quality of some soft winter wheat varieties. Cline (2007) explained that wheat quality can be improved if the biochemical and genetic factors affecting the properties are well understood.

Factors Affecting Wheat Quality

A wide range of factors have been considered to determine wheat milling and baking quality in the past. Guedira et al. (2002) reported that high shoot and high root temperature affected the quality of the wheat grain with the flour protein improving after all heat treatments. Habernicht et al. (2002) found negative effect on end-use quality of hard red and hard white spring wheat contaminated with grain of contrasting classes. Reported that water stress increased protein and lysine content as well as negative effect on grain yield.

Chemical Characteristics

Wheat is often assigned a numerical scale, which depends upon the results of certain tests comprising moisture percentage, ash contents, crude proton, wide fat, gluten, etc. These parameters are reviewed here.

Moisture Percentage

Moisture content is a very important quality criterion because all wheat grains are stored for a period of time before being used. High moisture cereals are difficult to store safely because they tend to cause heat damage and are also more attractive to pests and diseases. On the other hand, dry grains produced by oven drying in areas where grains cannot be naturally dried may have damaged proteins. The moisture content was between 11.7 and 13.45% (Nadeem et al. 2004; Din et al. 2007;Rehman et al. 2007).

Ash Content

It is a measure of purity of flour in wheat. A combination of high extraction and low ash is an indicator of efficient milling. The ash content ranged from 0.6 to 0.8% for extractions of 80% or more in Middle East flour. The ash content reported by various researches varies from 0.44% to 0.80% (Nadeem et al. 2004; Rehman et al. 2007).

Protein Content

The nutritional quality of wheat is determined mainly by the amount, composition, and digestibility of its protein. In approximate terms wheat consists of 72% carbohydrate, 12% protein, 2% fat, 2% fiber, 2% ash, and 10% moisture. The protein content itself can vary between 6% and 17%, mainly depending on the culture conditions, but to a certain extent genotype. Protein content and base hardness have been found to be the most appropriate classification tools for classifying wheat as hard red spring wheat and winter wheat. Protein is not only a factor that evaluates end-use properties, but it can also affect the baking properties of wheat flour. The amount of protein varies between 10.02% and 12.5% (Randhawa et al. 2002), Nadeem et al. 2004; Rehman et al. 2007).

Fat Content

Fats are rich source of energy. Nadeem et al. (2004) reported fat contents in wheat flour are in the range of 1.74 to 2.93% and 0.89%. In proximate analysis of wheat and vetch flour, Rehman et al. (2007) reported percentage of crude fat as 1.35/100 g, while Raymond (1993) reported 10% fat in soft wheat and 1.2% fat in hard wheat.

Gluten Content

The gluten content is an important parameter in the evaluation of flour quality. The quality of the flour is influenced by the type of gluten and its various components. Gluten is developed by the interaction of gluten and gliadin protein fractions, which are also linked to pentosans during dough formation. Din et al. (2007) reported that Pakistani wheat varieties varied significantly for physiochemical properties and concluded that gluten ranged from 8.72% to 10.69% in wheat flour, while Pasha et al. (2007) revealed that gluten ranged from 4.46% to 14.55% which can be used as indicators of gluten contents and, hence, the quality of wheat. Kadar and Moldovan (2003) demonstrated that only a small part of protein variation can be explained by variation of yield. They also reported heritability for protein content (H = 0.37) and gluten contents (H = 0.66), while computed heritability estimates comparatively low for grain protein and gluten contents.

In order to improve the quality of bread making, it is necessary to improve both the firmness and extensibility of gluten through the increased use of high-quality common wheat starch material in breeding programs (Abdalla et al. 2006).

Conclusion

In the field of wheat breeding, much research has been done, which represents a breakthrough in domestic wheat production. However, the importance of wheat quality was not improved. In Pakistan, work has hardly been done on the stress of water tolerance and its impact on the wheat quality. The aim of the current review was to examine the nature and intensity of the interrelationships between quality and quantity of the different chemical properties of spring wheat and to generate information of particular interest to breeders and millers and bakers in wheat.

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Climate Science Literacy

► Climate Change Literacy to Combat Climate Change and Its Impacts

Climate Solutions

► Climate-Resilient Cities in Latin America

Climate Variability

► Sociocultural Impact of Climate Change on Women and the Girl Child in Domboshawa, Zimbabwe

Climate Warming

► Sociocultural Impact of Climate Change on Women and the Girl Child in Domboshawa, Zimbabwe

Climate-Induced Displacement and the Developing Law

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Definition

The relocation within the homeland's border or across its borders, as a response to climate change effects, including rising sea levels and increased frequency of extreme weather phenomena attributed to climate change, in pursuit of a safer natural environment. The responses to climate-induced displacement are currently inadequate due to the inability of international law to protect climate refugees.

Climate Change as an Accelerant of Human Movement

According to the Department of Economic and Social Affairs – United Nations Secretariat: "Climate change consequences, in particular rising sea levels, increased intensity of storms, drought and desertification, environmental degradation, and natural disasters displace or will displace people, temporarily or – in many circumstances – permanently" (Department of Economic and Social Affairs 2017). Displacement triggered by climate changes is not a modern phenomenon and is not limited to the current "climate change" era. The earth has experienced multiple climate changes, and the associated social consequences are well documented (Welzer 2015). Relocation due to environmental factors has been observed historically following desertification as well as floods. The example of Sudan is illustrative of extreme cases where the social consequences of climate change go beyond displacement. Sudan is one of the most devastated countries, experiencing substantial decrease of harvest due to climate change and with a reported number of five million internally displaced people. These changes led to the creation of "bare land". In the absence of natural shelter, the country is experiencing an increase of murders and rapes of young women, evidence of the serious social consequences of climate change (Welzer 2015).

The primary reason for such climate-induced dislocation is the diminished sense of safety amidst climate change consequences. According to Myers and Kent, this includes those that leave their homeland because they can "no longer gain a secure livelihood. . .because of what are primarily environmental factors of unusual scope" (Myers and Kent 1995). The factors are such that are not traditionally expected in the geographic areas that are observed and would include floods, droughts, rising sea levels, and the increased frequency of severe weather phenomena, all attributed to climate change. The Overseas Development Institute (ODI) separates "climate migrants" into four categories: (1) people who move temporarily due to climate change effects, (2) those forced to move because of repeating phenomena, (3) people that are forced to migrate because of the deterioration of the natural environment and its effects on their quality of life, and (4) and those who move voluntarily as an adaptation method (Wilkinson et al. 2016).

The lack of a legally binding definition of "climate-induced displacement" and "climate migrants" under current immigration and refugee law has led to an inability to tackle the issue, award blame, and ensure duty fulfillment by states under international law. The issue cannot be addressed through the realms of traditional Environmental Law principles such as the "polluter pays" principle either. Climate change is a far more disruptive phenomenon, where law is falling short in addressing its consequences on human movement, beyond regulating adaptation and mitigation measures. As a result, and due to the general lack of political will in addressing the ensuing displacement of people, the ability of international and domestic law in covering climate-induced displacement is limited, as well as the possibility of reaching an international consensus on how to address climate-induced displacement. "There has been a collective, and rather successful, attempt to ignore the scale of the problem. Forced climate migrants fall through the cracks of international refugee and immigration policy – and there is considerable resistance to the idea of expanding the definition of political refugees to incorporate climate 'refugees'" (Brown 2007). As a result, climate migrants are not offered protection through international law in this pursuit of a safe "home" (Brown 2007).

"For some people, migration is an adaptation strategy, helping families to diversify their incomes and reduce their vulnerability to climate change impacts. In the context of some SIDS (Small Island Developing States), the ability to move is existential and greater support to facilitate these individuals and families' decision to move is important" (Wilkinson et al. 2016). The problem is augmented by the different perceptions of the phenomenon and how it is experienced in different areas and by different populations (Kälin 2010). In some occasions the experiences are detrimental; in others they have been financially beneficial (Tol 2013). These experiences determine how the responses to climate change are regulated and the political will to regulate these at a national level. Regulation does not necessarily reflect the need to manage greenhouse gas emissions more sustainably or address the environmental aspects of the problem but also the mitigation and adaptation measures to climate change, including climate-induced migration. Given the lack of consensus at a global level, at a domestic level, it could be more efficient to regulate climate-induced migration as an adaptation strategy. For example, New Zealand has proposed the creation of a climate migrant visa in order to support those leaving SIDS as a result of climate change. The proposal has received little support. In the event that this proposal is fulfilled, its implementation brings with it questions. For example, what is the threshold of loss that has to be experienced for such a visa application to be successful? In addition, questions are raised over the legal precedent this will create; could there be an extension of this visa to people affected by phenomena unrelated to climate change, such as earthquakes or volcano eruptions?

Climate-Induced Displacement Under International Law

There have been multiple attempts to address the reasons of climate change and its consequences, most notably the Paris Agreement which was the first universal legally binding climate agreement. The Agreement aimed at creating collective state obligations in addressing climate change (United Nations 2016). But, given the scope of the problem and the multidimensional consequences which are now directly affecting and generating human movement, climate-induced migration requires a human-centered approach rather than one that responds and limits the effects of climate change.

Protection of refugees derives from the 1951 Refugee Convention. The Convention was created in the postwar era in order to address the wave of refugees moving across Europe during and after War World II (Türk and Nicholson 2003). As a response to these events and the conflicts that followed the Cold War, the 1951 Refugee Convention laid down the definition of a "refugee" and the international "standards for treatment of refugees" (Clayton 2016). The 1951 Refugee Convention aimed at providing sanctuary to refugees with the most significant aspect of this protection being the principle of "non-refoulement" – no person should be expelled or returned to the country where he/she will be persecuted on the grounds of race, religion, nationality, membership of a particular social group, or political opinion. In an effort to protect people from severe human rights violations, the Convention provided the framework within which a person fleeing their homeland due to a conflict could ask for asylum in a foreign country. The scope of the 1951 Refugee Convention does not extend to offering protection to those fleeing their homeland due to environmental factors. More specifically, the 1951 Refugee Convention provides under Article 1(A)(2) that: "For the purpose of the present Convention, the term refugee shall apply to any person who: As a result of events occurring before 1 January 1951 and owing to *well-founded fear of persecution* for reasons of race, religion, nationality, membership of a particular social group or political opinion, is outside the country of his nationality and is unable or, owing to such fear, is unwilling to avail himself of the protection of that country; or who, not having a nationality and being outside the country of his former habitual residence as a result of such events, is unable or, owing to such fear, is unwilling to return to it (emphasis added)".

The Convention provides that people will be able to bring a claim under Article 1(A) if there is good evidence to suggest that the claimant has a reasonable fear of persecution upon return to their homeland due to their race, religion, nationality, membership of a particular social group, or political opinion. Persecution has three elements: "(1) serious harm that is (2) inflicted or tolerated by official agents (3) for illegitimate reasons" (Price 2009). Therefore, the consequences of climate change do not come under the definition of "persecution", since they do not derive from official state agents. Nevertheless, asylum claimants have claimed that the fact that the State chose not to spend money in order to protect the vulnerable group of people residing close to the shore and who were threaten by rising sea levels amounted to persecution by the government (Refugee Appeals 72179/2000, 72180/2000, 72181/2000).

According to Price, persecution does not apply to a specific type of harm induced to a person, and there is no specific definition in the relevant jurisprudence. Nevertheless, the humanitarian approach suggests that protection should be afforded regardless of the specific harm induced (Price 2009). This theory could prove beneficial to those fleeing their homeland due to the effects of climate change and in pursuit of asylum in a neighboring country. If the focus of the Article is the harm rather than the persecution itself, a wider interpretation could reveal that a harm that causes displacement could be addressed even when this is not anthropogenic, vis-à-vis a climate change-induced harm. The claimant should show genuine fear of being persecuted upon return to their homeland, evidenced by their previous experience and circumstances in accordance with the definition of "refugee". This "objective" or "subjective" fear derives from the effects of a natural phenomenon, despite the fact that climate change is attributed to human activity. "Fear" is at the center of appeals over asylum claims, where appellants are relying on their "fear" over the environmental and economic circumstances of their country, as a factor to base their asylum claims on (Refugee Appeal No, 72189/2000 to 72195/2000). As Price accurately states, "not only is it arbitrary to focus on persecution to the exclusion of other harms, but it is also arbitrary to focus on certain reasons for persecution to the exclusion of other reasons" (Price 2009).

Although optimistic interpretations of the 1951 Refugee Convention suggest a possible solution to

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the problem, this is far from becoming a reality. Considering the time and reasons of its creation, the Convention understandably does not cover some of the present-day circumstances, mentioned in these asylum claims, under which people decide to flee their homeland. Therefore, the coverage offered by the Refugee Convention does not accommodate people fleeing their homeland due to the climate change effects, as illustrated by the now heavily populated list of asylum claims, initiated by "climate migrants" seeking protection under the 1951 Refugee Convention. The majority of these cases are challenged on their inability to bring the applicant's concerns over returning to their homelands under the scope of the 1951 Refugee Convention (Refugee Appeal No. 72185/2000). Under the 1951 Refugee Convention, the asylum seeker bears the burden of proof in establishing that they are members of a particular group and persecuted due to this membership. But, these asylum claims are based on "fears" common to the whole population of several of the affected islands. Therefore, the applicants do not belong to a specific group which is persecuted under the Convention's wording (Refugee Appeal No. 72186/2000).

One such case was brought by Ioane Teitiota. He claimed that due to the serious effects of climate change on the island of Kiribati, he could not return. He claimed that Article 1A(2) of the Refugee Convention could protect "environmental refugees". He sought to appeal a decision of the Immigration and Protection Tribunal that Teitiota could not bring himself within the Refugee Convention on the basis that Kiribati was suffering the consequences of climate change. The Court said the following: "In the particular factual context of this case, the questions identified raise no arguable question of law of general or public importance. In relation to the Refugee Convention, while Kiribati undoubtedly faces challenges, Mr Teitiota does not, if returned, face 'serious harm' and there is no evidence that the Government of Kiribati is failing to take steps to protect its citizens from the effects of environmental degradation to the extent that it can. . . That said, we note that both the Tribunal and the High Court emphasised their decisions did not mean that environmental degradation resulting from climate change or other natural disasters could never create a pathway into the Refugee Convention or protected person jurisdiction. Our decision in this case should not be taken as ruling out that possibility in an appropriate case" ([2015] NZSC 107). Currently there is no refugee or immigration law to provide protection for climate migrants, but the Court left open the possibility of the Refugee Convention being interpreted to address similar circumstances. Due to this lack of relevant human rights protection and as a result award of asylum, "climate migrants" are caught in a legal lacuna.

In the case of AF (Kiribati), the Court said that the voluntariness of the decision to migrate is pivotal in decision-making over granting asylum ([2013] NZIPT 800413). In circumstances such as those in this case, where the applicant voluntarily and soberly decides to migrate to a safer natural environment, the voluntariness of the action is sufficient so as to exclude itself from the realm of the 1951 Refugee Convention. According to the Overseas Development Institute, when the effects of climate change are so severe as to be considered unbearable, then migration should be considered forced (Wilkinson et al. 2016). In addition, return to the place of origin might not be possible, due to the loss of land. As the Overseas Development Institute accurately observes, the difference between climate migration and those fleeing environmental disasters is that the first is a reaction to an anticipation of severe effects rather than to a severe disaster with current consequences (Wilkinson et al. 2016). Under such circumstances and in pursuit of a safe environment, migration tends to happen internally, meaning that people will choose to move to a safer environment within their homeland's borders. Such movement though is not one that could come under the scope of the 1951 Refugee Convention, even if the asylum seeker could show a genuine fear of returning home.

The Indirect Effects of Climate-Induced Displacement

Climate migration brings with it risks such as the movement towards areas with little or no adaptation measures to climate change effects (dykes, etc.) and to areas with little health provisions (IPCC 1990 and 1992 Assessments 1992). Added to these, climate change and its effects have been the prevailing factors for several disturbances, causing conflict and violence. It is important to understand that climate change can not only cause migration due to the environmental factors affecting the quality of one's life (securing food, water, shelter, safety, etc.). It can also accelerate unrest and conflict. In some occasions, and as history shows, such long-standing conflicts have also resulted or originated from the scarce natural resources (Türk and Nicholson 2003). The effects of diminishing resources and the ensuing conflicts can lead to issues currently covered by the 1951 Refugee Convention. In 2017, Steve Trent (Environmental Justice Foundation) said that "Climate change is the unpredictable ingredient that, when added to existing social, economic and political tensions, has the potential to ignite violence and conflict with disastrous consequences" (Taylor 2017). Such conflicts have also been reported in the case of AF(Kiribati), whereas the social effects of climate change are now reflected on the increased criminal activity in the area ([2013] NZIPT 800413).

In addition, the UN Refugee Agency suggests that migration itself could create tension in the new place of residence. Another problematic area, equally to that of hosting refugees for decades, due to decade-long conflicts is expressed by the United Nations Refugee Agency: "There is a real challenge as to how best to share responsibilities so as to ease the burden on any one state unable to shoulder it entirely. There is also a need to put in place burden sharing – not burden shifting – mechanisms which can trigger timely responsibility sharing in any given situation" (Türk and Nicholson 2003). This is true in climate-induced displacement, given the shared responsibility for hosting "climate migrants" as well. It should be noted that the responsibility of greenhouse gas emissions is not shared proportionately to the burden of receiving, hosting, and protecting "climate migrants" by several states. Those that are mostly affected by climate change are those least responsible for the phenomenon itself. In addition, as Goodwill-Gill and McAdam suggest, "[t]he study of refugee law invited a look not only at States' obligations with regard to the admission and treatment of refugees after entry, but also at the potential responsibility in international law of the State whose conduct or omissions cause an outflow" (Goodwill-Gill and McAdam 2007). This requires that there is recognition of the significance of each country's contribution to climate change but also the effect of each national regulation to the overall combat of the phenomenon. But, this is far from being realized.

Sustainable Development and Climate-Induced Displacement

The Sustainable Development Goals do not explicitly address the lack of protection of "climate refugees" under international law. The relevant indicators suggest a general concern over the phenomenon and address the different policy development efforts for ensuring integration of "climate refugees". Nevertheless, such connections and the need to explore ways to address this emerging wave of climate migrants have been included in the analysis of SDG 13. Indicator number 13.1 suggests "[strengthening] resilience and adaptive capacity to climate-related hazards and natural disasters in all countries". These are measured by the following:

1. Measurement indicators and correlated matrix for conditions of (a) potential displacement, (b) mitigation options, (c) adaptation alternatives allowing remaining in place, and (d) establishment of mitigation/adaptation measures.
2. Quantitative and qualitative assessment indicators of application and effects of mitigation/adaptive measures.
3. Quantitative and qualitative assessment indicators of mobility/migration arrangements for displaced populations, including indicators to measure livelihood viability, living conditions, and rights protections at relocation destination.
4. Measure of resources allocated to actions directly related to displaced/potentially

displaced populations as a supplemental indicator to those above (Department of Economic and Social Affairs 2017).

Given how displacement is now considered an adaptation measure, the following progress of the indicator is informative, potentially under 13.1.1 on the "[n]umber of deaths, missing persona and persons affected by disaster per 100,000 people". Progress since then has indicated a general development at an international and national level in relation to adaptation measures in response to climate change (UN Economic and Social Council 2017). The 2016 report on the progress toward these indicators suggests that climate change is affecting the most vulnerable countries and communities (UN Economic and Social Council 2016). The target indicates that responses to environmental disasters and environmental risks would limit climate migration and the need of displacement. Nevertheless, the indicators do not reflect on the asylum claim procedure upon arrival of a "climate refugee" to the host state.

The Future

Although we currently have a good understanding of the causes of climate change and its effects on the natural environment, the emerging numbers of climate refugees have not been addressed within the existing international law. The climate change effects range from increased and more severe weather phenomena to rising sea levels. For example, the Pacific Islands have been greatly affected by climate change due to more frequent extreme weather phenomena and rising sea levels affecting the secure gain of fresh water and food due to soil erosion. On the other hand, northern countries are experiencing the development of new industries contributing to the national gross domestic product. Therefore, reaching a consensus on a globally accepted response to climate-induced displacement is currently within the spectrum of impossibility. The problem primarily derives from the current definition of "refugee." The UN Refugee Agency defines refugees as "people fleeing conflict or persecution. They are defined and protected in International law, and must not be expelled or returned to situations where their life and freedom are at risk" (UNHCR 2018). The definition implies forced migration induced by life-threatening or freedom-threatening circumstances. In a situation where a conflict is present and the person faces persecution for any reason as provided by the 1951 Refugee Convention, an asylum claim could be straightforward if the evidence of such fear is available. Nevertheless, in cases of climate migration, where the urgency, the voluntary aspect of fleeing, and the questionable threat to freedom is present, an asylum claim is impossible to be successful. There is a need for redefining "refugees" by expanding its meaning and therefore expanding the scope of international law.

Definitions of climate change vary, and although they give an indication of its effects on the enjoyment of a life of quality, they are not directly drawing links with these. For example, the Oxford Dictionary of Environment and Conservation defines climate change as "Any natural or induced change in climate, either globally or in a particular area. Examples include the natural climate change that has caused ice ages in the past, and global warming that is now being caused by rising concentrations of greenhouse gases in the atmosphere" (Park 2008). The Intergovernmental Panel on Climate Change defines climate change for the purposes of the United Nations Framework Convention on Climate Change as "A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". For the use of the Intergovernmental Panel on Climate Change, the definition of climate change suggests that "Projections of future climate change reported by the Intergovernmental Panel on Climate Change generally consider only the influence on climate of anthropogenic increases in greenhouse gases and other human-related factors" (Houghton et al. 1996). The plethora of definitions is evidence of the general interest around climate change and its causes as well as its effects. Nevertheless, few definitions have explicitly linked climate change to human activity and legal responsibilities in tackling its ensuing effects. This is explained by Fischer who says that the consequences of climate change can rarely be attributed to identifiable human activities, while these can occur in multiple locations and at different times (Fischer 2013).

Several proposals for reform have been made. The aim of these proposals is the creation of a legal framework to cover the protection of "climate refugees". The first proposal put forward was the reliance on the United Nations Framework Convention on Climate Change in not only responding to climate change but also to addressing the protection of "climate migrants". The main criticism against this was that such instruments primarily impose duties between states regulating interstate activities. The discussion of duties of states toward individuals, as those required for the protection of "climate migrants", is usually addressed under human rights law or refugee law (Docherty and Giannini 2009). Another proposal was the creation of an independent convention that would bring together the affected communities and create an instrument that would address this issue independently from states. Docherty and Giannini suggested that "negotiations for a new convention could break out of the traditional state-to-state mould and involve communities and civil society, a growing trend in international treaty development. These groups could help increase the focus on humanitarian provisions and could push states to expedite the negotiating process" (Docherty and Giannini 2009). But McAdam has criticized this approach as problematic by saying that a universal instrument will not address the interests of the affected communities (McAdam 2012). The effects of climate change are perceived differently in Tuvalu, Kiribati, and Bangladesh "because of their particular geographical, demographic, cultural and political circumstances, and it may be that localized or regional responses are better able to respond to their needs. Such approaches can take into account the particular features of the affected population, in determining who should move, when, in what fashion, and with what outcome" (McAdam 2012). According to Docherty and Giannini, neither the current refugee law regime nor climate change regime was created to address this emerging migration issue. Therefore the solutions to the problem have to be identified elsewhere (Docherty and Giannini 2009).

At an international level, the United Nations agencies have been exploring ways of addressing the matter under refugee law and human rights law. In 2017, the United Nations High Commissioner on Human Rights released an overview of its role amidst environmental disasters, with a specific focus on displacement and movement across borders. Since then, further developments have taken place, such as discussions over the Paris Agreement and specific responses to displacement. A further step forward has been made by the United Nations High Commissioner for Refugees which has been engaging with the United Nations Framework Convention on Climate Change in relation to "migration, displacement, and climate change" with further collaboration since 2008. The latest development comes through the WIM Task Force on Displacement in 2017, with Activity II.4 asking for the United Nations High Commissioner for Refugees to map the "existing international and regional instrument, guidance and tools on averting, minimizing and addressing displacement and durable solutions" (UNHCR 2008). The expected submissions will be delivered in 2018.

Conclusion

The current migration wave due to rising sea levels – among other climate change consequences – is unprecedented and one that challenges the traditional notions of refugee law, human rights law, and international law. The effects of climate change are not limited to the "sinking islands" as there are multiple experiences of the consequences of climate change shared across the planet. Considering the examples of the shrinking Aral Sea as well as the outcome of increased temperatures observed in multiple European countries, the ensuing relocation measures as an adaptation method to climate change have been expected. In relation to those fleeing these sinking islands, international law has been proven to be inefficient in providing for their protection. The existing refugee protection framework is falling short, unable to address more modern and emerging issues deriving from environmental factors, albeit anthropogenic ones. In addition, the effects of climate change are not only experienced by "climate migrants" but also the rest of the world hosting these migrants (Stern 2007). International law does not have the provisions and is not supported by the political will to support changes in this area of law, in order to support individuals from the effect of a globally anthropogenic environment-altering phenomenon. Further developments in international law are necessary, and consultation with those affected more is pivotal to the efficient protection of "climate refugees".

Cross-References

- ▶ Climate Change Adaptation (CCA)
- ▶ Climate Change and Human Migration as Adaptation: Conceptual and Practical Challenges and Opportunities
- ▶ Climate Change Effects on Human Rights
- ▶ Climate Change Effects on People's Livelihood

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Climate-Related Human Displacement

► Climate Change and Human Migration as Adaptation: Conceptual and Practical Challenges and Opportunities
► Climate Refugees: Why Measuring the Immeasurable Makes Sense Beyond Measure

Climate-Resilient Cities in Latin America

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Synonyms

Cities; Climate change; Climate solutions; Intermediate cities; Latin America; Resilience; Small and medium sized cities; Vulnerability

Definitions

Climate change-related risks arise from climate trends, variability and extremes, as well as the vulnerability of societies, communities, or systems exposed in terms of livelihoods, infrastructure, ecosystem services, and governance systems. The adoption of effective measures for adapting to climate change and reducing the risks associated with it can respond to the three aspects of risk: **threats, vulnerability, and exposure** (CDKN 2014). The latter two are dynamic due to changes in economic, social, demographic, cultural, institutional, and governance circumstances. Additionally, strategies to strengthen resilience and reduce exposure and vulnerability must take into account local or regional specificity.

The vulnerability concept applied to cities is understood as a multidimensional phenomenon that encompasses the **a city's sensitivity** (which in turn depends on its physical, social, and economic characteristics) and its **reaction capacities** (the current capacity to respond to the short-term effects of an extreme climate event) and of **adaptation** (long-term capacity to plan, prevent, and/or manage the impacts of climate change) (Sakai et al. 2017). Measuring vulnerability is key to understanding what aspects of cities must be strengthened to achieve climate resilience. The evaluation of each component of vulnerability can be done through different methods, each of which has its own characteristics.

Other important concept for this chapter is the **definition of resilience** proposed by IPCC (2018) as the:

> *"ability of social, economic and environmental systems to cope with a dangerous event, trend or disturbance, responding or reorganizing in a way that maintains their essential function, their identity and structure, while preserving the capacity for adaptation, learning and transformation"*, we understand efficient urban governance climate resilience in this document as the process through which cities, on the one hand, prepare themselves to face a climate phenomenon and, on the other, have the capacity to recover from events and disasters produced as a result of climate change, but also the capacity to learn to improve and transform.

Another concept related to this chapter and climate resilience is that of an efficient urban governance system, that, according to UN-Habitat (2016), is the way in which institutions and citizens are organized and the processes they use to manage a city. These must be inclusive and integrated, which involves planning, budgeting, managing, and monitoring in a participatory manner, the provision of services in the city, as well as urban planning processes, including climate resilience.

Introduction

"*Climate change is already affecting people, ecosystems and livelihoods in the world.*" So states the last report on the impacts of a 1.5 ° C global warming by the Intergovernmental Panel on Climate Change (IPCC) launched in October, 2018. The impacts of global warming are being experienced rapidly and unequivocally (sea level rise, loss of biodiversity, declining crop yields, more frequent heat waves, and heavy rains) and the planet to this day has already experienced a 1 °C warming.

All countries are affected by this phenomenon, but the impacts tend to fall disproportionately on vulnerable population groups that, due to their conditions (socioeconomic, health, education, age, gender, ethnicity, livelihood, location, and housing characteristics, among others) are more exposed, and more sensitive to its effects. Their ability to adapt is also more limited, as is the case of most people in Latin America and the Caribbean. According to the executive summary of the Fifth IPCC Assessment Report of the Climate and Development Alliance published in 2014, the impacts of climate change in the region will mainly affect the water availability, the spread of vector-borne diseases, and the food production and quality.

As complex dynamic systems in permanent movement and change, cities have suffered an accelerated process of urbanization in recent years, seen especially in small- and medium-sized cities. They have experienced great demographic growth, as many people have migrated from rural areas to urban areas, and recently, migration from large cities to small- and medium-sized cities has increased (CEPAL 2018). In the last 30 years, the latter have grown faster than large cities, attracting most of the urban population.

Although there is no unified definition, the United Cities and Local Governments Network and UN-Habitat (2012) define thresholds of between fifty thousand and one million inhabitants to characterize small- and medium-sized cities, also called intermediate or secondary. However, beyond a characterization given only by the size of their population, these cities are defined by the relative size they have within their country, the system of cities in which they operate, and the similar functions they share in their country.

According to other information from UN-Habitat, more than half of the world population (54%) currently lives in urban areas. In the case of Latin America and the Caribbean, the urban population already reaches 80%, and, of it, half is located in small- and medium-sized cities. Additionally, projections show that this percentage will increase approximately to 90% by the year 2050.

This trend responds to different characteristics that small and medium cities have. For example, they play an important connecting role between urban and rural areas, and have a relevant role in the provision of different types of services (commercial, educational, governmental, social, touristic, logistic, cultural, among others) for the inhabitants of urban and rural areas.

However, this accelerated urbanization coupled with population growth have become strong drivers of climate change in cities, making them highly vulnerable and exposed to its threats, due to various factors such as land use change, deforestation, and their placement in high risk areas, among others. About 40% of the population of small- and medium-sized cities lives in coastal areas, which exposes them to a greater extent to disasters (CEGLU 2016). But also, and although the estimates are not exact, it is thought that cities contribute 80% of greenhouse gas emissions in the region, coming mainly from the transport and electricity sectors (UN-Habitat 2012). Thus, urban action becomes an urgent and fundamental need in facing climate impacts with strategies of mitigation, adaptation, and risk management, which can allow cities to prepare themselves and become more resilient.

The Climate Resilient Cities Initiative (CRC) was born in this context of opportunities and challenges to build urban climate resilience as a research-action program that supported the implementation of six projects (detailed information of each project in www.crclatam.net). CRC was part of a strategic alliance between the International Development Research Center (IDRC), the Climate and Development Alliance (CDKN), and Fundación Futuro Latinoamericano (FFLA), seeking to create a bridge between research and concrete action. The main objective of the initiative was to generate solutions that promote climate-resilient development in medium-sized and small cities in Latin America, many of which are experiencing rapid growth and climate change impacts contributing to improving the living conditions of the inhabitants.

The selected 13 cities, like many in the region, face common social, economic, environmental, and climate problems and challenges, among which we can mention:

- **Significant levels of social inequality, a large number of informal settlements, and high environmental degradation,** due to the accelerated urbanization processes they have experienced. Generally, the poorest people live in unsafe human settlements, on the banks of rivers, hillsides, or neighborhoods with limited access to basic services, and in situations of insecurity and violence. According to reports from 2016, the UN states that these great inequalities mean that climate threats have a disproportionate impact on poor and vulnerable groups, further increasing this inequality and poverty gap. In Latin America and the Caribbean, urban poverty levels reached 26.8% in 2016, while urban indigence reached 7.2% in the same year (CEPAL 2018).
- **Weaknesses in their institutional decentralization, which, among other things, makes local governance difficult**[1]. Although many cities have experienced interesting decentralization processes, these are still incipient in others. Resource transfer from the central level continues to limit their capacity for action and causes problems in budget planning and execution, preventing, for example, the necessary financing to provide access to basic services for the entire population (CGLU 2016).
- As a consequence of the above, **many cities show deficiencies in the provision of basic services and infrastructure** (water, sanitation, electricity). According to UN-Habitat data (2012), only 75% of homes are connected to the drinking water network in small- and medium-sized cities in Latin America.
- **Weakness in their urban planning processes**, characterized by a short-term vision, which meets urgent and nonstrategic needs. Therefore, neither adaptation nor risk management is integrated into the local planning process nor incorporated into their strategies and development plans. On the other hand, urban development plans usually emphasize the physical aspect, instead of incorporating an integral and interdisciplinary perspective that considers the different dimensions of the urban space (social, political, cultural, economic, environmental, climate dimensions, among others) (Sánchez 2013).
- Because of all of the above, **these cities are highly vulnerable to the effects of climate change** and are very exposed to suffering

[1]According to UN Habitat (2016), An efficient urban governance system is the way in which institutions and citizens are organized and the processes they use to manage a city. These must be inclusive and integrated, which involves planning, budgeting, managing, and monitoring in a participatory manner, the provision of services in the city, as well as urban planning processes, including climate resilience. In turn, for Fundación Futuro Latinoamericano, governance includes "those mechanisms, processes and institutions through which the State and civil society articulate their interests, exercise their powers, fulfill their obligations, have accoutability, mediate their differences, and achieve balances in power asymmetries".

hydro-meteorological, climate, and geological disasters. In general, and as previously stated, the most affected groups are those living in poverty. In the last 30 years, in Latin America and the Caribbean, around 160 million people have been affected by these disasters, and between 40% and 70% of economic losses have occurred in small- and medium-sized cities, which are those that normally have weaknesses in disaster risk management (UN-Habitat 2012).

Climate Threats and Vulnerability in Cities

For small- and medium-sized cities, there seems to be a widespread belief that understanding how vulnerable they are to climate change can be an impossible task. Specialized human resources are limited, the necessary data do not exist or are in different formats and, often, local authorities' awareness about the importance of the subject, although on the rise, is still low. The urgency to solve everyday problems does not allow a medium- and long-term vision. This contrasts with the national and regional trends where many countries are developing their plans to adapt to climate change, although there are also many in the process of drafting and implementation. In some Latin American countries, such as Peru, progress is also being made with Regional Climate Change Strategies (*Estrategias Regionales de Cambio Climático, ERCC*) that are also integrated into the Regional Concerted Development plans3. Some cities may have their own local adaptation plans, but, in general, this is not common and their degree of implementation is low. Therefore there are planning efforts at the national and regional level, but few are seen at the local level.

In light of these climate-induced changes, one of the key questions that decision-makers ask themselves is how to determine the level of vulnerability of their cities. If there is no information on how climate change is affecting and will affect the local scale, it is difficult to define appropriate adaptation actions for urban resilience. The answer is not simple nor is it unique, and it depends on the context of each city.

This section explores the different approaches that the CRC Initiative has used to answer this question. This has allowed us to answer these two questions:

1. How were the existing data and information gathered?
2. How are risk areas determined and how are climate trends that affect cities defined?

How Were the Existing Data and Information Gathered?

It is important to build on existing data and studies and to identify the information that has been generated for the region or the city. Based on this, it is possible to determine the existing gaps regarding local information and thus develop specific research to cover them. In the projects of the CRC Initiative, this has been key, since secondary information has been used in censuses, studies of other areas, and institutions inside or outside the municipalities. During this process, it was discovered that, contrary to what was expected, *there is a wide variety of data and knowledge in each city to begin a diagnosis of the situation.* However, the data is available in fragmented form, in different formats and scales. This complicates its integration and comparison. Frequently, the administrations and organizations of the city do not know the type of information that exists in other dependencies or, sometimes, do not fully understand content and how it can serve to advance the decision-making process based on evidence. For this reason, as part of the projects, formats were combined and information was integrated, generating databases open to the community, readily available and at different scales that are necessary for decision-making.

It was also concluded that analyses carried out with census information have been valuable and appropriate for investigating vulnerability to climate threats. However, the scale at which these censuses are conducted is limited to regions and does not capture local specificities. This includes a lack of information about access to basic services, which is not included in the census data, such as pollution of the urban water supply or lack of maintenance in the plumbing system. In addition, information on this scale does not identify residents' perceptions of these problems and their knowledge about how to deal with them. Therefore, at this stage, it has been essential to listen to the perceptions of the community through interviews, focus groups, and workshops.

It is important to highlight that CRC, as an action-research initiative, found out that *knowing citizen's perceptions on the risks they are subject to was essential to understand the real vulnerability of the population and it was the basis for the co-building of knowledge*. This approach turned out to be key, especially in the four cities of the Amazon Delta where the study delved deeper into understanding the problems associated with flooding, such as food security and health (Pinedo-Vazquez et al. 2018a), as well as in the two communities around Coyuca Lake where the study focused on the population's strategies to deal with floods (Becerril et al. 2019), and also in the population of Nueva Ciudad de Belén in Iquitos (Peru), where the study identifies the consequences of flawed housing plans for the community's welfare, among others (Desmaison et al. 2019).

In addition to working with the community, consultations were held with key stakeholders, either to provide new information or to validate the knowledge generated through scientific studies or climate models. When the necessary information did not exist or was not on the appropriate scale, the researchers consulted with experts and key informants from each locality and affected community. This was done through interviews, group discussions, participatory workshops, and focus groups, which helped supplement existing information and close knowledge gaps.

How Are Risk Areas Determined and How Are Climate Trends that Affect Cities Defined?

To understand climate variability and extremes in cities and their surroundings, the research centers and partner universities of the CRC developed local studies to complement the information gathering mentioned in the previous section. This involved, among other things, developing climate models using meteorological data, analyzing historical trends of climate events, and mapping at an appropriate scale to better visualize the situation. This was especially useful for quantitative data, but, moreover, social vulnerability was defined, taking into account data from existing censuses and the community's perception and that of the affected groups through interviews and focus groups.

In the six projects of the CRC Initiative, there were three types of approaches to define what are the factors that cause vulnerability in cities: looking to the past and learning about climate trends (Pinedo-Vazquez et al. 2018b); taking a snapshot of reality as it is today (Sakai et al. 2017); and looking into the future with 20 or 30 years of climate projections (Sabogal et al. 2018b).

One important conclusion from these research is that *the way to define vulnerability must effectively be multidimensional, prioritizing the local reality for a co-generation of knowledge.* This manner of working where the key stakeholders of the community and the vulnerable population are included in all stages provides, in addition to inputs, a validation of actions. It also allows to identify areas that require greater attention in terms of optimization, investment, management, and mainly articulated policy guidelines.

Building Resilience Through Participation, Dialogue, and the Incorporation of the Gender Perspective

The CRC Initiative projects contribute to the understanding of how participation, dialogue, and the incorporation of the gender perspective constitute fundamental conditions for the building climate resilience.

Participation and dialogue constitute systematic processes of collaboration between academia, civil society, authorities, social and community groups that self-manage knowledge through an inclusive dialogue and the opening of permanent processes of reflection and action that enable reciprocal learning (everyone learns from everyone), social empowerment, and building collective solutions (Vásquez et al. 2017).

These projects have confirmed the added value of participation and dialogue in the research-action processes, in which local stakeholders were involved. This was evidenced in knowledge building with key community stakeholders as a legitimate exercise to modify power relations in decision- making. Additionally, the importance of incorporating gender analysis in vulnerability assessment was confirmed, valuing the role, voice, and active participation of women in the promotion of climate-compatible strategies, actions, and development policies.

It also allowed the understanding and assessment of the knowledge that each group has in terms of adaptation and resilience, especially women's knowledge and skills, which are invisible as a result of unequal gender relations.

Levels of Participation

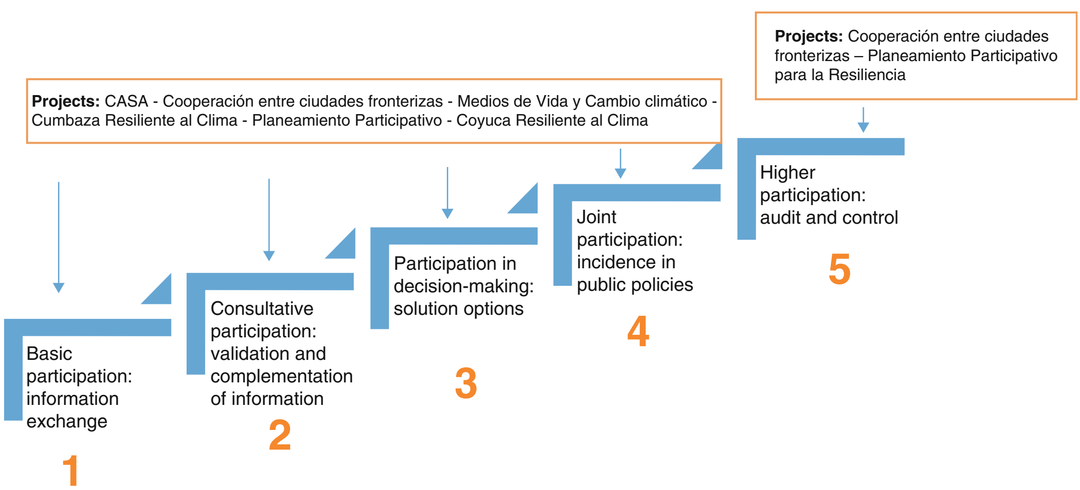
The participatory processes allowed to validate, co-construct, and enrich the information. Through them, the understanding of the needs of the diverse stakeholders and the generation of solutions related to the main climate vulnerability factors existing in the cities were promoted, with the purpose of encouraging policies or decisions that are sustainable over time, promoting urban climate resilience.

One way to represent the level of participation is through a ladder of participation (Fig. 1) that identifies several steps or levels of power. The greater the involvement of the stakeholders, the greater the possibility of transforming power relations and promoting citizen empowerment in decision-making. The proposed steps range from an informative and consultative participation, through a collaborative participation for co-management, to a participation for supervision and social control at the higher level.

As shown in the graph below (Fig. 1), the CRC Initiative projects mainly went through the first three levels: informative and consultative processes were carried out on the research problems and alternative participatory solutions were proposed, including the generation of policies through collaboration and co-management. These processes had the contribution of authorities, NGOs, technical and academic bodies, and grassroots organizations, with whom we worked, above all, in the research, exchange, and validation of the information generated by the projects. Two of these managed to agree mechanisms of oversight and control, with particular scopes, according to their contexts and processes.

The Gender Perspective in Building Climate Resilience

The gender perspective helps to make visible and transform inequalities in the exercise of rights, development opportunities, and power relations between men and women. This approach allowed the development of differentiated analyses on how the effects of climate change affect the social groups present in the researched contexts of vulnerability, according to their sex, gender, age,



Climate-Resilient Cities in Latin America, Fig. 1 Participation ladder in the CRC Initiative. Of author's creation based on Martín (2010) socioeconomic status, geographical origin, and other aspects that involve more or less vulnerability (Kratzer and Le Masson 2016).

The effects of climate change affect the living conditions of people residing in vulnerable settlements and do so in a differential manner. It is the people who live in poverty, who are mainly harmed. Among them are women, adolescents, and girls, who are affected not only because of their situation of social, economic, and environmental vulnerability but also because of their gender.

The differentiated impacts of climate change between men and women are linked to historical gender inequalities, related to roles, knowledge and skills, the access, use, and control of natural resources and production, as well as power relations and their participation in decision-making. The projects of the CRC Initiative show how women's situation of vulnerability increases due to living conditions, with disadvantages in the access to health and social security, employment, and income generation. It also increases due to the fact that they maintain a subordinate position at home and in community organization, but also because of the excessive workload in relation to their domestic role, as well as situations of violence that limit the exercise of their rights (Vásquez et al. 2018). It was demonstrated that most of the women who participated in the surveys, focus groups or interviews, play a preponderant role in different tasks. For example, in the care of family members, in productive activities that support the family's economy, or in community participation; however, it has been found that they are absent in the decision-making spaces, where their opinions, their particular needs, their capacities, and contributions are not taken into consideration.

Making gender gaps and differences visible in the assessment of climate vulnerability is an opportunity to plan adaptation actions that include men and women and other population groups, but above all, it is an opportunity to promote structural transformations in the future, in relation to inequalities, asymmetric power relations, use, access, control of resources, and decision-making. It also contributes to making visible the value, the roles, and the experiences of women as preponderant stakeholders in climate resilience building.

Findings of Gender-Differentiated Vulnerability

Research findings from the CRC projects related to gender-related vulnerability indicate that there is an urgent need of hard statistical data and qualitative information to sensitize decision-makers and policy makers. This will help to deepen their understanding and the urgent need to incorporate this perspective in their actions, policies, programs, and projects, not only in the planning and management of climate risks but also in the planning and management of development. Strengthening the vision of gender differences contributes to a necessary coordination between development policies, climate policies that promote equality. As an example of this, Vázquez, Rovelo et al. (2018) show the following information that helped to understand the context in which women and girls live:

- In Coyuca (Mexico) a large proportion of the female population is illiterate or did not finish their basic studies. The average level of schooling for the male population is 7.9 years, while for women it is 7.4 years (López 2017). Also there is little access by women to the formal labor market and, therefore, to health rights obtained by having a fixed and formal job, unlike the male population, which represents more than 60% of the employed population. In the percentage structure of the economically inactive population, the female population predominates with 75% for El Bejuco, and 80% for La Barra (López and Palacios 2017).
- The situations that most affect the population of Nueva Ciudad de Belen (Iquitos) are child malnutrition and teenage pregnancy. The second cause generates barriers that prevent girls and adolescents from accessing education, maintaining and reproducing the cycle of poverty and the lack of opportunities across generations, as well as the risks of neonatal maternal morbi-mortality. Another aspect that is related to this problem is the high rate of sexual violence (Desmaison et al. 2019).
- In the Cumbaza River micro-basin, rural women face difficulties in accessing biomass for food preparation, due to their scarce

availability, which forces them to spend more time searching for firewood. On the other hand, the holders of rights of irrigated rice plots are mostly men, and the role of women in this activity is circumscribed to salaried work as part of family groups that have specialized in rice planting and harvesting under irrigation (Sabogal et al. 2018a).

- Women heads of household in Chicolândia (Abaetetuba) reported the difficulties they have in accessing food, and how their children had to take only one meal a day or spend a whole day without eating. This is directly related to the limited opportunities of formally or informally paid economic activities. Often, these women exchange care jobs with members of other families, in exchange for food (Pinedo-Vazquez et al. 2018a).

From this section, it is obvious that climate change affects the population in a differentiated way. To improve the capacity for adaptation and increase resilience, the visions and experiences of the different social groups (women, men, children, elderly, indigenous) must be incorporated. Each group provides important solutions from their roles, experiences, and knowledge. Women, given their reproductive and care role (family, community, and environmental), have developed specific knowledge and have the capacity to respond comprehensively to risk.

Instruments, Policies, and Practices to Develop Climate Resilience

This section presents a summary of the solutions proposed by the six projects, emphasizing the fact that participatory planning and implementation processes are the basis for generating urban climate resilience.

Adequate Plans, Programs, and Policies

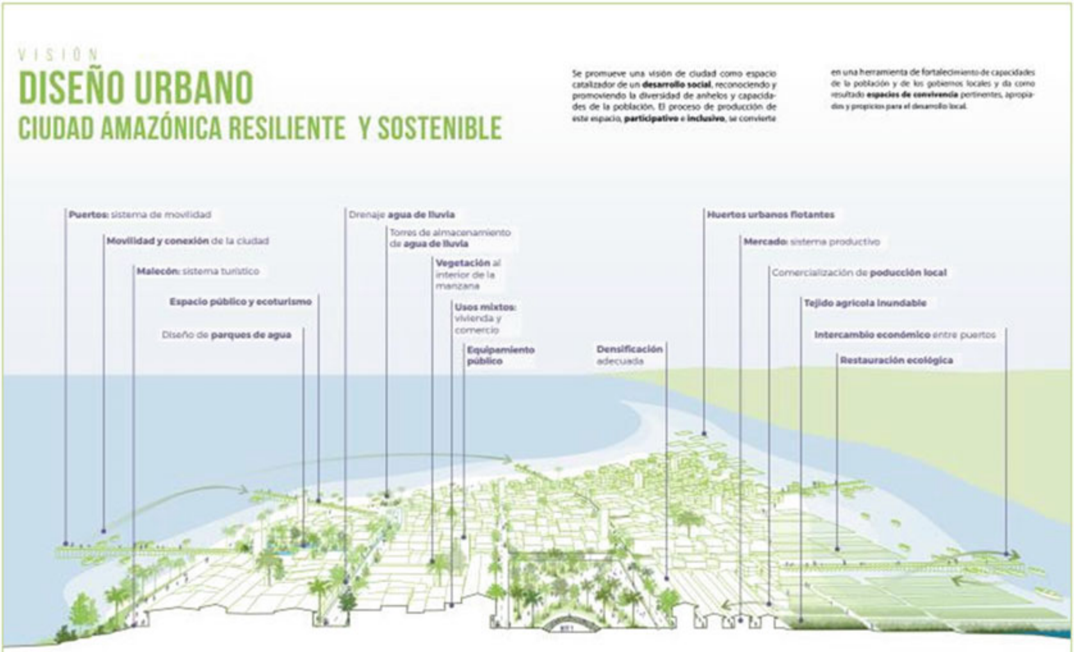
Most projects started in a context with little information about the impacts of climate phenomena, and their development plans did not include this variable. From the start, the proposals for solutions among the projects were diverse, going from carrying out capacity building processes and building road maps for the incorporation of these issues into local planning to influencing legislative processes so that climate change is included in city regulations.

In relation to the legal framework, the *Cumbaza Resiliente al Clima* project was based on the premise that adequate management of natural resources requires laws and regulations that are consistent with each other as well as efficient inter-institutional coordination. At this point, the project generated a governance analysis, which researched the consistency of policies and the regulatory framework; a comprehensive work that identified gaps. Based on them, the stakeholders established their priorities and commitments which were set in a road map. The road map defined the steps to follow in order to incorporate the results of the quantification of this link within their planning, and to adopt the corrective measures for an efficient use of natural resources. This road map is expected to guide local institutions in each sector, on what actions to take to improve the management of resources (forests, water, energy, food) and to develop green infrastructure adapted to the local reality (Sabogal et al. 2018b).

The *CASA* project developed a guide with guidelines and strategies that seek to visualize alternatives to city urbanization and expansion processes (see Fig. 2). The guide is supplemented with proposals for the diversification of the economic-productive activities used by the population to reduce the impacts of unsustainable extractive activities, while reducing their levels of vulnerability to unexpected changes. Resilience and adaptability in the population and public authorities was generated through participatory work in the development and co-design of common spaces that are sustainable (Desmaison et al. 2018).

Solution Portfolios Adapted to Cities

Two projects worked on proposals for city solution portfolios. Coincidentally, the projects were implemented in cities of different countries, and although the portfolios do contain common methodologies and similar solutions, they were built according to the reality of each place. Within the *Planeamiento Participativo* and *Cooperación*



Climate-Resilient Cities in Latin America, Fig. 2 Urban Design. Resilient and Sustainable Amazon City: taken from: CASA Project: www.casapucp.com/

entre Ciudades Fronterizas projects, participatory exercises were carried out to define these solutions and for each of them implementation conditions were listed (e.g., to include a project in the municipal budget), as well as the costs, responsability, and their limitations.

In the case of the *Planeamiento Participativo* project, the proposal was to work based on existing planning instruments and processes and other types of information in each of the cities. For example, the stakeholders' perception served as a starting point to build a consensus-based list of action options, conducive to proposals that were realistic and that they were able to implement, anchored in ongoing processes or in strong interest of local stakeholders, and, in some cases, secured a budget that facilitates its implementation (Hardoy et al. 2019).

Similarly, in the triple border between Paraguay, Argentina, and Brazil (of the *Cooperación entre Ciudades Fronterizas* project), a Steering Committee was formed that contributed to the construction and validation of the vulnerability study mentioned earlier in the chapter and proposed solutions to face climate change. The solutions were grouped into four categories: Green Infrastructure and infiltration measures, Prevention and response measures, Efficiency and Cooperation measures (Sakai et al. 2018). The team proposed pilot projects for most of the solutions in order to evaluate their effectiveness before proposing an extended implementation. According to the calculations made, the cost to start up and maintain all the solutions in the Triple Border is around 230 million dollars. With a lifetime of 20 years for most solutions, the annual cost would be approximately 11.5 million dollars each year for the three cities in total, which corresponds to 0.3% of the GDP in the Triple Border cities. The benefits (economic, social, environmental, etc.), on the other hand, are on average 3.5 times greater than the costs; thus the investments would be cost-effective (Sakai et al. 2018). It is worth mentioning that cost-benefit studies are not so common in resilience initiatives; thus, this project presents an innovative and significant activity (Sakai et al. 2018).

Technological Innovation

The *Medios de Vida y Cambio Climático* project in the Amazon delta developed an application **(AquiAlaga APP)7** for the collection of data on floods caused by rain and rising tides, developed for the small cities of the Amazon Delta (Pinedo-Vazquez et al. 2018). This application makes it possible to obtain information almost immediately, so that the corresponding agencies can act quickly against the impact of climate phenomena. The application is easy to access and use through mobile phones and the information that users generate is transmitted to planners and aid agencies. Currently, the tool is being used in the municipalities of Belém, Abaetetuba, Ponta de Pedras, Mazagão, and Santana. With the training workshops, the citizens learned how to collect data and locate it geographically. This application is being developed in collaboration with the SIPAM (Amazonia Protection System), so that anyone can receive alert data from the government climate radars, and for these to be validated by users in small cities of the Amazon Delta.

When proposing solutions to climate change, it is important from the start to offer the means and tools for active participation and empowerment to stakeholders, including the most vulnerable groups, and all levels involved in decision-making in order for them to appropriate the implementation of the identified solutions. Additionally, innovation plays a very important role, because these solutions must respond to people's needs, adapt to local contexts, and become sustainable alternatives for the areas where they are implemented.

In this context, the solutions proposed by the projects were directed towards promoting processes with a comprehensive and multilevel approach, reinforcing the importance of participation and decision-making from the bottom-up, thus motivating agreements between stakeholders from different sectors to seek joint solutions. This shows that research projects that promote concrete actions and respond to the needs of the population have the greatest impact and contribute to urban development and resilience.

Finally, as each of the projects of the CRC Initiative has shown, it is necessary to consider that the solutions must adapt to two clearly identifiable characteristics of climate change at the local level:

1. Heterogeneity, that is, each region or city is affected differently, for example, what for a coastal area can be devastating, for a mountain region can be perceived as an "improvement in climate";
2. Uncertainty, that is, the time, magnitude, and location of the impacts cannot be exactly known. In this sense, investment in innovative activities to face the effects of climate change will continue to evolve as knowledge continues to develop.

Conclusions

This report reflects on some important lessons and opportunities for 13 small- and medium-sized cities in Latin America as they grow and take on multiple and interconnected challenges of deteriorating water quality, more frequent storms, and flooding and soil erosion, as well as the informal occupation and development of land in high-risk areas. These cities have an opportunity to develop in a way that minimizes the risks associated with climate change, now and in the future.

This report offers "hope" for cities suffering from multiple environmental and development challenges, even those with significant gaps in terms of professional and administrative capacities and severely limited financial resources. It underscores the complexity of climate change impacts in urban areas, and specifically, the gendered nature of climate vulnerability. If city authorities fail to take these gendered vulnerabilities into account, or to engage people in finding solutions through participatory urban planning, they may lose the opportunity to do so with relatively small-scale, manageable solutions.

These projects demonstrate that at the local level resilience building can and should be integrated into development agendas. Small-scale initiatives that seek to improve urban services, manage climate risks, and promote development can directly address local needs and priorities, helping local stakeholders to thrive and prosper in the face of environmental change and as their cities grow.

The Contribution of Climate Resilience to Development (and Vice Versa)

Adaptation and resilience actions are often discussed and proposed in isolation from development planning. But these CRC projects reveal the very interrelated nature of climate resilience and development, particularly social development, including through the provision of improved urban services. Resilience actions contribute to development goals and vice versa.

By undertaking research and analysis at the local level and with the participation of different social groups, the CRC projects have been able to understand the complex interactions between climate change and extreme events, social and economic conditions, and environmental processes in a way that would not have been possible at a larger scale or without the participation of local stakeholders. This process has brought into sharp focus the interrelationships and interdependencies of climate resilience and local development needs and goals.

CRC projects are multipronged (essentially multisectoral) and have contributed to multiple social development objectives simultaneously, without visibly causing harm in any domain. The *CASA* project, for example, is making progress in terms of strengthening livelihoods as well as explicitly addressing food security and the empowerment of women and girls. Similarly, the Delta project is addressing the health and water access problems exacerbated by climate change by developing a rainwater collection system so families have access to clean and safe water from rainfall. These interdependencies were made clear through the vulnerability assessments conducted in each of these projects, underscoring the importance of undertaking this kind of analysis in both climate resilience and development initiatives.

Research conducted under the CRC projects has also highlighted how multiple factors interact to shape vulnerability of different groups and hence provide a starting point for identifying actions to improve resilience and well-being. Gender roles, the use, access, and control of resources, and women's practical needs and strategic interests, all shape women's and girls' vulnerability, and so action to build resilience needs to focus on these. It is at the local level where support services can be effectively delivered to prevent girls dropping out of school, and these services will have spillover benefits for achieving climate-resilient development.

The Importance of Local Autonomy

A vision of climate resilient cities does not have to be imposed by the national government: it can arise through local initiative and build on local knowledge.

Collectively, the projects funded under the CRC initiative have demonstrated significant progress in identifying and implementing appropriate actions for climate resilience in a relatively short time frame. This has been achieved by harnessing local knowledge and catalyzing collective action and knowledge sharing, with very limited national input or external resources. There are tremendous reservoirs of human capital that CRC projects have managed to tap into by providing a small resource to help organize people, bring them together, introduce contextual information, and promote joint analysis of climate change impacts and sources of vulnerability. The *Cumbaza Resiliente al Clima* project's analysis of the river basin is a good example of this. The projects have played a catalytic role, helping people to validate their own lived experiences and to build their self-confidence and agency in promoting greater climate resilience.

Valuing these local (nonfinancial) resources is therefore critical to climate resilience in cities, but local governments will need additional resources to take forward many of the ideas created by the projects. The projects demonstrate that climate resilience can and should be locally built, but ultimately the success of local initiatives will depend on being able to access external resources. Some of these Latin American countries have high levels of decentralization on paper, but in practice local governments receive very low levels of funding through fiscal transfers to spend on locally defined priorities (the majority is earmarked for specific sectors, to implement national initiatives). To truly value and support local action, greater fiscal and administrative decentralization is needed.

Results from the CRC initiative therefore support a localization agenda in climate resilience, recognizing that even in small cities a lot can be achieved without the need to have a national strategy or national programs in place to guide local processes. Local authorities can innovate using their own resources (and those of their partners) and small and medium cities can be engines of change.

The Benefits of a New, More Integrated Style of Planning

A new style of local development planning is needed to deal with the complexity of climate change impacts and the interaction of climate vulnerabilities with other social and economic development challenges. Efforts under the CRC initiative to undertake planning involving multiple actors and across sectors were critical to understanding risk and adaptation options and demonstrated that this kind of planning is possible. But it is not the norm and needs to be institutionalized, so all local development planning is a process of multistakeholder consultation, integration, and knowledge sharing.

In some of the projects, new institutions have been created to help promote this kind of multisectoral planning in the future, but these now need to be recognized in law and supported by local and national governments. Essentially, this form of multistakeholder planning will require a shift in local governance so complex and multiple sources of data can be used and different social groups have a voice. In the 13 Latin American cities where these action-research projects took place, local governments have realized that high levels of risk are creating huge development challenges and were keen to engage in these projects. The next step is to convince them of the need to share the responsibility and use local resources more effectively in decision-making going forward. Governments should see their role in climate resilience as promoters of collective action through partnerships with multiple actors and between different territorial levels (horizontal and vertical governance), including universities and permanent dialogue platforms.

Cross-References

- ▶ Climate-Induced Displacement and the Developing Law
- ▶ Community Planning Priorities
- ▶ Disaster Risk Reduction
- ▶ Making Communities Resilient to Global Climate Change
- ▶ Resilient Cities and Regions: Planning, Initiatives, and Perspectives
- ▶ Urban and Regional Planning for Sustainability
- ▶ Urban form and Function
- ▶ Vulnerability
- ▶ Vulnerable Communities: The Need for Local-Scale Climate Change Adaptation Planning

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Co-benefits of Climate Change Mitigation

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Synonyms

Multiple benefits; Sustainable development (SD) benefits

Definition

Co-benefits The term "**Co-benefits**" refers to simultaneously meeting several interests or objectives resulting from a political intervention, private sector investment or a mix thereof. Co-beneficial approaches to climate change mitigation are those that also promote positive outcomes in other areas, such as air quality and health, economic prosperity and resource efficiency (cf. Ministry of the Environment Government of Japan 2009) or more general in terms of Sustainable Development (SD) Benefit (cf. United Nations Framework Convention on Climate Change (UNFCCC) 2015a).

This entry differentiates between "**Opportunistic Co-benefits**" which appear as auxiliary or side effect while focusing on a central objective or interest and "strategic co-benefits" which result from a deliberate effort to seizing several opportunities (e.g., economic, business, social, environmental) with a single purposeful intervention (cf. Helgenberger and Jänicke 2017).

Co-benefit Assessment The term "**Co-benefit Assessment**" refers to systematic analyses on social, economic and environmental impacts of specific climate policies and actions. Co-benefit assessments are based on scientifically sound and reproducible methods, which take into account benefits as well as negative repercussions. This lends validity and credibility of performed assessments (cf. Helgenberger and Jänicke 2017).

With the aim to build coalitions across sectors for ambitious, effective, and timely climate policy and action, the "**Strategic Co-benefit Assessments**" approach addresses specific interests, associated with particular social, economic or environmental co-benefits (IASS/COBENEFITS 2018a). Hence they focus on specific net benefits that unfold within a timeframe relevant to the specific interest groups or countries.

Introduction

In the political discourse around the implementation of the Paris Agreement in the context of the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations 2030 Agenda on Sustainable Development and the Sustainable Development Goals (SDG), co-benefits with their the strategic role for building alliances and stimulating ambitious and early action are increasingly being acknowledged (cf. United Nations Economic and Social Commission for Asia and the Pacific, UNESCAP 2015, b; UNFCCC 2018; Bach 2016; LEDS GP 2016; Helgenberger et al. 2017; New Climate Economy 2018). In view of Nationally appropriate mitigation actions (NAMAs), coined in the UNFCCC/Bali Action Plan of 2007, the authors of an UNESCAP Co-benefit Assessment argue that "a successful NAMA is one that is driven by domestic public and private interests unrelated to climate mitigation" (UNESCAP 2015).

Progress is being made on strengthening the strategic connection between the Paris Agreement and the 2030 Agenda on Sustainable Development with a particular emphasis on the co-benefits of these policies (ibid.). The evolution of the co-benefits paradigm in the political debate over the past two decades shows how it has gained increasing prominence in recent years through its strategic role in climate and sustainable development policy.

Co-benefits: From the Side-Lines Toward the Centre of Debate

Emergence in the 2000s Through OECD and Intergovernmental Panel on Climate Change (IPCC)

Emerging from public and political debates on win–win solutions and *no-regrets* strategies since the beginning of the 2000s, the co-benefit approach has gained increasing prominence within climate policy. Particular attention has been given to the energy sector, beyond climate policy, as focus area for describing, conceptualising, and systematising possible co-benefits. In recent years, intensified efforts can be noticed towards operationalising this approach for systematic co-benefit assessments within this sector. In this section, it is described how the notion of co-benefit has been continuously moving from the side-lines toward the centre of debate on climate and energy policy and action.

The co-benefit or multiple-benefit approach in climate change mitigation policy was initially expressed as a "win–win solution" or a "no regrets strategy" (Adler 2000). At first, the Organisation for Economic Co-operation and Development (OECD) spoke of "ancillary benefits" (OECD 2000; Krupnick et al. 2000; c.f. O'Connor and Dessus 1999). Early studies on this topic – often using synonyms such as "collateral benefits," "side effects," or "associated benefits" – frequently related to developing countries and often focused on the advantages of climate change mitigation measures for controlling air pollution.

The Intergovernmental Panel on Climate Change (IPCC) first used the term "co-benefit" in its 3rd Assessment Report (IPCC 2001). The multiple benefits of climate change mitigation were already sectorally anchored within the IPCC's 4th Assessment Report (IPCC 2007), addressing the following sectors: energy, industry, transportation, housing, agriculture and forestry, as well as health, air quality, waste, and environmental systems.

The OECD and the U.S. Environmental Protection Agency (EPA) contributed to further developing and defining the co-benefits approach in the field of climate policy. In 2009, the OECD published a literature study entitled "Co-benefits of Climate Change Mitigation Policies" (Bollen et al. 2009). The study viewed co-benefits as the "potentially large and diverse range of collateral benefits that can be associated with climate change mitigation policies in addition to the direct avoided climate impact benefits."

Based on the conceptual work of the EPA, in 2009 the Japanese Ministry of the Environment proposed a first co-benefit assessment framework in the field of climate policy, which was specifically directed to the Clean Development Mechanism (CDM) of the United Nations Framework Convention on Climate Change (UNFCCC). Here, the authors emphasize the relevance of "Co-beneficial approaches" to climate change mitigation "to promote positive outcomes in other areas such as concerns relating to the environment (e.g., air quality management, health, agriculture, forestry, and biodiversity), energy (e.g., renewable energy, alternative fuels, and energy efficiency) and economics (e.g., long-term economic sustainability, industrial competitiveness, income distribution)" (Ministry of the Environment Government of Japan 2009).

Impulses from the Energy Sector in 2010s

The Global Energy Assessment (GEA 2012) prominently emphasises the multiple-benefit approach to the energy sector, presenting many important social and economic co-benefits of a transition to sustainable energy. Furthermore, the International Energy Agency's application (IEA 2014) – depicting 15 co-benefits in the area of energy efficiency – received a great deal of attention. It addresses positive economic co-benefits (job creation, energy security, industrial productivity, etc.) as well as social co-benefits (health benefits, poverty alleviation, consumer surplus, etc.). The publication calls for a "multiple benefits approach" in the promotion of energy efficiency. In the same year, the IPCC further spelled out the co-benefits of climate change mitigation, listing overall 18 economic, environmental, and social co-benefits resulting from climate change mitigation (cf. IPCC 2014; Jänicke et al. 2015). Further expansions and compilations of potential co-benefits have been suggested by several authors (see e.g., Ürge-Vorsatz et al. 2014; Kraemer 2016; Mayrhofer and Gupta 2016; Deng et al. 2018; Table 1).

The New Climate Economy (2014) report presented a multiple-benefit assessment of low-carbon policies across economic systems (cities, land-use and energy), including an "exploratory quantification" of co-benefits. The International

Co-benefits of Climate Change Mitigation, Table 1 Categories of co-benefits. (Adapted from Mayrhofer and Gupta 2016)

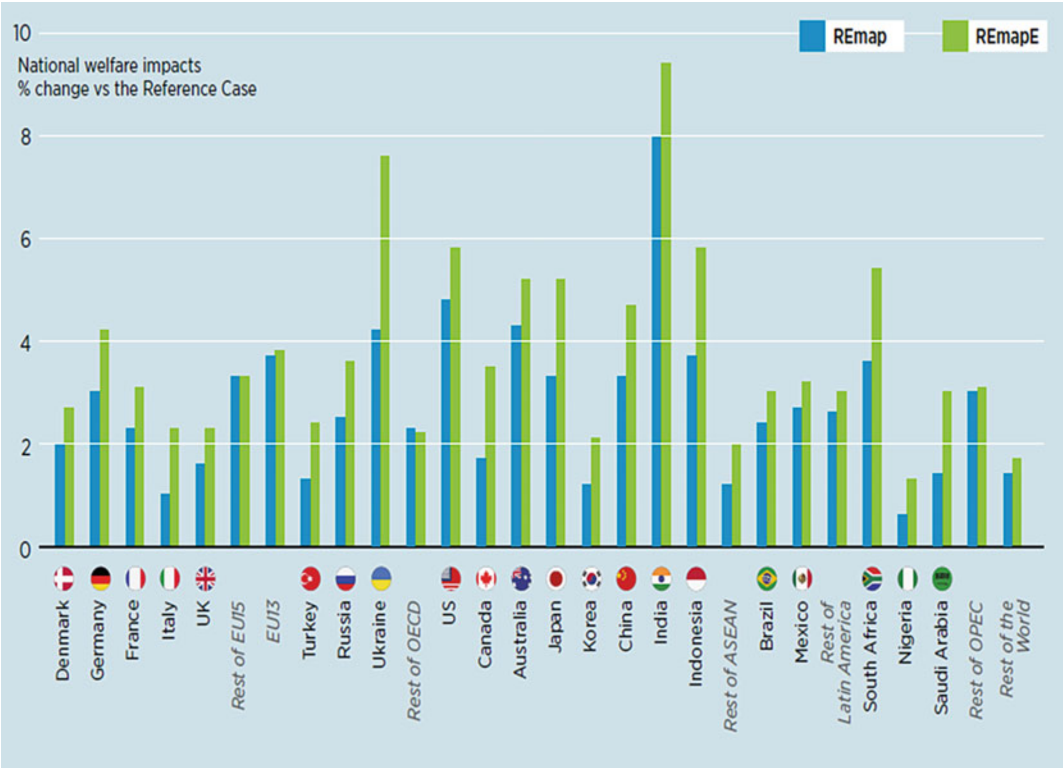
Climate-related	Economic	Environmental	Social	Political and institutional
Reduce GHG emissions	Enhance energy security	Protect environmental resources	Enhance energy access	Contribute to political stability
Enhance resilience to climate change	Trigger private investment	Protect biodiversity	Reduce poverty incidence and inequality	Improve democratic qualitY of governance
	Improve economic performance	Support ecosystem services	Contribute to food and water security	Contribute to interregional collaboration
	Generate employment	Improve soilquality	Improve health	
	Stimulate technological change	Reduce airpollution	Reduce stressors (e. g., noise traffic congestion)	
	Contribute to fiscal sustainability			

Renewable Energy Agency (IRENA) took the next step toward operationalising co-benefits within the renewable energy sector and contributing to co-benefit assessments. In a study of the co-benefits of renewable energies, IRENA (2016) presented a combined benefit indicator termed "Total Welfare Impact" that entails seven co-benefits within three categories: (a) *Economic* – consumption and investment; (b) *Social* – employment, health, and education; (c) *Environmental* – greenhouse gases and materials consumption. This combined benefit indicator has been applied to many countries (see Fig. 1) and embedded in a broader macro-economic analysis, also including domestic economic performance (GDP), employment, and trade (see also Borbonus 2017). Besides air-quality- and pollution-oriented co-benefit assessments (e.g., Ma et al. 2013; Xue et al. 2015), particularly in the field of socio-economic assessments, a variety of approaches and methods are being elaborated which can serve as valuable inputs to co-benefit assessments in the field of climate and energy policy (Borbonus 2017).

Ongoing: Co-benefits Listings and Categories: The Quest for Strategic Orientation

The existing listings of potential co-benefits could easily be expanded, for instance by addressing foreign trade balances, which in the cases of China and India are negatively impacted by massive increases in imported fossil fuels. In terms of avoided costs and avoided productivity losses through environmental protection, the EU, the United States, China, India, and Brazil/Mexico could experience an overall benefit of USD1.23 trillion within the areas of health and energy savings alone by the year 2030 (World Bank 2014). The value of such calculations lies not least in the fact that they go far beyond conventional cost–benefit analyses. The problems of such calculations – particularly if they extend to additional co-benefits – relate to their omni-directional use and lack of strategic orientation of the argument.

The broadly accepted co-benefit categories seek to establish a common denominator that is advantageous for the political discourse. As a consequence, the listings of co-benefits remain heterogeneous and general, making it difficult to address specific interest groups. Even if the aspect of climate change mitigation serves as the central point of reference in the discussion on "co-benefits," the term is used to evaluate very different qualities of climate, energy and sustainability policy measures: For example, it is applied equally to long-term macro-economic effects and to short-term business earnings. As this example shows, the mixing of assessment systems means that the co-benefits are not



Co-benefits of Climate Change Mitigation, Fig. 1 National welfare impacts of doubling renewable energies by 2030, with and without increased power generation (IRENA 2016)

directed towards defined target groups. Clear definitions and demarcations are required in the developing discourse on co-benefits, in view of specific strategic usages.

Against this background, the following definition is being proposed to distinguish between purposeful and undirected approaches to the term "Co-Benefits":

> The term "Co-Benefits" refers to simultaneously meeting several interests or objectives resulting from a political intervention, private sector investment or a mix thereof. *Opportunistic co-benefits* appear as auxiliary or side effect while focusing on a central objective or interest. *Strategic co-benefits* result from a deliberate effort to seizing several opportunities (e.g., economic, business, social, environmental) with a single purposeful intervention.

Post 2020: Co-benefits to Become Pivotal for Implementing NDCs and SDGs?

In the recent political discourse around the implementation of the Paris Agreement and the SDGs, the strategic role of addressing and leveraging co-benefits of related policies is being repeatedly emphasized (cf. UNESCAP 2015; UNFCCC 2015b, 2018; Bach 2016; LEDS GP 2016; Helgenberger and Jänicke 2017). Consistently, co-benefits are acknowledged repeatedly in the documents to the Paris Agreement (For an overview of the evolving co-benefits discourse with in the UNFCCC prior to the Paris Agreement, see United Nations Economic and Social Commission for Asia and the Pacific, UNESCAP 2015), which can be interpreted as call for options to activating the co-benefits perspective by addressing social and economic opportunities of climate change mitigation.

Although the Paris Agreement breathes the spirit of integrating the climate policy agenda with other urgent political issues such as promoting sustainable development (SD), the treaty text itself features only a modest number of references to co-benefits of climate action (see Table 1).

Nevertheless, the references where co-benefits are mentioned explicitly provide a motivation to strengthen this perspective in the implementation process. In comparison to the treaty text of the 21st session of the UNFCCC Conference of Parties (COP), the complementary and non-binding COP Decision offers a few more connection points regarding co-benefits of climate action. A large part of the political conversation on co-benefits in the UNFCCC remains focused on interests and policy objectives within the global climate agenda, pinpointing mitigation co-benefits for adaptation and vice-versa (cf. UNFCCC 2015a, b). Yet, several of the mechanisms established by the convention and re-emphasized in the Paris Agreement offer opportunities to incorporate social and economic benefits of climate action more strongly, thereby allowing to address political interest beyond the global climate agenda (cf. Table 2).

The recognition of "the social, economic and environmental value of voluntary mitigation actions and their co-benefits" in the non-binding COP Decision (1/CP.21) that accompanies the Agreement is complemented by the request to the UNFCCC secretariat to develop an annual technical paper on mitigation benefits and co-benefits. Co-benefits are also highlighted in relation to specific mechanisms such as voluntary cooperation, transparency, or finance (Table 3).

While the cornerstone for a strong involvement of co-benefits is laid by the Paris Agreement and the COP Decision, much clarification is still needed, especially while rules, modalities and procedures are developed in the process of creating the rulebook for the Paris Agreement. Progress is being made on strengthening the strategic connection between the Paris Agreement and the 2030 Agenda on Sustainable Development: Co-Benefits are addressed as political opportunity to strengthening the connection between the Paris Agreement and the SDGs, e.g., by connecting to the SDGs in Future Market Mechanisms under the UNFCCC as well

Co-benefits of Climate Change Mitigation, Table 2 Co-benefits (sustainable development benefits) as mentioned in the Paris Agreement. (Source: UNFCCC (2015a), Paris Agreement (emphases added))

Paragraph	Quotation "The Parties to this Agreement. . ."	Context
Preamble	". . .Emphasizing the intrinsic relationship that climate change actions, responses and impacts have with **equitable access to sustainable development and eradication of poverty**" "Also recognizing that **sustainable lifestyles and sustainable patterns of consumption and production** [. . .] play an important role in addressing climate change"	Introductory remarks
Art. 2, para. 1	"This Agreement [. . .] aims to strengthen the global response to the threat of climate change, **in the context of sustainable development and efforts to eradicate poverty**"	Aim of the agreement
Art. 4, para. 7	"Parties aim [. . .] to undertake rapid reductions [. . .] on the basis of equity, and **in the context of sustainable development and efforts to eradicate poverty.** [. . .] 7. **Mitigation co-benefits resulting from Parties' adaptation actions and/or economic diversification plans** can contribute to mitigation outcomes under this Article"	Parties' contributions
Art. 6, para. 4	"A mechanism to contribute to the mitigation of greenhouse gas emissions and **support sustainable development** is hereby established"	Sustainable development mechanism
Art. 6, para. 8	"Parties recognize the importance of integrated, holistic and balanced non-market approaches being available to Parties to assist in the implementation of their [NDCs], in the context of **sustainable development and poverty eradication**"	Nonmarket approaches
Art. 10, para. 5	"Accelerating, encouraging and enabling **innovation** is critical for an effective, long-term global response to climate change and **promoting economic growth and sustainable development**"	Technology framework

Co-benefits of Climate Change Mitigation, Table 3 Co-benefits (sustainable development benefits) as mentioned in Decision 1/CP.21. (Source: UNFCCC (2015b) Decision 1/CP.21. Adoption of the Paris Agreement. FCCC/CP/2015/10/Add.1. (emphases added))

Paragraph	Reference: "[The COP]. . ."	Context
Adoption of the PA/preamble	". . .Emphasizing the **enduring benefits of ambitious and early action**, including major reductions in the cost of future mitigation and adaptation efforts. . ."	Introductory remarks
Adoption of the PA/preamble	". . .Acknowledging the need to promote **universal access to sustainable energy** in developing countries, in particular in Africa, through the enhanced deployment of renewable energy"	Introductory remarks
III. Decisions to give effect to the PA/ para. 37	". . .Recommends that [the CMA] adopt rules, modalities and procedures for [the SDM] [. . .] on the basis of [. . .] (b) **Real, measurable, and long-term benefits related to the mitigation** of climate change"	Mitigation/sustainable development mechanism (Art. 6.4)
III. Decisions to give effect to the PA/ para. 39	". . .Also requests the [SBSTA] to undertake a work programme under the framework for non-market approaches to sustainable development [. . .] considering **how to enhance linkages and create synergy** between, inter alia, mitigation, adaptation, finance, technology transfer and capacity-building, and how to facilitate the implementation	Mitigation/nonmarket approaches (Art. 6.8)
IV. Enhanced action prior to 2020 / para. 108	". . .Recognizes the social, economic and environmental value of voluntary mitigation actions and their **co-benefits for adaptation, health and sustainable development**"	Voluntary action
IV. Enhanced action prior to 2020 / para. 111 (b)	". . .Requests the secretariat to organize [a strengthened technical examination process (para. 109), including by] [. . .] updating, on an annual basis [. . .] a technical paper on the **mitigation benefits and co-benefits of policies, practices and actions for enhancing mitigation ambition**, as well as on options for supporting their implementation"	Technical examination process on mitigation
IV. Enhanced action prior to 2020 / para. 127	". . .Decides that [the technical examination process on adaptation] [. . .] will be pursued by: (b) Identifying actions that could significantly enhance the implementation of adaptation actions, including actions that could enhance economic diversification and **have mitigation co-benefits**"	Technical examination process on adaptation

as with proposals to reform the existing qualitative ex-ante assessment tool for Sustainable Development (SD) Co-Benefits (Helgenberger et al. 2017; IASS/COBENEFITS (2018b).

In light of political ambitions in NDC to the implementation of the Paris Agreement are still far from sufficient to meet the Paris target of holding global temperatures "well below 2 °C above pre-industrial levels," Bach (2016), Helgenberger et al. (2017) and others are advocating for a stronger integration of the co-benefits perspective into the instruments and rulebook for implementing the Paris Agreement in the years 2020 onwards. The strategic connection between NDC implementation and SDG reviews, nationally and internationally, could have the potential to facilitate the process from policy to action (2020 to 2030) on both the sustainable development and the climate agenda (ibid.)

Examples of Co-benefits in the Energy, Transport, Agriculture, Building, and Waste Management Sectors

With ongoing transition processes to more sustainable modes of production and consumption an increasing number of specific examples of co-benefits of climate change mitigation is being monitored and communicated for different sectors, such as energy, transport, building, agriculture or waste management. Given the high pace in the global transition towards renewable energy examples of social, economic and environmental co-benefits of this sustainability transition can be increasingly monitored, both on country and global level:

- In India over 300,000 workers will be employed in the next 5 years by achieving India's clean energy targets. Jobs created from renewable energy offer a significant opportunity to meet the government's objectives on employment generation (Council on Energy, Environment and Water, CEEW, and Natural Resources Defense Council, NRDC 2017).
- South Africa by the end of 2017 with its Independent Procurement Programme for Renewable Electricity has attracted investments of more than USD 16,000,000,000 and generated socio-economic value creation of more than USD 40,000,000 while saving carbon emissions of 22 million tons in CO_2 in the process (Independent Power Producer Office of South Africa, IPP Office 2018).
- Germany with its Energiewende (energy transition) to increasing shares of renewable energy is fostering societal ownership in its energy system, by 2017 involving more than 1,500 citizens' energy cooperatives across the country and more than 42 GW renewable electricity, creating direct revenue for citizens and local communities (Kahla et al. 2017; trend:research 2017)
- Worldwide more than 10 million people are employed in the renewable energy sector. What's more, doubling renewables in the global energy mix could save up to four million lives annually by reducing outdoor air pollution (IRENA 2018).

But also evidence of co-benefits in related areas such as energy efficiency improvements (cf. Fig. 2) and other sectors, such as the building sector, transport and agriculture, have been assessed. For the building sector, measures to reduce greenhouse gas emissions and increasing energy efficiency of buildings, outdoor and indoor health benefits (such as fewer diseases, reduced mortality, improved worker productivity) are being reported (Næss-Schmidt et al. 2012).

Even though not displayed as prominently as in the areas of renewable energy and energy efficiency, also in the farming sector the multiple benefits of sustainable and organic agriculture do receive some attention – these include climate benefits through soil carbon sequestration and less energy intense fertilizer practices, as well as soil productivity (see e.g., New Climate Economy 2014).

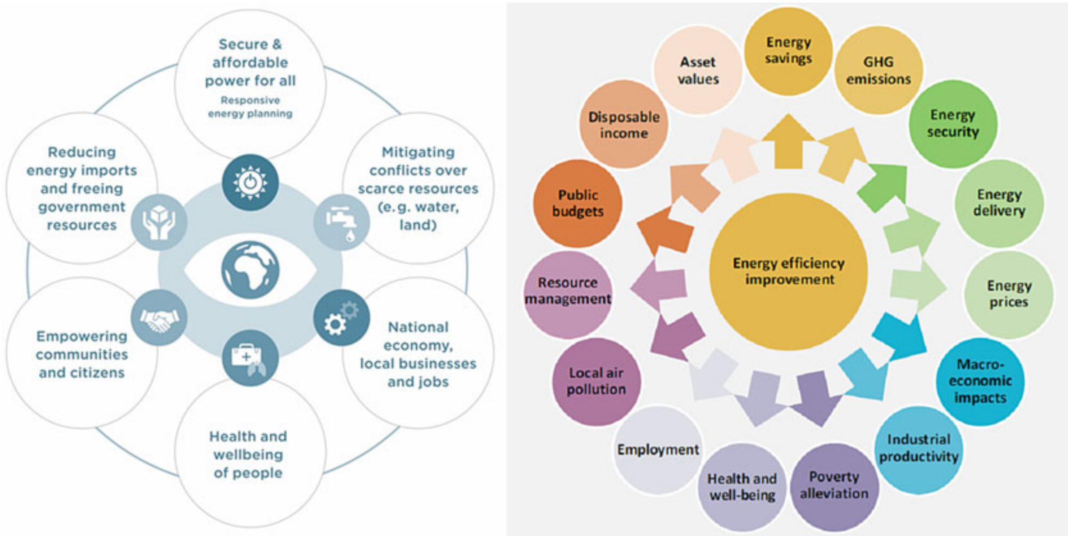
Similarly, for the transport sector, initial co-benefit assessments of sustainable and climate-friendly mobility have been conducted, detecting a wide list of co-benefits such as access to mobility, reducing traffic and parking congestion, saving consumers money, supporting economic development, increasing public health and safety, and reducing air and noise pollution (cf. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) 2015).

In the area of climate-friendly waste management, co-benefit assessments have identified opportunities such as recovering valuable resources such as compost or biogas, induced local value creation and employment effects, as well as health improvement (UNESCAP 2015).

Beyond Climate Impact: Co-benefit Assessments as Drivers of Ambitious and Effective Climate Policy

The term co-benefit assessment refers to systematic analyses on social, economic and environmental impacts of specific climate policies and actions. Co-benefit assessments are based on scientifically sound and reproducible methods, which take into account benefits as well as negative repercussions. This lends validity and credibility of performed assessments (cf. Helgenberger and Jänicke 2017).

A couple of co-benefit assessments are being underway, such as studies by the International Renewable Energy Agency (IRENA 2014, 2016), the assessment of sustainable development co-benefits of climate change mitigation



Co-benefits of Climate Change Mitigation, Fig. 2 Illustrations of different co-benefits – of renewable energy (left, IASS 2018, license: CC-BY) and of energy efficiency (right, IEA 2014, licence: www.iea.org/t&c)

actions by UNESCAP (2015), the global COBENEFITS project (see www.cobenefits.info), and an assessments series by the New Climate Institute (see https://newclimate.org/portfolio/co-benefits-of-climate-change-contributions/) on the co-benefits of different Intended Nationally Determined Contributions (INDC) to the Paris Agreement.

Co-benefit assessments offer key reference points for avoiding negative social, economic, or environmental impacts of global warming. For an interest-based anchoring of climate policy, however, the possible positive impacts are likely to have a greater motivating effect, both for making and advertising related decisions. Such motivating effects can be particularly expected in terms of economic co-benefits that address specific interest groups. This applies to such key areas as technology innovation, new business areas, and gains in productivity, or employment.

Co-benefit assessments, based on the multiple-benefit approach to climate change mitigation and renewable energies in particular, represent a recent strategic variation of policy-oriented impact assessment (for recent methodological contributions see, e.g., Ürge-Vorsatz et al. 2014; Khosla et al. 2015; Jakob and Steckel 2016, Borbonus 2017).

Helgenberger and Jänicke (2017) point out the opportunities for co-benefit assessment to connect the multiple (net) benefits of climate action and renewable energies to the interests of specific economic and administrative sectors, in terms of an *interest-focused policy integration* in climate policy. This sets it apart from norm-driven approaches, which range from ethical justifications to mandatory norms of action (see van Schaik and Schunz 2012). In this regard “interests” are defined as fundamental orientations for action based on specific advantages that can, with a high degree of probability, be assumed for the respective actors. In this view, an assessment study by the US Environmental Protection Agency (EPA 2015) expressly calls for a sectoral approach and anchors company interests primarily in the cost of avoided sectoral losses.

With the aim to build coalitions across sectors for ambitious, effective, and timely climate policy and action, the *Strategic Co-benefit Assessments* approach (IASS/COBENEFITS 2018a) should address specific interests, associated with particular social and economic co-benefits. Hence they need to focus on specific, near-term (net) benefits that unfold within a timeframe relevant to the specific interest groups or countries.

Importantly, the negative impacts and co-risks should not be excluded from this approach, but should be incorporated in the net benefit estimation. This lends plausibility and scientific rigor to the approach, which is particularly important given the central role that legitimacy and persuasiveness play here. Accordingly, the assessment of energy savings would take into account the loss of jobs in traditional forms of energy supply, while the assessment of the growth of renewables would take into account potential accompanying declines in the area of fossil fuels. Such detailed calculations of potential negative effects remain relevant for evaluation purposes even in cases where the overall net effect is positive. In this regard, the 5th IPCC Assessment Report (2014), for example, takes into account both sides – the positive and negative side effects – of climate action.

Future Directions and Open Challenges

Energy independence, better air quality for citizens, rural value creation and poverty reduction – these are just some of the social and economic opportunities of renewable energies. As co-benefits of climate change mitigation measures, they have become key drivers of the global transition to a sustainable energy world, based on renewable energy and energy efficiency. Co-benefits have led to a paradigm shift in our understanding of what mitigation means – from "burden sharing" to an increasing degree of "opportunity sharing" – a shift that was reflected in the 2015 Paris Climate Agreement (Helgenberger and Jänicke 2017).

Despite the fact that the global transformation toward renewable energies and energy efficiency appears to be irreversible in the long run, given its many advantages and increasingly competitive outlook, investments in fossil fuel-based energy systems still present a serious threat to the global climate. This applies to a number of countries which are experiencing sharply increasing demand for energy and will thus have to make important and far-reaching decisions in the energy sector. The planned expansion of coal-fired power plants, intended to cover increasing energy demand, entails path dependencies that could persist for decades. Given the already identified climatic tipping points and the need to accelerate the global transformation of energy systems, such path dependencies should be avoided by all means. In face of the increasing economic advantages of renewable energies, the same holds true from an investor's perspective with regard to containing the risk of stranded assets resulting from early – market or policy driven – suspensions of fossil fuel-based energy infrastructures (For a recent case in China, see cleantechnica (18.01.2017). China Suspends 104 Under-Construction & Planned Coal Power Projects, https://cleantechnica.com/.).

Besides regulatory options in support of the general wellbeing and with a longer-term perspective, co-benefits of climate action, when connected to specific interests, can serve as important drivers for accelerated transformation and for overcoming long-lasting political deadlocks in order to prevent environmentally harmful path dependencies (see "Assessing co-benefits could accelerate action on climate change," Bach 2016).

Co-benefit assessments contribute to raising awareness for the social and economic co-benefit to address specific interest and to build strong, possible new alliances for ambitious climate policies and action. With the objective to mobilize specific interests (politics, private sector, civil society) for ambitious and early climate action the strategic application of the co-benefit approach in climate policy extends previous norm-driven action by interest-oriented action. This development is consistent with legal requirements being extended by new forms of voluntary participation. The "Sustainable Development Co-benefits Tool" (SD tool) developed, in the context of the UNFCCC/Clean Development Mechanism (CDM), and the COBENEFITS project of Germany's International Climate Initiative (IKI) have been initiated to raise awareness on the social and economic opportunities of climate change mitigation and to mobilizing political and economic interest for ambitious and early climate action.

While this article addresses the social and economic co-benefits of climate action for different sectors, also the “climate co-benefits” of other sectors, in terms of mitigation and adaption benefits are being addressed in several studies (for an extensive list of activities and policy interventions in different sectors, entailing “climate co-benefits,” see World Bank 2012).

This article has described the strategic relevance of the co-benefits approach for harnessing support for ambitious and early climate action by mobilizing domestic public and private interests, not necessarily related to climate change. An increasing number of specific examples on co-benefits particularly in the energy sector but also resulting of co-benefit assessments in other sectors are substantiating the described paradigm shift to a global “opportunity sharing.” By formulating its seventeen SDGs, the UN 2030 Agenda for Sustainable Development reflects shift in a broader context (Helgenberger and Jänicke 2017). Yet, challenges remain for mobilizing co-benefits for a successful implementation of the Paris Agreement.

Though the importance of co-benefits in climate and sustainability policy is being acknowledged widely, the approach is not without criticism. Critics of the increasing political focus on co-benefits are underlining risks that the emphasis of specific public and private interests might in fact impede ambitious action, in that

- Desired, particularly socio-economic co-benefits are formulated as a condition to increasing the ambition level in NDCs.
- Co-benefit assessments are not being used to reconsider the ambitiousness and appropriateness of a particular NDC but only to prioritize implementation options of an already fixed NDC.
- The co-benefit argument gives legitimacy to existing interests, public and private, within an unsustainable economic environment, thereby failing to challenge and work towards a deeper transformation of a dysfunctional socio-economic system.

The implementation of the Paris Agreement and its instruments beyond the year 2020 will offer substantial empirical evidence to better understand to what extent promises or criticism of the co-benefits approach to climate policy and action will prevail.

C

Cross-References

▶ Climate Change Mitigation
▶ Global Warming
▶ Planetary Boundaries: A Sustainability Framework

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Community Activities

▶ Community Planning Priorities

Community Planning

▶ Urban and Regional Planning for Sustainability

Community Planning Challenges

▶ Community Planning Priorities

Community Planning Challenges: Climate Change Impacts on Cultural Heritage

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Synonyms for Community Planning

City planning (USA); Town planning (UK); Urban planning (USA and Canada)

Definitions

Community planning encompasses the processes, structures, plans, and policies that govern the planning and management of communities. Professional urban planners utilize these community planning tools to problem solve and make improvements to the physical, social, and natural environments of a settlement. Planners also rely upon various stakeholders throughout the community planning process, including government officials, engineers, architects, and policy writers.

Though community planning is a uniquely Canadian term, it reflects similar meaning to *city planning* from the United States of America, *town planning* in the United Kingdom, and *urban planning* from the United States of America and Canada (Hodge and Gordon 2014). The phrase first appeared in the report *Housing and Community Planning*, which was prepared for the Canadian government to provide advice for dealing with challenges communities faced at the end of the Second World War (Hodge and Gordon 2014). Community planning gained common use over the next decade as it captured a broader and wider range of what was representative of settlements of all locations and sizes in Canada, including cities, towns, hamlets, suburbs, and agricultural communities located in urban, suburban, and rural areas.

Community planning challenges are the obstacles, threats, and risks that jeopardize the well-being, stability, and future of a community and its planning processes. Climate change, urban sprawl, environmental degradation, and demographic shifts are all relevant and significant examples of threats that have tangible and intangible impacts. Tangible impacts take direct physical form and include phenomena such as sea-level rise or flooding that can damage infrastructure and natural environments. Intangible impacts take an indirect form and are less visibly noticeable, including inadequate access to public transit for low-income neighborhoods that in turn creates accessibility barriers for residents.

To address community planning challenges, planning practitioners and decision-makers turn to policy making, plans, and other methods including developing tool kits, strategies, and best practices. These policies and other resources employed in community planning are informed by a variety of stakeholders and are developed with context-specific challenges in mind. As a result, community planning is in a constant state of evolution as needs shift and new information, techniques, innovations, and ideas for combatting challenges are introduced.

Heritage planning is the application of *heritage conservation* and seeks to manage change of *cultural heritage* wisely in the context of a modern and changing world. This subset of the professional urban planning discipline seeks solutions to the loss or degradation of cultural heritage through a planning context. Heritage planning is interdisciplinary but is typically led by a heritage planner or conservation officer who connects stakeholders and other professionals to assist with conservation.

Heritage planning is managed through policy standards and best practices. At the international level, consensus of best practice is decided through intergovernmental organizations and professional associations, including the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the International Council on Monuments and Sites (ICOMOS). These standards are then adopted by countries into national policy. How heritage is managed within each country varies, but national policy and management typically involves state/provincial and local municipal levels as well.

Heritage conservation is a broad discipline that extends beyond heritage planning and addresses all aspects of enhancing and retaining historic places (Kalman 2014). Conservation captures a wide range of all measures carried out to preserve historic resources, including the following treatments as defined by the Australia ICOMOS Burra Charter (ICOMOS 2013): preservation, restoration, rehabilitation/adaptation, and reconstruction. Heritage conservation is carried out through a number of professions and roles. These stakeholders include heritage planners, conservationists, and officers, as well as historic resource managers, conservation scientists, and conservation and heritage architects.

Cultural heritage, as defined by UNESCO (1989, p. 57), is "... the entire corpus of material signs - either artistic or symbolic - handed on by the past to each culture..." Cultural heritage includes all tangible and intangible artifacts of human history ranging from buildings, monuments, books, and artworks to traditions, languages, and oral histories. Heritage planning typically deals with the tangible aspects of built cultural heritage (buildings, monuments, and structures), but can also include cultural landscapes, and intangible aspects of heritage. Common terms used for referring to cultural heritage include heritage assets, historic resources, and historic sites.

Introduction

Climate change is one of the most significant **planning challenges** facing communities today. The Intergovernmental Panel on Climate Change (IPCC 2014) states that there have been observed decreased snow and ice levels and increased global mean sea levels and atmospheric and oceanic temperatures. These altered climate dynamics are largely anthropogenic, or human-driven in nature (Tollin et al. 2017; IPCC 2014), and have led to an increase in the frequency, intensity, and duration of extreme weather events across the globe (IPCC 2014). As a result, there is a change in dynamics of storm surges, heavy rainfall, droughts, and heat events. Impacts of climate change, compounded with existing stresses, affect urban areas, including residents, infrastructure, cultural assets, and natural environments.

Climate Change Threats for Coastal Communities and Cultural Heritage

Coastal communities in particular are experiencing increased stresses as a result of climate change. According to the Global Climate Risk Index 2018, published by Germanwatch, the top ten countries most affected by climate change from 1997 to 2016 were all coastal countries (Eckstein et al. 2017). Increases in population and the urbanization of these countries over recent decades have led to a massive increase in coastal development. These pressures are only expected to continue to intensify, leading to further socioeconomic and environmental changes (Neumann et al. 2015).

These changes are creating monumental hurdles for community planning in coastal regions. Along with the existing community stresses and threats of rapid urbanization, conflict over resources, and environmental degradation, the loss of cultural heritage is intensifying in coastal regions (Markham et al. 2016). Erosion, coastal and ravine flooding, sea-level rise, and extreme weather events (Phillips 2014a; Markham et al. 2016) are directly causing adverse and irrevocable damage to cultural heritage community assets in those coastal communities. Community planning practitioners and decision-makers are being confronted with how to quickly and efficiently address and incorporate appropriate adaptation and mitigation actions into heritage policy to manage these threats to cultural heritage. Evidently, the consideration of climate change effects and incorporation of adaptation and mitigation strategies into planning policy is critical for the future of heritage assets; failure to address threats may lead to permanent damage, abandonment, or inappropriate interventions that may compromise the significance or authenticity of heritage assets (Phillips 2014a).

Value of Heritage in Communities

Addressing and managing these impacts are integral for heritage, as it makes considerable contributions to communities which include economic, environmental, and social benefits. A rich local heritage attracts tourism, provides employment opportunities, and generates investment in historic areas (Phillips 2014b). Built heritage, such as historic homes, old factories, religious assemblies, and other buildings, promotes sustainable development and growth in communities through the adaptive reuse of existing buildings. Cultural heritage also contributes to the character and identity of communities (Phillips 2014b). Heritage serves as a connection to the past and can help create a strong sense of community and local identity, creating a sense of belonging, meaning, and attachment to these places. From an educational perspective, cultural heritage serves as a valuable informational resource; it illustrates the governance and social structures of previous generations and can reveal important stories and information about cultural groups. Additionally, cultural heritage has potential to contain valuable information about past human adaptations and mitigations to climate change which could help inform current strategies (Phillips 2014b).

Climate Change Impacts on Cultural Heritage

A rare, finite, and nonrenewable resource, cultural heritage is particularly vulnerable to climate change impacts (Phillips 2014a; Graham and Spennemann 2006). As a vital asset for communities, it is paramount to understand and acknowledge the hazards that cultural heritage faces. Since the adoption of the World Heritage Convention in 1972, climate change has been recognized as one of the most significant threats to emerge for cultural heritage (Markham et al. 2016). When climate change causes damage to cultural heritage assets or causes them to be forcibly moved, a part of their significance and meaning is diminished and becomes irreplaceable (Jarvis 2014; Markham et al. 2016). This threat occurs through two main forms: direct physical impacts and indirect impacts.

Direct Impacts

Direct physical impacts to cultural heritage occur through exposure to climatic parameters such as wind, sea level, precipitation, temperature, and humidity (Daly 2014). The most vulnerable components of cultural heritage to direct physical impacts include tangible assets, such as built heritage (buildings, structures, and monuments), archaeological sites, and parks and gardens. Changes in soil moisture and humidity pose a threat to built heritage as historic buildings are typically more porous than their modern counterparts. Increases in soil moisture lead to greater salt mobilization, which damages decorative details through the forming of crystallization on these surfaces (Colette 2007; UNESCO 2007).

Building foundations of heritage structures can be destabilized through these increases or decreases of soil moisture and by changes in freeze-thaw cycles (Markham et al. 2016). Structural damage can also occur due to increased precipitation from increasingly volatile extreme weather events (Colette 2007). Many coastal heritage structures are located along cliffs and are frequently prone to foundation destabilization from erosion and cliff collapse (Murphy et al. 2009). In addition to climate fluctuations in moisture and humidity, flooding (either from sea-level rise or storm surges) poses a major threat to historic buildings or archaeological sites not suited to prolonged immersion in water (Colette 2007; Murphy et al. 2009). Exposure to moisture through flooding and post-flood drying increases susceptibility to mildew, mold, and rot in heritage buildings (Markham et al. 2016; UNESCO 2007).

Indirect Impacts

The indirect impacts that climate change has on heritage are subtler than the physical direct impacts, making them all the more crucial to address. Climate change indirectly assaults cultural heritage through disrupting the way cultures live, work, worship, and socialize (Colette 2007). Changes in the physical environment through associated sea-level rise and extreme weather events, such as storm surges, heavy rainfall, drought, and heat events, can interfere with how cultures behave in, interact with, and utilize cultural building sites and landscapes. Ignoring the cultural effects of these events could lead to the improper care, neglect, or even abandonment of important cultural heritage assets. Climate impacts also can affect livelihoods, and food security can force communities to find new resources and relocate, resulting into the loss of cultural traditions, customs, and rituals.

Community Planning Challenges for Coastal Cultural Heritage

Planning practitioners are faced with a multitude of challenges when it comes to planning for coastal cultural heritage. Challenges and restraints related to stakeholder consensus, policy and planning time scales, and cost and modification restrictions are common in heritage planning; however, they are made increasingly complex when climate change impacts are introduced.

Stakeholder Consensus

Coordinating with stakeholders and decision-makers to identify cultural heritage values, assets, and conservation preferences in the community must be addressed before heritage policy decisions can be made. Finding consensus on what is important, what should be conserved, how it ought to be done, who has authority over the sites and decisions made, and how maintenance and/or restoration will be funded can be an onerous task for cultural heritage planning practitioners. In many, "decisions about *what* to conserve and *why* are often taken independently from those dealing with *how* to conserve, and vice versa" (Avrami et al. 2000, p. 3). This gap can create a non-ideal situation where not all perspectives and information are shared between those working on the *what* and *why* (e.g., conservation groups and community members) and those working on the *how* (planners and decision-makers). These matters are further complicated in achieving stakeholder consensus when the cultural heritage assets are held in private ownership (Hall et al. 2016).

Property owners may not wish to comply with the rules that would govern aspects of how they are able to modify or use their property and choose not to have their property designated as a cultural heritage site or resource. This resistance can lead to tensions, disagreements, and conflicts that slow down the cultural heritage planning process. Planning practitioners must work closely with cultural heritage conservation professionals and other stakeholders to gain community buy-in and support in order to successfully carry out cultural heritage planning activities.

These matters become significantly more complicated in the light of climate change impacts for coastal communities. The large number of human settlements in coastal areas over multiple centuries has resulted in certain climate change-sensitive coastal regions hosting dozens or in some cases hundreds of cultural heritage sites. Sea-level rise is causing damage to historic sites along the world's coastline and has already resulted in a number of losses of historic sites around England and Europe that will continue to occur (Murphy et al. 2009). As cultural heritage sites continue to be threatened by climate change, decisions of what assets will be prioritized and how it will be managed will have to be made. This issue raises questions on how differing stakeholders will agree with what should be prioritized and how it should be managed, even as higher profile sites with national and international recognition come into contention (Hall et al. 2016).

Policy and Planning Time Scales

Policy and planning time scales create challenges for the effective management of coastal cultural heritage. When it comes to climate change impacts, planning policy overall is often lagging behind in incorporating mitigation and adaptation strategies to these threats (Birchall and Bonnett 2018). Headway has been made at international levels with organizations such as UNESCO recognizing the impacts and significance of climate change on cultural heritage; this has resulted in the publishing of several of works on the research of climate change impacts and strategies for mitigation and adaptation (UNESCO 2007; Colette 2007). However, these polices have yet to make their way to local-level planning policy in any significant way; there is a disconnect between community planning and heritage conservation and difficulties in implementing effective planning time scales that contribute to this issue.

Although heritage planning is a recognized subset of planning, there are obstacles that exist between planning and heritage conservation which prevent the effective incorporation of international policy. First and foremost, what a planner can do will depend greatly on the political and administrative context they are in (van Assche and Duineveld 2013). Documents, policies, and information for heritage conservation may exist, but if the political and administrative context does not include the adoption and incorporation of these works into the planning framework, there is very little the planner can do to implement or enforce actions that would address threats to heritage.

For planning practitioners in coastal communities, low political will to implement heritage conservation becomes a significant barrier to managing the vulnerabilities of heritage assets to the effects of climate change. Heritage planning has a considerably higher chance of becoming part of the planning process if there is a strong planning system in place (van Assche and Duineveld 2013). For coastal countries that lack strong governments and administration, the ability to include heritage conservation plans is further undermined, leaving those responsible for planning with even less ability to manage threats to heritage.

Planning policy and process time scales play an important role in effectively addressing the impacts of climatic variations on cultural heritage. Planning time scales refer to the lengths of time and cycles of planning policies and processes. Time scales can range from weeks for the approval of permits to years and even decades for the revision and renewal of municipal development plans, bylaws, zoning, and other related policies, such as building codes and standards. Due to this long-term nature of planning cycles, there are difficulties for implementing effective planning time scales for the impacts of climate change on cultural heritage (Hall et al. 2016) even if political will to do is high. Often, adaptation, mitigation, and renewal/renovation of heritage assets for climate change require large-scale investments and typically occur over long periods of time (Hall et al. 2016).

Slow planning time scales have substantial consequences on heritage assets that are currently vulnerable or are already being impacted by sea-level rise or extreme weather events. The inability to react quickly to climate threats will lead to the damage of heritage assets and could involve costly reactive measures to protect or restore the assets. In order for heritage conservation strategies to be effective, realistic planning time frames are critical for the adaptation and mitigation to climatic threats (Hall et al. 2016).

Cost and Modification/Conservation Restraints

Cost and modification/conservation restraints inhibit the ability to realize the plans and policies set in place to safeguard heritage from threats of climate change. Although maintenance of cultural heritage in the context of climate change may be a key concern among stakeholders (Hall et al. 2016), if there is little to no funding available for conservation projects, very little can be done to implement and safeguard cultural heritage against threats. In the report *Climate Change and the Historic Environment*, Cassar (2005) notes that coastal heritage sites are under the highest level of threat, but lack adequate management strategies, and that funding to monitor and record these sites is critical for conservation but is likely "unrealistic." As Hall et al. (2016) point out, adaptation and mitigation for historic resources can require large-scale investments; this is problematic for planning practitioners in coastal communities with small or limited financial budgets and large amounts of historic resources. Even in cases where actions, such as the recoding of sites, excavation of archaeological remains, or relocation of building have taken place, full mitigation and adaptation using these options is simply not finically feasible in coastal communities with considerable numbers of heritage assets (Murphy et al. 2009).

Modification or conservation restraints complicate the process of implementing climate change adaptations for cultural heritage. Planning practitioners are limited not only by the restraints of funding but the types of interventions that can be made to heritage assets. Modifications are complicated, as they may not comply with the strict modification requirements laid out in conservation policy (Hassler 2006). Strict requirements for alterations exist for assets that have been designated as historic resources and greatly limit the types of interventions/modifications that are able to be made to a historic resource. In the highest levels of conservation, components, such as windows in historic buildings, are only allowed to be replaced by ones of the same era and style, and changes to structure, unless true to the period and style of the building, are typically not allowed. These types of restrictions are problematic for two key reasons. Firstly, there are issues related to cost; if assets become damaged due to the effect of climate change, finding historically replacements and the instillation of these replacements is a costly endeavor compared to modern installation of the comparable components.

Secondly, disallowing for interventions such as modern, more efficient infrastructure, or alterations to adapt to climate change can do more harm to heritage assets than good. Noninvasive or invisible fixes may not always be a possible solution for adapting heritage to climate change threats (Hassler 2006; Cassar 2005); moderate to significant alterations may need to be implemented to ensure the conservation of heritage assets. If the appropriate interventions are not made to safeguard heritage, historic resources are left vulnerable; rising sea levels and extreme weather events are likely to cause more significant damages to the heritage asset than the interventions would. This raises the question not only to local planning practitioners but to global practitioners of what elements must we forfeit in order to conserve the rest (Hassler 2006; Cassar 2005).

Future Directions

Climate Change, Cultural Heritage, and Community Planning

"Changes to cultural heritage caused by climate change cannot be viewed separately from changes in society, demographics, people's behavior, the impact of conflicting societal values and land-use planning which will also need to evolve in the face of climate change" (UNESCO 2007, p. 24). Therefore, in the context of community planning, a cultural heritage challenge cannot be viewed separately from a community planning challenge as they are highly linked to one another. To effectively address each of these challenges, they must be considered in respect to each other.

Community heritage values need to be given prominence, with processes for their management and conservation mainstreamed into overall planning frameworks. Further, planning frameworks should be considered in the development of heritage conservation guidelines, policies, and practices (Getty 2009). It will not be possible to retain all heritage sites or fully protect them due to restraints of resources and funding. As a result, collaborative efforts of stakeholders and heritage and planning practitioners will be needed to prioritize, document, and record historic resources to ensure conservation of information and records for the future (Murphy et al. 2009). Monitoring, management, and maintenance of heritage resources also play a significant role in heritage conservation (Hall et al. 2016).

These steps are integral to have in place as they assist with observing and understanding the effects heritage assets are experiencing, provide guidance for appropriate measures and interventions to be implemented, and allow for evaluation throughout these processes to ensure the integrity of the resource is preserved (Hall et al. 2016). In addition, heritage and planning practitioners must work collaboratively to establish realistic plans and time frames for planning processes in order for these conservation strategies to be successful (Hall et al. 2016).

In terms of evolution in the face of climate change, substantial challenges lay ahead for community planning practitioners that will need to be addressed; however, despite all the difficulties climate change impacts create for community planning challenges, it also offers the possibility for community planning opportunities. In the face of challenges, opportunities for new information, techniques, innovations, and ideas for community planning will evolve as old methods suited a different time and context become obsolete. The conservation of cultural heritage in the face of climate change will require these innovative planning opportunities to ensure the safeguarding of heritage for the future.

Practitioners and academics have already begun to explore what the future of community planning for cultural heritage may look like, expressing new ideas for consideration. Hall et al. (2016) suggest exploring policy options of directing funding toward the restoration and preservation of built heritage resources rather than investment in new works. The restoration or adaptive reuse of existing heritage buildings has the potential to benefit not only heritage but also the environment through the reuse of existing materials.

Flatman (2009) suggests the consideration of a "heritage offset" in the same way a person may sponsor a "carbon offset" for the planting of a tree to reduce greenhouse gas emissions. Programs could be created to sponsor heritage resources through donations of individuals, groups, businesses, or governments wishing to offset the damages to heritage from climate change. These funds could be put toward various projects for heritage conservation including documenting, restoring, or fortifying heritage assets against threats. In Daly (2014), the author identifies a framework for assessing the vulnerability (exposure, sensitivity, and adaptive capacity) of archaeological sites to climate change which can be used by heritage practitioners. This framework could be adapted for use of all cultural heritage sites to assess their adaptive capacity and integrate findings into planning policy and strategies.

In the adversity of climate change, communities have the potential to reinvent themselves and become more resilient and sustainable, environmentally, socially, and economically. The ideas above highlight only a small sample of the vast possibilities for community planning opportunities in the context of climate change. These actions to combat community planning challenges for heritage nonetheless will be unsuccessful unless significant and immediate actions are taken at an international level to reduce greenhouse gas emissions; without these actions, threats associated with climate change will continue to intensify and exacerbate community planning challenges. These threats are already being experienced by coastal communities around the world. Subsequently, it is paramount for planning practitioners to address the community planning challenges that arise through policies that take into account the full impacts of climate change. Current stakeholders, professionals, and governments will have to plan not only for current community challenges but will have to consider dynamic and complex future urban problems and include these in their policies, plans, and tool kits to ensure the resilience and sustainability of communities into the future.

Cross-References

- ▶ Climate Change Adaptation (CCA)
- ▶ Climate Change Impacts and Resilience: An Arctic Case Study
- ▶ Climate Change Planning: Understanding Policy Frameworks and Financial Mechanisms for Disaster Relief
- ▶ Community Planning Opportunities
- ▶ Immediate Climate Vulnerabilities: Climate Change and Planning Policy in Northern Communities
- ▶ Making Communities Resilient to Global Climate Change
- ▶ Vulnerability

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Community Planning Opportunities

► Community Planning Priorities

Community Planning Opportunities: Building Resilience to Climate Variability Using Coastal Naturalization

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Synonyms

City planning; Democratic decision-making; Interactive planning; Town planning; Urban planning

Definitions

Community planning is the process of solving problems, making improvements, or advancing a community in any way, shape, or form using plans, policies, and structures. This process can lead to progressive improvements in a community's physical, social, and ecological contexts. The task of community planning is typically carried out by professional urban planners, with assistance from stakeholders, governments, and other professionals such as engineers and architects.

Community planning is also known as city planning, town planning, and urban planning (Hodge and Gordon 2014). The use of the term "community" however, rather than "town" or "city," is more accurately representative of many Canadian settlements, which include cities, towns, hamlets, suburbs, and agricultural communities, among others. Regardless of the location or size of a settlement, it is a community, hence the term community planning.

The Oxford Dictionary (2018) defines **opportunity** as a culmination of circumstances that allow for the possibility of something. Ultimately, an opportunity is an order of events that allow for some form of growth or progress.

Community planning opportunities can be defined as moments that arise – often following a community planning challenge – that provide the necessary circumstances for a diverse array of members in a community to enact democratic decision-making processes for community-building and improvement.

Community planning opportunities often appear when a community is faced with an obstacle that challenges the community's welfare and stability. These obstacles can be physical, environmental, social, or economic in nature, but regardless of their origin, all community planning challenges demand a desired solution or response. In the process of resolving or improving the problem, a community's assortment of professionals and stakeholders gain the chance to work collectively toward a common goal or objective that aims to make a direct, positive impact on the community. This objective could take the form of a new plan or policy, transforming what was initially considered a community planning challenge into a community planning opportunity.

Creating opportunities out of challenges is especially relevant for coastal communities grappling with the growing threat of climate change. While the impacts of climate change are problematic to a community on multiple levels, this circumstance provides the opportunity for a forward-thinking community to integrate and implement an appropriate plan of action to improve resilience against local climate change impacts.

Introduction

Climate change is an inevitable topic when discussing the current and future status of our ecosystem. As stated by the Intergovernmental Panel on Climate Change (IPCC) (2013), *climate change* refers to pattern changes in Earth's climate system. Although a politically controversial topic, scientific research strongly suggests an anthropogenic nature to climate change; human activities have increased the release of greenhouse gas (GHG) emissions (IPCC 2013). The buildup of GHGs in Earth's atmosphere creates instability in the climate system, resulting in observable climate impacts including rising global mean temperatures, sea level rise, severe and frequent storm events, extreme precipitation events, and retreating glaciers (IPCC 2013).

The impacts of climate change affect all regions across the globe, with coastal zones being particularly susceptible (IPCC 2014; Birchall and Bonnett 2018). Due to their proximity to oceans, coastal land is directly vulnerable to climate impacts such as sea level rise – mainly a result of thermal expansion and water transfer from land to the sea (IPCC 2013, 2014). The stress of climate change-induced sea level rise is amplified by increasingly severe storm surge (Gopalakrishnan et al. 2016). According to the IPCC (2014), coastal regions are experiencing, and will continue to experience, increased foreshore inundation and erosion as sea levels rise and storm surges intensify.

The physical impacts of climate change along the world's coastlines are increasingly concerning due to the burden that these impacts impose on coastal populations and urban development. Coastal regions have long been favorable for human settlement because they offer efficient trade, accessible transport, ample recreational opportunities, and sense-of-place connections (Neumann et al. 2015). Indeed, in the territory of Nunavut, Canada, for instance, 25 of the territory's 26 communities are coastal communities (Labbé et al. 2017).

In many situations, the attractiveness of coastlines to mass populations make coastal land highly valuable from a developmental perspective (Neumann et al. 2015; Birchall in review). Most urban centers located along the coast benefit economically from the large numbers of tourists that visit coastlines every year (Toubes et al. 2017). For this reason, coastal urban development is expansive. Indeed, many of the world's megacities are located on coastal land and are projected to experience extensive growth into the future, incrementally more than non-coastal communities (Neumann et al. 2015).

The impacts of climate change exacerbate pre-existing stressors that these expanding communities are already facing (Schmidt et al. 2013). As coastal communities grow, they must contend with the stresses of urbanization, loss of coastal resources, and destruction of natural ecosystems (Neumann et al. 2015; Cormier-Salem and Panfili

2016). For instance, since 1980, mangroves have globally reduced in size by at least 20% due to human activities (Cormier-Salem and Panfili 2016). The effects of these stresses are worsened by localized climate change impacts, including foreshore flooding and erosion from climate change-induced sea level rise and storm surge (Cormier-Salem and Panfili 2016).

Ultimately, there are physical, economic, and social implications for coastal communities dealing with the effects of climate change. In one scenario Neumann et al. (2015) project the coastal flood risk to spread to 286 million people worldwide by year 2030. The physical component to climate change – flooding and erosion brought on by climate change-induced sea level rise and storm surge – will result in changes to land use. The economic effects of these physical changes are obvious, as the destruction of coastal environments severely hinders coastal urban development and tourism; tourism is crucial to the economy of many coastal urban communities (Toubes et al. 2017). This economic detriment also has a social association, since citizens of these coastal communities will have their livelihoods significantly impeded (Schmidt et al. 2013). The multifaceted nature of these implications and their localized impacts pose as significant planning challenges to coastal communities.

With climate change becoming an increasingly pressing concern, coastal communities must discover ways to overcome these community planning challenges. Though mitigative efforts to reduce atmospheric GHG levels have been made globally (e.g., Birchall 2014; Birchall et al. 2015, 2017), the benefits will be experienced in the long term and do not help coastal communities deal with the immediate impacts of climate change. While still pursuing mitigation, coastal communities must also adapt to these impacts. Adaptations allow coastal communities to address the immediate impacts of climate change and integrate resiliency in both the short and long term. Examples of adaptations for coastal communities experiencing climate change-induced sea level rise and storm surge include building seawalls, increasing flood construction levels – minimum construction height of the first floor of a building within a hazardous zone – and relocating their most vulnerable infrastructure/assets.

Coastal Adaptation as a Community Planning Opportunity

The incorporation of climate change adaptation into planning and policy in response to climate impacts is a prime example of a community planning opportunity. Urban planners and community stakeholders can achieve this through integrating resilience to climate change using an adaptation strategy or other planning instruments. Climate change impacts disturb the entire community, as will the adaptations to such impacts; therefore, there is a need for community involvement in the incorporation of adaptation into planning (Schmidt et al. 2013). The desired goal of a coastal community's planning opportunity is to incorporate adaptation that is beneficial for the entire community and feasible to implement at ground level, for the purpose of building resilience.

Coastal communities can adapt to climate change using a variety of methods. The three main categories of adaptation include coastal retreat, accommodation measures, and direct protection of coastal areas (Harman et al. 2015).

1. Coastal retreat can be defined as organized recession from hazardous areas along the coast (Harman et al. 2015). Harman et al. (2015) discuss the following methods of retreat:
   - *Managed retreat* grants use and habitation of a hazardous coastal zone. When the hazardous level, however, becomes exceedingly dangerous – often referring to flood height or erosion of a coastline – occupants are expected to withdraw from the coast for their safety. If infrastructure is involved, relocation or abandonment is the expected procedure.
   - *Setbacks*, in a planning context, are defined as regulations that require development to take place a certain distance back from a focal point. In a coastal setting,

infrastructure cannot be developed within a designated minimum distance from the shoreline.

2. Through decreasing the vulnerability of development, accommodation measures allow communities to continue using and developing in hazardous areas. Harman et al. (2015) discuss the following methods of accommodation:
   - *Building codes* can be revised or updated to meet a standard that correlates with hazard levels of climate change-enhanced impacts. A raised flood construction level (FCL) can reduce the exposure of infrastructure to foreshore flooding.
   - *Urban design standards* can ensure that coastal development meet certain criteria in which adaptation is incorporated during the design and construction phase.
   - *Public disclosure* includes open communication with the community/stakeholders within at-risk coastal zones; stakeholders must be aware of the threats they face regarding climate change.

In October 2012, the province of British Columbia, Canada, released "Cost of Adaptation – Sea Dikes and Alternative Strategies Final Report" (Delcan Technologies 2012). This document noted the following additional accommodation methods:

- *Secondary dikes* are backup or additional measures. A dike is typically considered a method of protection; however, a secondary dike is an accommodation measure because it works in conjunction with a primary dike. A secondary dike is not the first line of defense against coastal climate impacts – that is the job of the primary dike – but rather a method to further decrease vulnerability of susceptible development, such as highly urbanized coastal communities.
- *Emergency preparedness* requires plans and strategies to respond to emergency situations.

3. Protection of coastal areas involves the physical defense of a shoreline. Harman et al. (2015) discuss the following methods of protection:
   - *Hard defenses* such as dikes, levees, groynes, revetments, and sea walls are engineering projects that substantially shield the coastline. Hard defense structures work by absorbing the energy of water that is rushing toward the shoreline or by blocking the inflow of water directly.
   - *Soft defenses* such as beach nourishment and coastal/shoreline naturalization involve the use of natural processes within a coastal setting. Soft defenses can artificially supplement a pre-existing environment – beach nourishment imports sand to beaches to counteract erosion – or allow natural ecosystems to completely invade a coastal space and apply adaptive processes.

Each adaptation method has its own strengths and weaknesses that make it appropriate for different contexts. Managed retreat is expensive during the time that a community is physically retreating (not as active retreat) but may be less costly in the long run compared to other methods that require continual upkeep or could incur serious damage costs. Managed retreat may even be the only viable option in situations where the flood or erosion risk has elevated to an unsustainable level. Nonetheless, managed retreat can be unsuccessful due to public disdain, legal restrictions, and issues involving displacement of people and infrastructure (Harman et al. 2015). Schmidt et al. (2013) demonstrate the unwillingness of stakeholders to retreat from the coast of Vagueira, Portugal, even though the stakeholders are knowledgeable regarding devastating future climate risks facing the community. The unwillingness of stakeholders and high up-front financial demand of managed retreat make it a less-preferred adaptation option for highly developed coastlines.

Setbacks are considered a low-cost substitute to managed retreat (Harman et al. 2015). While setbacks offer a buffer zone between coastal development and climate risks, the buffer capacity will reduce with intensifying climate conditions (Harman et al. 2015). Therefore, shorelines experiencing increased risks at an alarming rate may not benefit substantially.

Accommodation measures such as building codes and urban design standards are inexpensive ways of building infrastructural resilience within a community (Harman et al. 2015) that can be set to adapt to all climate conditions for every coastal community. The drawback to building codes and design standards is that they require constant monitoring and revision to keep pace with rising risk levels.

Hard protection methods also require routine maintenance – in fact, countries across the globe are enhancing their hard-engineered structures, such as levees and dikes, to accommodate climate change-induced flooding (Harman et al. 2015; Deltacommissie 2008; Ligtvoet et al. 2012); yet, as demonstrated by Schmidt et al. (2013), stakeholders gravitate toward hard protection measures over other adaptation alternatives. Highly developed or tourist-oriented coastlines greatly contribute to a coastal community's economy, and constructing hard defense structures leaves the coastline relatively unaltered from its current, highly attractive state – an explanation for the observable, global preference for this adaptation method. While hard defense structures appear to be an appropriate choice for coastal urban development, they can degrade (e.g., Butler et al. 2016). Due to these degradation and failure risks, a hard structure can be more of a maladaptation – rather than an adaptation – that offers false protection to a community (Cooper and Pile 2014). Hard structures also alter sediment patterns and transport sediment along coastlines, which may enhance erosion rates (Harman et al. 2015).

Soft defense measures can better supplement sediment modifications from hard defense structures (Harman et al. 2015) and offer benefits that are more suited for coastal urban development. Soft defenses create aesthetically pleasing coastlines that offer an organic defense system with natural adaptive abilities. Soft defenses such as beach nourishment simply build on a natural system in place, resulting in an adaptation with the ability to withstand high-energy coastal systems and events (Harman et al. 2015), decreasing storm-induced damage (Gopalakrishnan et al. 2016). Gopalakrishnan et al. (2016) define beach nourishment as a process that regularly repairs or restores the eroded surfaces of beaches using externally dredged sand. While beach nourishment can temporarily mitigate the erosive and inundating effects of rising sea levels, the monitoring demands and upkeep costs are still extensive. Thus, coastal naturalization is a superior choice of soft defense adaptation for coastal communities.

Coastal/Shoreline Naturalization

As an adaptation against the impacts of climate change, coastal naturalization, also known as shoreline naturalization, foreshore naturalization, coastal greening, and greening flood protection, requires coastal land remain in an undeveloped state. This can be achieved through coastal ecosystem restoration, which is defined as certain measures taken to rehabilitate ecosystems that have been degraded, damaged, or completely devastated (Montoya et al. 2012). For instance, naturally occurring mangrove networks, coastal forests, oyster beds, and dune systems along the coast have been destroyed with urbanization (Cormier-Salem and Panfili 2016; Janssen et al. 2014, 2015; Yudhicara 2015). Naturalization efforts can be fulfilled by returning an artificially developed, coastal zone back into its natural state or by using avoidance measures along untouched coastlines. Avoidance measures simply refer to refraining from developing in hazardous coastal zones, thereby allowing the naturalized state of a coast to remain intact. Communities aid this process by utilizing planning instruments to regulate and prevent development in coastal areas (Harman et al. 2015). Coastal communities can greatly benefit from coastal naturalization.

Naturalized shorelines are inherently resilient and can provide coastal developments with a natural buffer to immediate climatic impacts (McDougall 2017). These ecosystems, such as coastal vegetation and wetlands, act as protective barriers against the flood risk of sea level rise and storm surge (McDougall 2017). Natural ecosystems reduce flood risk by absorbing wave energy and stifling tidal flow inland (Cormier-Salem and

Panfili 2016), minimizing foreshore inundation. Naturalized shorelines also provide a form of erosion control along the coast. For instance, mangrove forests stabilize the coast by trapping sediment within their roots (Cormier-Salem and Panfili 2016), while oyster beds attenuate waves and allow sediment to settle (De Vries et al. 2007; Janssen et al. 2014; Piazza et al. 2005; The Oyster Restoration Workgroup 2018).

Naturalized shorelines can be aesthetically pleasing as well and facilitate public access to recreation and leisure opportunities (Gopalakrishnan et al. 2016; Harman et al. 2015). Natural beach-like settings, along with activities such as fishing and wildlife observation, encourage ecotourism and tourism (Cormier-Salem and Panfili 2016).

Lastly, naturalized shorelines contribute to a coastal community's mitigative actions by sequestering carbon; coastal vegetation can remove carbon-based GHGs from the atmosphere (Cormier-Salem and Panfili 2016). Altogether, natural shorelines offer coastal communities both adaptive and mitigative benefits.

Coastal naturalization, and adaptation methods in general, offer a variety of solutions to the problematic effects of climate change and, in turn, build resilience throughout a community – a clear example of how a community planning challenge is transformed into a community planning opportunity.

It is important to recognize that shoreline naturalization does have its limitations. With urbanization of coastal zones on the rise, coastal land is highly profitable and sought after for developmental purposes (Mueller and Meindl 2017), putting the detainment of undeveloped land in direct conflict with conventional economic interests. Many areas that appear to be undeveloped, such as sand-only beaches, are often manufactured artificially and are not conducive to a naturalized shoreline. Even naturally occurring beach environments are less than ideal as they are easily eroded and demand constant monitoring (Harman et al. 2015). Although coastal naturalization is considered the economical choice when compared to hard defense adaptation measures (McDougall 2017), naturalization is often the less-preferred choice among conventional stakeholders (Schmidt et al. 2013).

Similar to retreat measures, coastal naturalization can be viewed as economically hindering, specifically in the instance of re-naturalization. In a study conducted by Schmidt et al. (2013), coastal property owners were more inclined to pursue hard defense measures over others because their idea of adaptation followed a hold the line concept. Private property owners – commercial in particular – receive economic benefits from the tourist attraction of artificial beaches and have a vested interest in keeping them in their current state. Re-naturalization, including ecosystem restoration, changes the beachfront coastline, which may have the potential to negatively impact the tourist industry. Schmidt et al. (2013) discovered that majority of the adaptation methods recommended by stakeholders included the coast remaining unchanged from its artificial and developed state.

This disinterest in coastal naturalization by community stakeholders may be a result of a lack of knowledge. Coastal naturalization is a relatively new adaptation approach, especially in the fields of planning and policy (Janssen et al. 2014). Janssen et al. (2015) recognize that the lack of support and implementation around coastal naturalization projects is due to a lack of knowledge among stakeholders. In fact, Schmidt et al. (2013) specifically mention the rarity of naturalized viewpoints from stakeholders. It can be understood that lack of knowledge results in little understanding of how coastal communities can benefit from coastal naturalization. While soft defense approaches are still being learned and understood, hard defense structures have a long history of knowledge distribution and implementation, giving insight into why stakeholders show preference for hard defense structures.

Future Directions

The need for appropriate planning and policy around coastal land is critical to the success and resilience of coastal communities. Coastal communities must adapt and build resilience to the impacts of climate change, and planning instruments can assist these communities in efficiently implementing the various aforementioned approaches. Siders (2017) identified that using planning to initiate climate change adaptation is a successful method for distributing knowledge and awareness of climate change risks, for integrating the adaptation efforts already in place, for offering leadership and encouraging stakeholders to participate in personal and independent adaptation, and for inspiring future leaders and administrations to maintain and pursue further adaptation.

There is a need for multilevel governance in current and future adaptation planning. Multilevel governance is necessary for two significant reasons. First, many adaptation options are not attainable due to fiscal constraints at a local level (Harman et al. 2015), and higher levels of government – state, national, or international – can offer funding for large-scale projects (Harman et al. 2015; Siders 2017). Second, social and political pressure can easily slow the progress of adaptation efforts at the local level (Harman et al. 2015). For instance, Australia is highly decentralized for coastal adaptation planning – local governments and private stakeholders are completely responsible for discussion, funding, development, and implementation (Harman et al. 2015). Adaptation efforts throughout Australia have been limited by the direct influence of cultural, political, and institutional norms on local governments (Harman et al. 2015). Higher-level government is less confined by local norms than local governments and can mandate the implementation of adaptation at the local level.

The need for multilevel governance in adaptation efforts includes both government – local, state, and national – and community members. Schmidt et al. (2013) stresses the need for a better approach that incorporates stakeholders into the adaptation process.

The community buy-in and widespread understanding of coastal climate change adaptation are where sound planning practices and policies are key. Community engagement is critical to any adaptation mechanism becoming socially amenable, especially when concerning measures that are perceived to be more drastic such as shoreline naturalization. The implications of shoreline naturalization are currently considered to be economically damaging due to its up-front cost and potential impacts on tourism and existing development. Therefore, community stakeholders must be incorporated in the conversation and decision-making process early on and often. While community engagement seems like an obvious and necessary step in adaptation planning, many communities are disregarding this step. In fact, in Vagueira, Portugal, attempts to communicate with and incorporate the public and stakeholders in the decision-making process rarely take place (Schmidt et al. 2013).

Community engagement can take on many forms. Public meetings that allow citizens the chance to voice their opinions and offer ideas are commonly used to communicate with stakeholders. Other forms of engagement, to list a few, include open houses, citizen juries or committee groups, public workshops, essay/letter or photo submissions, debates, design competitions (Van Assche et al. 2016), and online forums.

A necessary step to community engagement moving forward is the incorporation of education and information. Citizens must first understand the severity of climate change and the detrimental effects they are facing due to local climate impacts; a perspective of climate change as a community planning challenge will emerge from this knowledge. Citizens must then be made aware of the multiple adaptation options provided to them, including the benefits and downfalls of each method; stakeholders must understand how each adaptation can benefit them specifically. Educating the community about adaptation possibilities will likely foster greater and more in-depth discussion during community outreach. Thorough community engagement allows municipalities to better incorporate climate change adaptations into planning practice and policy, perpetuating the attitude of climate change as a community planning opportunity rather than a challenge and, in turn, building a more resilient and better-equipped community.

Cross-References

- ▶ Climate Change Adaptation (CCA)
- ▶ Climate Change and Human Migration as Adaptation: Conceptual and Practical Challenges and Opportunities
- ▶ Climate Change Impacts and Resilience: An Arctic Case Study
- ▶ Climate Change Planning: Understanding Policy Frameworks and Financial Mechanisms for Disaster Relief
- ▶ Immediate Climate Vulnerabilities: Climate Change and Planning Policy in Northern Communities
- ▶ Making Communities Resilient to Global Climate Change
- ▶ Vulnerability
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Community Planning Preferences

► Community Planning Priorities

Community Planning Priorities

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Synonyms

Community activities; Community planning challenges; Community planning opportunities; Community planning preferences; Effective community engagements

Definition

Considering there is no uniform and complete definition of the specific term “community planning priorities,” this chapter will provide separate clarifications of the phrases “community planning,” “community development,” “prioritization,” and “community” in order to accomplish the mission of making the meaning of the full syntagma. The UNESCO made one of the first and most holistic definitions of *community development* or *community organization development*, by explaining this phrase as “a generic term used to describe the processes by which local communities can raise their own standards of living. These processes include the organization or establishment of services, e.g. for social welfare, health protection, education, improvement of agriculture, development of small-scale industries” (UNESCO 1956). In addition, the United Nations defines *community development* as “a process where community members come together to take collective action and generate solutions to common problems” (United Nations 2018).

On the other hand, *community planning* is interpreted as “a process whereby the public services in the area of a local authority are planned and provided after consultation and (ongoing) co-operation among all public bodies and with community bodies" (The Act of Community Planning, Advice Note 2, by the Scottish Government 2004). Moreover, Regional County Council of Devon (UK) made a comprehensive definition of *community planning* as "a way of giving local people the opportunity to create a shared vision for their area and identify priorities for action which are agreed by a wide range of people, organisations and groups" (Cave 2013, pp. 7–8). Furthermore, the *community* has been very broadly described "as a group or network of persons who are connected (objectively) to each other by relatively durable social relations that extend beyond immediate genealogical ties and who mutually define that relationship (subjectively) as important to their social identity and social practice" (James et al. 2012, p. 14). Finally, according to the Merriam-Webster's Collegiate Dictionary (2018), the term *priority* presents "something given or meriting attention before competing alternatives." According to mentioned definitions above, it can be concluded that *community planning priorities* determinate and involve residents' preferences, intentions, and organized actions toward present and future development, improvements, and well-being (economic, social, political, cultural, and/or environmental) in the local surroundings (both rural and urban).

Introduction

All over the globe, local communities' plans are facing different issues and concerns which produces an obligatory need for their internal, local organization. Understanding communities' aspirations and prioritizing research goals should occur through well-organized and beneficial cooperation between residents, local authorities, local organizations, and scientists (Frasso et al. 2018). The communities provide "the essential social 'glue' between locality and inhabitants" (Richards and Hall 2000, p. 2), and even more, they represent "the essential link between the local and the global" (p. 3). Starting from the 1950s, many different segments of "community" could be identified (Hillery 1955; Rothman and Tropman 1987; Thompson and Kinne 1990). Urry (1995) has analyzed this term in detail (according to previous sources/references) and defined four distinctive aspects: the idea of community belonging to a specific topographic location, a same social system, a feeling of "togetherness," and as an ideology, often hiding the influence relations which unavoidably underlie communities.

Generally observed, community planning priorities comprise of a public participatory and usually cooperating form of local planning and design in which various community members (so-called local stakeholders) contribute toward the design of the directions and local priorities, planned project implementations, and reevaluation of documented local planning policy. Local priorities seek to empower individuals and local groups with the skills they need to effect change within their communities. These skills are often created through the formation of social groups working for a mutual plan. Community developers must understand both how to work with individuals and groups, such as local associations and institutions. It is a logical "bottom-up" evolution of regional, rural, and urban planning in an era of diminishing public resources, increasing local burdens and responsibilities and public activism. It often promotes public and private partnership as a means to connect physical development activities in support of community-defined goals. In addition, it seeks community consensus for proposed allocations of scarce resources among rival demands. In more vigorous application, community members access a full range of planning tools, shaping and being shaped by shared understanding of a complex community information base; directly informing and guiding local plan content; persuading resulting development budgets, projects, and thus future infrastructure and land uses; as well as helping coordinate the work of overlapping jurisdictions, levels of government, internal and adjacent communities, and various providers (Hoch et al. 2000), such as private companies and public enterprises.

To realize the priorities of community planning measures taking shape at a range of scales, the following discussion presents a review of key global and national policy frameworks and priorities. The discussion highlights the importance of context and organization programs.

Frameworks on Community Planning Priorities

Key Issues

Several researchers explained the interinstitutional (Berry 1981; King, Feltey and Susel 1998; McGlasnan and Williams 2003 in Norton and Sadler 2006) and communicative (McComas 2001 in Norton and Sadler 2006) aspects of community planning practice. Planning preparation and participation in the community is an aspect of organizing process of local politics of interests (re)produced through organizing (Forester 1989). Collin et al. (1995) have underlined the fact that planning practice is "disjointed" from theory because the former is laden with politics that disallow the democratic promises of the latter. Moreover, for any local planning and making the priorities in the community, there is an essential need for well-organized phases or steps in order to accomplish local development goals. Those are:

1. The starting point, as the first step, comprises the following: Setting up of a preliminary work group; classification of local stakeholders that should be engaged in the preparation of a community planning; method of addressing and calling on other associates; strategy for gaining local political support; and information strategy.
2. The second phase includes managing structures' positioning, i.e., participation of all stakeholders in the development; setting up a structural and administration organizations for the preparation of a community planning; and definition of guidelines for activities taken by a management structure.
3. The next is understanding communities' issues by the following aspects: Demonstration of ideas, interests, and needs of all stakeholders; forming and publishing instruments for active engagement of the public analysis of needs and an evaluation of current resources; assessment of strengths and weaknesses of a present local services system; and identification of opportunities and threats, outlining trends of the local development.
4. The fourth step proposes visions and strategies for development comprising the next segments: Key underlying values that will be esteemed and observed in the process of a community planning preparation and its following implementation; direction in which local services will develop in future; priorities that is to be met; difficulties that will have to be overwhelmed; regional and supra-regional resources that can be used; and vision of local services development which is accepted by a majority of partners engaged in the community planning.
5. The next phase is the strategy for local services development, e.g., a plan of gradual steps and tasks to meet defined objectives and priorities; a system of monitoring the implementation of a community plan; preparation of the final version of community planning; submitting the text of a community plan to the public to comment on it; and approval of a community planning by a municipal council.
6. And finally, the implementation of the community plan by informing the public about achieved results; continuous identification and engagement of new partners; and instruments that enable to introduce changes in the original community planning (Žežula and Vasková 2009).

Moreover, positive results of the connections with NGOs or other companies supporting community development, as Hughes and Scheyvens (2018) wrote, can be a progressive way to improve interactions in the development area, providing that projects are informed through processes built on community planning priorities. The advanced community participation processes enable organizations to maintain strong links with communities that increase understanding of local priorities and foster results that are relevant and sustainable for the community. Moreover, the evidences of many meaningful and positive development processes already exist in the many local communities that demonstrate the success of alternative and community-led development initiatives (Maiava and King 2007; Meo-Sewabu and Walsh-Tapiata 2012). Several models of community infrastructure development or fundraising show the potential of such processes to gain community planning priorities and intentions. Identifying community-based procedures that already function well may establish resources for administrations to work jointly with communities to more successfully prioritize and identify new methods to disseminating more equitable results. Community planning priorities, development, and engagement are inseparably connected. Without operational community engagement, well-meaning attempts to indorse community well-being can miss their mark or work at cross intentions to the communities' visions and priorities.

Public Documents: Official Tools for Implementing Community Planning Priorities

For the proper prediction of community planning priorities, there is a vital need to establish official community plans for further development. According to Department for Communities of the Northern Ireland (2015), community plans should identify various short-term/long-term priorities for community improvements. They have to perceive all aspects for well-being of the area and the locals. Furthermore, establishment of the community planning partnerships will develop and implement a shared plan for promoting the welfare of the community, improving cohesion and the life quality for the inhabitants. The community planning would be effective only with the partnerships of community, public and private bodies. In this regard, the main aims of community planning can be highlighted by ensuring that individuals and communities are directly involved in decision-making with public services that influence them and by focusing on the organizations' commitment to work jointly with the aim to provide better public services (Cave 2013). Additionally, an organized method of community planning emphasizes the involvement of the local stakeholders, mutual negotiations, and achieving results supported by the majority of the participants (Žežula and Vasková 2009).

When it comes to the priorities of the community planning, an integrated form of partnership with local stakeholders could potentially offer many advantages. The partnerships in the local communities are not necessarily exclusive to an incorporated body, i.e., the corporate support services of the various public bodies comprising the community planning partnership could be drawn together on behalf of the teamwork (such as research, statistical information, support, administration, and procurement). Even more, many public enterprises, such as local establishments and health and voluntary sector, are already participating in community planning. This also includes travel guides, travel agencies, hospitality sector, environmental companies, and research centers. The authorities, as potentially main local community actors, should actively invite and encourage all public establishments to be involved in the community planning process, and the advantages of being included should be strongly highlighted.

In this respect, there will be welfares to the community in receiving services that are more closely related to their daily needs, but there will be benefits to organizations as well. On an individual level, potential interests of being involved include personal experience, practice and knowledge, and moreover a professional development. Locals' engagement in other public bodies can be functional through different means (e.g., local plans and strategies; meetings and events; dealing with the local political, cultural or environmental issues; etc.) (The Act of Community Planning (Advice Note 2) by the Scottish Government 2004). According to the same document (Advice Note 5), one of the crucial roles in community planning priorities is the "effectiveness" of the community engagement. There are a large number of key, long-term steps presenting the effectiveness:

- Determining which development work should be carried out in order to improve the communities' representation
- Sharing learned experiences in the practice of community engagement

- Consenting roles and responsibilities in the areas of managed actions to support local development involving resources, staffing, training, and information exchange
- Realizing that there is a number of ways to engage and include communities by finding "general" approach
- Marking the existing levels of community activity, creating community profiles, conducting community needs assessments
- Recognizing main obstacles to become involved with communities and elaborate how they need to be resolved
- Making best use the resources of the voluntary sector (e.g., evolving and executing community engagement approaches, improving capacity-building activities, infrastructure development, etc.)

Moreover, community participation is required for sustainability goals of any development plan. When planning programs, make provision to build community capacity to manage projects, establish links with other organizations, and use a community organizing approach to design and manage community development projects (Prospectors & Developers Association of Canada 2018). Furthermore, the quoted Act of Community Planning (Advice Note 9) by the Scottish Government (2004) drew attention to the shared local targets in community planning: starting from the targets for neighborhood plans (including community safety, individuals' lifestyles, local regeneration plans, etc.) through plans for communities of special interests (e.g., children, ethnic or religious minorities, persons with disabilities, older persons, etc.) toward a shared target to individual agencies to agency-specific targets for each of these functions.

The "intervention models" from rural and urban community perspectives provide useful examples. These models are highly mixed in the way they theorize rural-urban connections, as well as in their emphasized theory about the strength and weakness of urbanization (Allen 2003). The rural planning perspective tends to focus on localized and discrete actions, which combine the following: decentralized water and sanitation, microcredit, land-based incomes, and environmental management. On the other hand, the urban perspective seeks the change of planning systems (transport and land use and land regularization and housing) and localized activities from an urban perspective (infrastructure and sanitation, health and pollution). In this respect, perspectives from the rural and urban communities' point of views will be discussed in the next paragraphs.

Community Planning Priorities: Perspectives for the Rural Residents

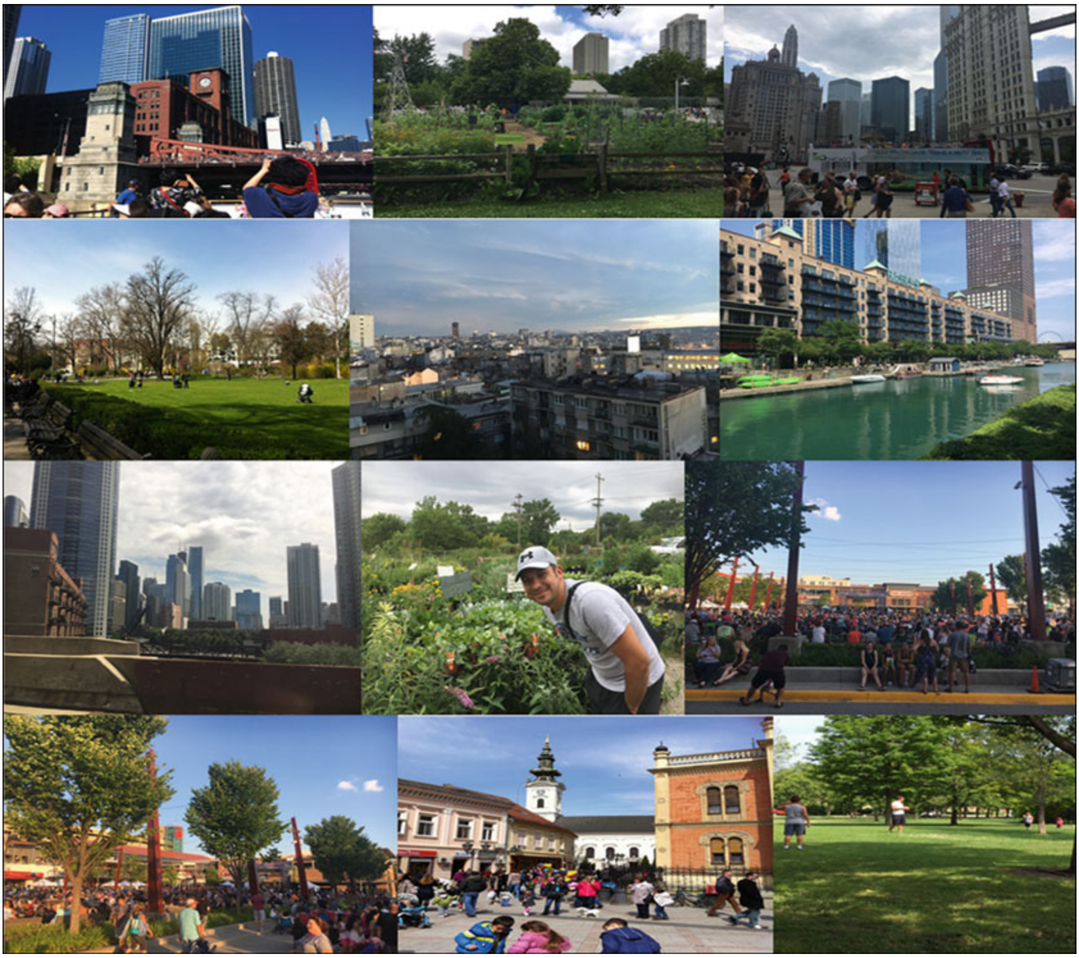
Although community planning is well developed in the management of urban areas (mostly in developed countries), its use in rural communities is a fairly new manifestation (Hibbard and Lurie 2000), primarily as an attempt to limit urban sprawl (Esparza and Carruthers 2000). A segment unique to contemporary community planning is its application to rural areas. Formal planning processes constitute a new dimension in rural surroundings, while they are well established in the urban settings. Moreover, rural communities have remained relatively insular, making intercommunity collaboration somewhat unfamiliar (Hibbard and Lurie 2000; Sargent et al. 1991). Rural planning has required promotion of balanced development between urban and rural areas by responding a perceived "urban bias" in government programs and policies, e.g., by trying to limit rural-urban migration through supported rural production (such as rural industrialization programs and integrated rural development programs) (UNDP 2000). Furthermore, rural community planning requires the organized process of refining the quality of residents' life and economic welfare of the locals in rural areas, often relatively isolated and sparsely populated areas. Rural development has traditionally centered on the exploitation of land-intensive natural resources, such as agriculture and forestry. The reform of rural society requires a more diversified countryside with developed rural infrastructure, increasing respect for sociocultural and ecological specificities. In this respect, the concept of integrated development provides rural societies with new forms and content, and the rural economy becomes a set of diverse activities in relation to available local resources (Fig. 1). Alternatives to employment in agriculture, depending on the specificities of local community, are seen in mostly complementary nonagricultural activities, especially in relation to manufacturing industry (e.g., organic production), services (e.g., agritourism, recreation, ecotourism, etc.), crafts, trade, culture, and other industrial and service activities (Demirović et al. 2018; Kremen et al. 2012; White 2012; Todorović 2007). At the same time, this will affect the rural community priorities development through so-called entrepreneurial small business, including various types of nonagricultural farm businesses, income from social transfers, commerce, rents, and income from permanent or seasonal employment in urban areas (e.g., Knickel and Renting 2000; Petrović et al. 2017, 2018; Renting et al. 2009; Wilson 2006).

The development of the nonagricultural economy, or the diversification of rural activities, has proven to be an appropriate instrument for increasing the quality of rural communities and providing additional sources of income. It is assumed that this concept can overcome some of the key problems of rural communities. These

Community Planning Priorities, Fig. 1 Local resources in rural communities (examples from Serbia). (Source: Made by author from the private photos collection (between 2013 and 2017)) are, first of all, the reduction of unemployment and the absorption of labor surplus, the supplementation of household income, the accelerated growth of the local economy, and thus the reduction of poverty and deprivation in rural areas, which affect the improvement of the quality of life of rural communities and overcoming differences with urban areas (Bogdanov 2007). The need for rural communities to achieve their priorities from a wider viewpoint has created more attention on a broad range of progress goals rather than merely creating incentive for traditional businesses (e.g., agriculture). Education, entrepreneurship, and physical and social infrastructure all play a significant role in developing rural communities. Rural community planning is also characterized by its emphasis on locally formed economic development strategies. Contrary to urban settings, which have many similarities, rural areas are extremely distinguishing from one another, i.e., there are a variety of community planning approaches in the countryside used internationally. Rural community planning priorities essentially focus on actions for the development of areas outside the conventional cities' economic systems. These actions are intended to further the economic and social development of rural communities, and they have historically been top-down from local or regional authorities, regional development agencies, NGOs, national governments, or international development organizations. Rural residents can also bring about endogenous initiatives for community development, and this is not restricted only to developing countries. Actually, numerous developed countries have very dynamic rural development programs (e.g., Canada, Germany, New Zealand, the UK, the USA), with the focus on finding ways to advance rural communities with the participation of residents themselves, so as to meet the required needs of the communities. The outsider may not recognize the specifics and circumstances dominant in the local area, so rural people themselves have the crucial part in contribution in their sustainable rural community development and local planning priorities (Moseley 2003).

Community Planning Priorities: Perspectives for the Urban Residents

Unlike organized rural planning, urban community planning is not a new model in most of developed countries. For instance, local governments in the USA and Canada have managed urban development through organized planning since the late nineteenth century (Beauregard 2001; Hoover 1928). Even today, urban communities all over the globe are strung together by various infrastructure and political processes (Rakow et al. 2003), making interinstitutional politics somewhat common. In response to a variety of environmental, political, and social concerns, an increasing number of state legislatures in the USA are enacting comprehensive community planning legislation, so-called *Smart Growth* (Norton and Sadler 2006). This model of planning began with the 1928 Standard City Planning Enabling Act that enabled local municipalities to "make, adopt, amend, extend, and add to a master regional plan for the physical development of its region" (Hoover 1928, pp. 49–50). To the middle of twentieth century, most of the urban communities were considered as dominantly closed societies and relatively unchanging structures, contrary to what was the case in nowadays. Urban communities are increasingly observed as generally adaptive and data-centric systems, characterized by active modifications, multifaceted interactions, and multidimensional effects (Fig. 2). Furthermore, the modern concept of so-called smart sustainable cities (Bibri 2018) is a brilliant model and example of how contemporary urban life faces an increasingly computerized and urbanized world. Most of the urban community planning priorities (even now) deal with many vital issues such as air, water, and soil pollution, safety, high real-estate prices, overcrowding, congestion, and traffic jams. Nevertheless, many activity examples demonstrate that local communities can face these issues more or less successfully. One of the tools is the knowledge about conservation and efficient use of resources, reducing copying costs by formalized local solutions in the urban setting, increasing autonomy through community actions, participating actively in the urban policy-making, conserving local natural resources and water



Community Planning Priorities, Fig. 2 Urban communities and their activities (examples from Serbia and the USA). (Source: Made by author from the private photos collection (between 2015 and 2017))

supplies, and sharing the data that will be useful for the future initiatives.

By using well-prepared community plan, many daily and long-term problems can be reduced to an acceptable and sustainable level in urban societies. The question is: how should a well-prepared community plan look like? First of all, the plan is an outcome of negotiations among all urban stakeholders engaged in the process, and its implementation is based on a broad partnership in a community. In addition, it should support locals' needs, suit local settings, and recognize targets and priorities of the community development. It also maps all public, private, and voluntary bodies and entities from the perspective of activities that help achieve targets that have been set. Moreover, the well-organized plan should incorporate a system of monitoring and evaluating the process and a system of reporting to the public needs (Žežula and Vasková 2009).

On January 1, 2016, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development, adopted by world leaders in September 2015 at an UN Summit, officially came into force. One of the SDGs defined "Sustainable Cities and Communities" (see the Goal 11: Make cities inclusive, safe, resilient and sustainable on UN's website) (Fig. 3), which gives special importance and priority to this topic. Most of these targets should be

Community Planning Priorities, Fig. 3 The "Sustainable Cities and Communities" Goal among the SDGs. (Source: From the Sustainable Development Goals (SDGs) of the UN 2016, by (author(s)/editor(s)/department name), © (2016) United Nations. Reprinted with the permission of the United Nations.)

realized by 2030, which sounds very promising and encouraging. The special targets of the Goal 11 include, among the other, the following actions in the urban settings:

- Ensuring access for all to adequate, safe, and affordable housing
- Providing access to sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations
- Enhancing inclusive and sustainable urbanization and capacity for participatory, integrated, and sustainable human settlement planning and management
- Reinforcing efforts to protect and safeguard the world's cultural and natural heritage
- Reducing the adverse per capita environmental impact of cities
- Providing universal access to safe, inclusive and accessible, green, and public spaces
- Supporting positive economic, social, and environmental links between urban, peri-urban, and rural areas by strengthening national and regional development planning and so on (UN 2016).

Suggestions for Future Contributions

Finally, what should an organized community plan comprise? Ensuring realization of the communities' priorities can maximize opportunities associated with future directions on where and how communities will progress. The potential answers are the following:

- Combined explanation and an overview of existing local resources (e.g., in the sphere of health care, education, jobs, leisure, opportunities for voluntary work, possibilities for neighbor assistance)

- Statistical, sociological, and demographic data (for instance, age structure of the population, birth rate and mortality rate, forecasts of demographic development)
- A clarification and an analysis of aspirations that locals have; a future vision of development by identifying priorities and objectives
- A timetable for the work progress and principles; a manner in which individual stakeholders at local level will be engaged in the development and implementation of a community plan – definition of responsibilities of stakeholders
- A method of monitoring, assessment, and possibly modifying a local community plan (Žežula and Vasková 2009)

Generally observing, both rural and urban community planning process anywhere in the globe should ensure a well-established framework for creating local public services that are directly responding to the communities' aspirations, needs, and prosperities. The basis of community planning priorities (Fig. 4) should contain four key elements:

– *Local population's life quality* needs to take care of the population's well-being, as well as the continuous research on what the locals think and act about the current and future plans for community development in their surroundings
– *Visitors' exchange* should provide sharing of knowledge and experiences among (similar) communities, e.g., how to improve their local strategies and future local plans, dealing with the daily, long-term, and alarming issues; visitors can also provide cultural and social cohesion in the visited community, which may produce many benefits to both sides.
– *Local economic prosperity* needs to include the assessment of work quality and the careers of those employed in the local economy branches, as well as the well-being of local corporations.
– *Ecological quality* should demonstrate all positive and negative effects on the local environment, i.e., on nature, local culture, and heritage in the community setting.

According to the findings and explanations provided above, it can be repeated and confirmed that *community planning priorities* can be defined as a combination of residents' goals, aspirations, and planned activities with the aim to improve present condition of the local community to achieve five main goals:

1. *Economic priorities* (by providing new employment opportunities, increasing income, diversifying the local economy, and supporting local infrastructure, facility, and service improvements)
2. *Social priorities* (by creating a preferred image of the community and providing recreational facilities and opportunities for additional education for the community residents)
3. *Political priorities* (by supporting community-responsible local authorities, involving actively in local political events and meetings connected to short-term/long-term community issues and improvements; by participating in the local elections and supporting selected, community-care local leaders)

Community Planning Priorities, Fig. 4 Proposed framework for the community planning priorities directions. (Source: original)

4. *Cultural priorities* (by sustaining local cultural events, encouraging pride in the community arts, crafts, and cultural expression, and preserving cultural heritage)
5. *Environmental priorities* (by justifying environmental protection and improvement, protecting local wildlife, and encouraging environmental education and awareness of the community members of the local natural values)

With the proper synchronization of these priorities, the planning of local communities can be highly practicable. These are the key propositions to start an initiative for the residents to actively participate in local community development. In this regard, the chapter provides graduate students with a good place to look up facts or to get a general overview of a community planning priorities pertaining to the possible development directions.

Cross-References

► Community Planning Challenges
► Community Planning Opportunities
► Vulnerable Communities: The Need for Local-Scale Climate Change Adaptation Planning

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