Chapter 9

The Impacts of Climate Change on Ecosystem Services and Resulting Losses and Damages to People and Society

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Abstract So far, studies of Loss and Damage from climate change have focused primarily on human systems and tended to overlook the mediating role of ecosystems and the services ecosystems provide to society. This is a significant knowledge gap because losses and damages to human systems often result from permanent or temporary disturbances to ecosystems services caused by climatic stressors. This chapter tries to advance understanding of the impacts of climatic stressors on ecosystems and

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implications for losses and damages to people and society. It introduces a conceptual framework for studying these complex relations and applies this framework to a case study of multi-annual drought in the West-African Sahel. The case study shows that causal links between climate change and a specific event, with subsequent losses and damages, are often complicated. Oversimplification must be avoided and the role of various factors, such as governance or management of natural resources, should be at the centre of future research.

Keywords Loss and Damage · Climate change · Ecosystem services Livelihoods · Adaptation limits and constraints · Sahel · Africa

9.1 Introduction

Climate change amplifies extreme weather events such as heatwaves and extreme rainfall, with implications for losses and damages affecting vulnerable populations around the world. Global surface temperature has increased already on average by 0.85 °C relative to pre-industrial temperature (IPCC 2014), and there is evidence that even with very ambitious mitigation measures, the Earth's atmospheric system may already be committed to warming of approximately 1.5 °C above pre-industrial levels by 2050 (World Bank 2014). While mitigation continues to be of paramount importance to limit losses and damages, the extent and magnitude of climate change impacts will almost certainly increase in the future. Decision makers will need to be prepared to implement both adaptation and risk reduction measures to avoid losses and damages and a suite of other approaches within comprehensive risk management frameworks to address losses and damages that are not averted (see introduction by Mechler et al. 2018).

Defining Losses and Damages

No universally agreed-upon definition of losses and damages as part of the Loss and Damage debate exists, and a fit-for-purpose working definition varies by scale and purpose. This chapter refers to losses and damages as the adverse effects of climate-related stressors that cannot be or have not been avoided through mitigation or managed through adaptation efforts (adapted from Van der Geest and Warner 2015). Losses and damages occur when adaptation measures are unsuccessful, insufficient, not implemented, or impossible to implement; when adaptation measures have unrecoverable costs; or when measures are maladaptive, making ecosystems and societies more vulnerable (Warner and van der Geest 2013).

Verheyen (2012) makes an important and policy-relevant distinction between avoided, unavoided and unavoidable losses and damages (see also Mechler et al. 2018). Avoided losses and damages refer to impacts and risks that have been prevented through mitigation and adaptation measures. For example, if an African rainfed farmer has planted drought-resistant crop varieties that yielded well in a season of extremely low rainfall, he or she has avoided adverse effects of drought. Unavoided losses and damages refer to impacts of climate change that could in theory have been avoided but that have not been avoided because of inadequate efforts to reduce risks or adapt. For example, unavoided losses and damages may result if a coastal storm and high tide inundate properties because available measures to adapt to sea level rise were not adopted. By contrast, impacts and risks that are impossible to avoid through mitigation and adaptation efforts are characterised as “unavoidable losses and damages” (Verheyen 2012). In reality there is ambiguity around what can and what cannot be avoided. It depends on technological, social, economic or political limits to mitigation and adaptation, which are context-specific and subjective. Strong disaster mitigation, for example, might be technically possible but not politically feasible or economically viable. Similarly, if a small, low-lying atoll would be confronted with 6 m of sea level rise, it could be technically possible to build a dyke around the island, but the costs of such an effort would probably be prohibitive. This chapter does not attempt to resolve these ambiguities. However, it is important to acknowledge that they exist because there are important policy implications. In some cases, resources would be invested most efficiently in trying to avoid losses and damages, and in other cases it will be better to accept losses and find sustainable and dignified solutions for the people who are affected.

A useful concept in the discussion about avoidable and unavoidable losses and damages are ‘adaptation limits’ (Dow et al. 2013; Preston et al. 2013; Warner et al. 2013). According to the IPCC, adaptation limits are reached when adaptation is no longer able to “provide an acceptable level of security from risks to the existing objectives and values and prevent the loss of the key attributes, components or services of ecosystems” (Klein et al. 2014). An adaptation limits is considered ‘hard’ when no adaptive actions are possible to avoid intolerable risk, while soft adaptation limits occur when options are currently not available to avoid intolerable risk through adaptive action (Agard et al. 2014). In practice, it is not always clear whether an adaptation limit is hard or soft. Similarly, what renders risk acceptable, tolerable or intolerable is subjective, context-specific and socially constructed (Mechler and Schinko 2016).

A common way of analysing losses and damages is by differentiating economic and non-economic losses and damages (NELD). Economic losses are understood to be the loss of resources, goods and services that are commonly traded in markets, such as livestock and cash crops. Non-economic losses and damages involve things that are not commonly traded in markets (UNFCCC 2013). Examples of NELD in natural systems include loss of habitat and biodiversity and damage to ecosystem services. While such items are not traded in markets, there is a strong research community dedicated to valuing the services ecosystems provide, and hence also to quantifying losses when they occur (Costanza et al. 2014). Examples of NELD in human systems include cultural and social losses associated with the loss of ancestral land and forced relocation. Such climate change impacts are difficult to quantify but important to address (Morrissey and Oliver-Smith 2014; chapter by Serdeczny 2018).

Losses and damages can also be categorised as direct and indirect. Examples of direct losses and damages include loss of life, land, crops, or livestock–as well as damage to houses, properties, and infrastructure. Such losses and damages are generally quite well covered in disaster loss assessments (Gall 2015; chapter by Bouwer 2018). By contrast, indirect losses and damages are harder to quantify or estimate, so they are often underreported (UNFCCC 2012). Indirect losses and damages are associated with the measures actors implement to adapt to or cope with direct impacts. For example, if a community is displaced by flooding and has to live in a school building for six months, there will be indirect effects of the flood on the students' education level (Opondo 2013). When coping measures are beneficial in the short term but have adverse effects on livelihood sustainability in the longer-term, we speak of 'erosive coping' (van der Geest and Dietz 2004).

Research Gaps and Outline of Chapter

There is a long tradition of scholarly work on assessing disaster losses, and a small, but emerging body of literature on losses and damages from climate change. More research has been done about losses and damages from sudden onset disasters—such as cyclones and floods—than from slow onset processes—such as sea level rise, ocean acidification and drought. While scientific conceptualisations and empirical work on Loss and Damage has focused primarily on human impacts (Warner and van der Geest 2013; Wrathall et al. 2015), little attention has been given to the loss of ecosystem services and the cascading impacts on human societies resulting from this (Zommers et al. 2014). Yet, according to the IPCC's Fifth Assessment Report, "evidence of climate-change impacts is strongest and most comprehensive for natural systems" (IPCC 2014). Moreover, adaptation options for ecosystems are limited (IPCC 2014) and in the case of progressive and permanent change, current measures are unlikely to prevent loss and damage to ecosystems and their services.

This chapter[1] tries to enhance understanding of how impacts of climate change on ecosystem services result in losses and damages to people and society. This helps in determining what kind of interventions could reduce such losses and damages now and in the future. We first present a conceptual framework for studying how impacts of climate change on ecosystem services can result in losses and damages to human systems. The next section discusses current knowledge of climate change impacts on four types of ecosystem services—provisioning, regulating, supporting, and cultural. A case study follows where we present how losses and damages to ecosystem services affects human well-being in the drylands of the West African Sahel. The conclusion section of this chapter summarises key findings and discusses policy options. As well, we identify two important areas for future research and evidence gathering.

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[1] This chapter builds on a report published by the United Nations Environment Program, entitled "Loss and Damage: The role of Ecosystem Services" (UNEP 2016).

9.2 Conceptual Framework for Understanding the Role of Ecosystem Services

The working definition we use in this chapter refers to losses and damages as the adverse effects of climate-related stressors that cannot be or have not been avoided through mitigation or managed through adaptation efforts (adapted from Van der Geest and Warner 2015). Following from this definition is the notion that there is a conceptual difference between climate impacts and losses and damages. Despite its negative connotation, the concept of losses and damages gives central stage to the role of mitigation and adaptation and the opportunities that exist for avoiding harm, as illustrated in Fig. 9.1. However, too many opportunities to mitigate or adapt are missed because of adaptation constraints, such as due to a lack in understanding, deficits in long-term commitment and motivation, and inadequate financial resources (Ayeb-Karlsson et al. 2016). Losses and damages result from these failures.

The purpose of this framework is to illustrate the central focus and storyline in this chapter. It does not elaborate on all elements and relations of the complex reality of climate change, impacts, and adaptation. Starting at the top of the diagram, climatic stressors affect human systems and natural systems. Impacts on human systems can be direct, or indirect through damage to natural systems and the ecosystem services they provide to society. When human systems are affected—be it directly or indirectly—adaptation options may exist. If adaptation measures are adopted and successful, there are no losses and damages. If there are no adaptation options at all, when adaptation limits have been surpassed, then losses and damages to human systems is inevitable. If there are possibilities to adapt, but adaptation action does not materialise or is not efficient because of adaptation constraints, then actors will also incur losses and damages. Often, successful adaptation is possible in theory, but doesn't happen in practice because of adaptation constraints, such as lack of knowledge, skills, and resources (chapter by Schinko et al. this 2018).

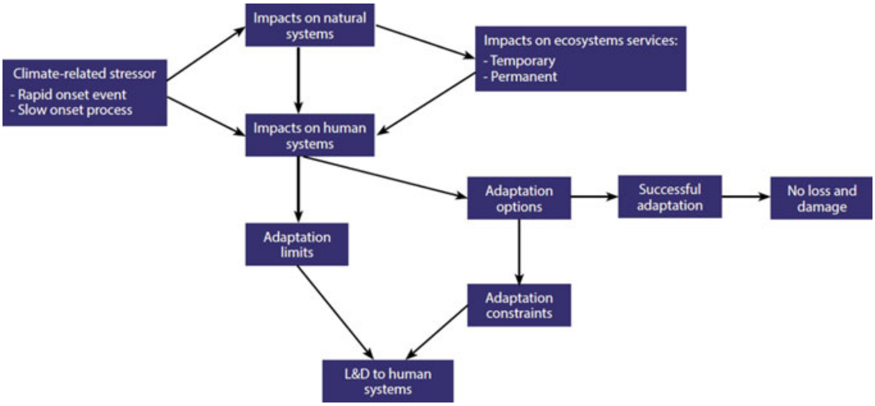

Fig. 9.1 Conceptual framework for understanding the role of ecosystem services

9.3 Impacts of Climate Change on Ecosystem Services-Current Knowledge

Ecosystems are collections of macro and microscopic biota that form critical life support systems. Degradation of ecosystems is occurring worldwide due to over-exploitation and because of insufficient recognition of the vital importance of the services that ecosystems provide to human well-being (WWAP 2015; MA 2005). Climate change has the potential to exacerbate ecosystem degradation and reduce the efficiency of ecosystem services (Staudinger et al. 2012; Bangash et al. 2013; Lorencová et al. 2013).

The Millennium Ecosystem Assessment defines ecosystem services as the benefits that people obtain from ecosystems (MA 2005) and distinguishes four types of ecosystem services :

- provisioning services (food, water, fuel and wood or fiber),
- regulating services (climate, flood and disease regulation and water purification),
- supporting services (soil formation, nutrient cycling and primary production),
- cultural services (educational, recreational, aesthetic and spiritual).

The quality of ecosystem services increases with the level of intactness, complexity, and/or species richness of ecosystems (Díaz et al. 2006). Many of the negative consequences human societies experience from climate change are related to the adaptation limits of individual species that provide us with food, fiber, fuel and shelter, as well as the services provided by whole ecosystems. Dow and others (2013) provide two telling examples of such adaptation limits. First, there is a limit to the temperature that rice in South Asia can cope with in the pollination and flowering phase: After a threshold temperature of 26 °C, every 1 °C increase in night-time temperature results in a 10% decline in yield. Beyond a night temperature of 35 °C it is impossible to grow current rice varieties there, which constitutes a hard adaptation limit beyond which different types actors (farmers, traders, the economy at large) incur losses and damages due to changes in the ecosystem service (Dow et al. 2013).

The second example demonstrates how a society itself can choose its adaptation limits: After settling in Greenland around 1000AD, the complex and advanced Norse society there ended around 1450. The settlements' collapse can be attributed to their adaptation limits. When harsh conditions began, Norse Greenlanders adopted new ways of exploiting marine mammals as declines in agriculture and domestic livestock production persisted. But faced with growing competition from Inuit hunters, declining trade in ivory and fur with Norway as pack ice blocked their access, and a generally chilling climate, these adaptations were insufficient to maintain risks to community continuity at tolerable levels. At the same time, the Norse settlers refused to adopt techniques that proved useful to the Inuit (Dow et al. 2013). Impacts of climate change on ecosystem services are characterised by high levels of complexity arising from interactions of biophysical, economic, political, and social factors at various scales (Ewert et al. 2015). These impacts are often specific to a given context or place, making generalisations difficult.

9.4 Case Study: Multi-annual Drought in the Drylands of the Sahel

While climate change impacts on ecosystem services are already highly localised, this applies even more to the resulting losses and damages to people and society. Differences between places in terms of culture, social organization, governance, development and adaptive capacity cause the local specificity of climate change impacts in human systems. This section uses a West African case study to further explore conceptual links between climate change and losses and damages to ecosystem services, and consequently to human well-being. The following questions are explored:

- What is the weather-related stressor and does climate change play a role?
- How does the stressor affect ecosystems and the services they provide?
- How does the change in ecosystem services affect human systems?
- What are adaptation options, and how effective are these at avoiding losses and damages?
- What is the evidence on losses and damages?
- What can be done in terms of better preparedness or adaptation to avoid future losses and damages?

The Sahel and the semi-arid drylands of East Africa are emblematic of climate change vulnerability. The regions have faced challenges such as crop and livestock losses, food insecurity, displacement, cultural losses including traditional livelihood systems, and conflict. A major factor in these challenges is climate variability exacerbated by climate change. In contrast with other parts of the world, most agriculture in Africa is rainfed and therefore crops yields are extremely sensitive to climatic conditions (Zaal et al. 2004). In early 2015 an estimated 20.4 million people were food insecure as a result of ongoing drought—mostly in Niger, Nigeria, Mali, and Chad where conflict and poverty compound food insecurity (ReliefWeb 2015). A number of climatic changes are occurring in the region. For one, it is becoming hotter, and this is clearly consistent with climate change. Temperature increases vary widely within the region, up to as much as 0.5 °C per decade from 1951 to the present (or 3.5 °C total) in a large part of Sudan and South Sudan; and are also high, 0.2–0.4 °C per decade, in large parts of Mauritania, Mali, Niger, Chad and Uganda (Fig. 9.2). Recent studies suggest that in some African regions the pace of warming is more than double the global and tropical average (Cook and Vizy 2015; Engelbrecht et al. 2015). Higher temperatures increase evaporation from soil and water surfaces and transpiration from vegetation—a process known collectively as evapotranspiration. Therefore, even in places where rainfall increases, it may not be sufficient to offset overall soil moisture loss, affecting primary productivity and food production, which are supporting and provisioning ecosystem services respectively.

In the drylands of Africa, there is high rainfall variability from year to year, and even from decade to decade. Figure 9.3 shows the rainfall variation for the Sahel

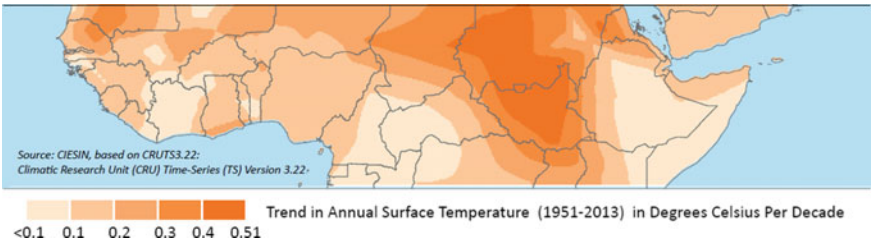
Source: CIESIN, based on CRUTS3.22: Climatic Research Unit (CRU) Time-Series (TS) Version 3.22

Fig. 9.2 Temperature change in degrees Celsius per decade from 1951 to 2013. *Source* UNEP (2016). *Notes* Trends are obtained by adjusting a linear trend to inter-annual anomalies (anomalies with respect to the average over the 63 year observation record), with no other filtering (not removing any other scales of variability). It is expressed in degrees C/decade

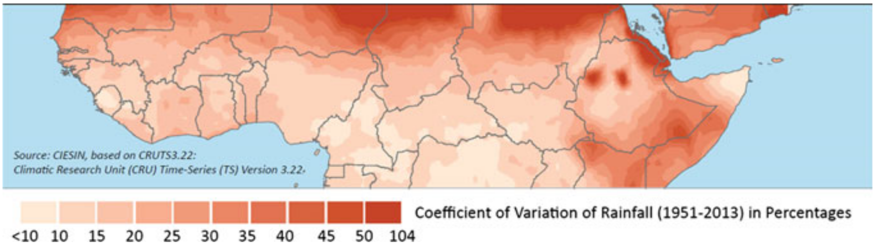
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Fig. 9.3 Coefficient of variation of rainfall from 1951 to 2013 (in percent of the long-term average). *Source* UNEP (2016)

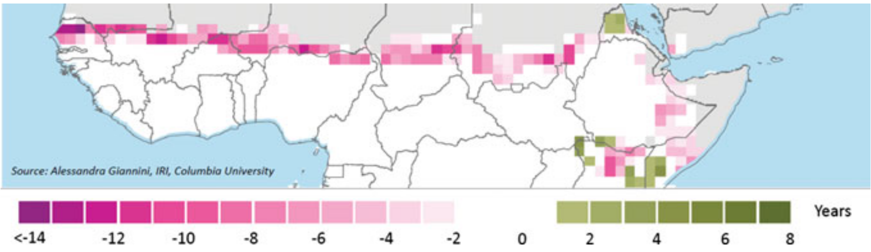

Source: Alessandra Giannini, IRI, Columbia University

Fig. 9.4 Difference in the number of years that received adequate rainfall for sorghum and millet (1990–2009 compared to 1950–1969). *Source* UNEP (2016)

from 1951 to 2013. Large areas of the drylands have inter-annual rainfall variability that is ±30% of the mean.

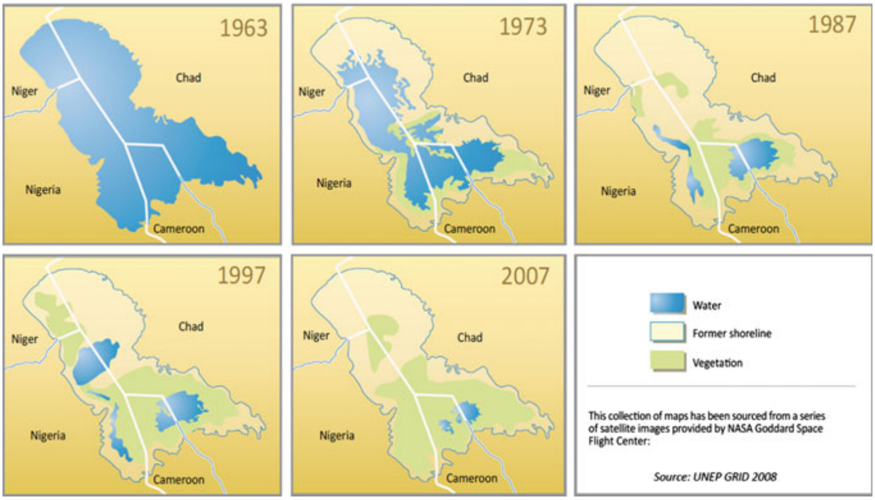
During the 1970s and early 1980s the Sahel experienced a long and widespread drought that was associated with a devastating famine (Held et al. 2005; Conway et al. 2009). Trends for the late 20th and early 21st century suggest an increase in the intensity and length of droughts in West Africa (IPCC 2012), and a decline in rainfall of between 10 and 20%, with rainfall becoming less dependable (Turco et al. 2015). The region also has strong decadal variability, related to swings in ocean temperatures in the North Atlantic. Even controlling for the effect of decadal variability, pronounced shifts in rainfall are evident. For example, in the drylands of Mali and Burkina Faso, the number of years that exceed the minimum required to grow sorghum and millet has changed over time (Fig. 9.4). During the period 1950–69, generally recognised as a wet period for the Sahel, there was reliable rainfall for sorghum and millet in many regions, but in the last two decades the number of years that met the threshold was 60–80% lower. This demonstrates how climatic variability and change can threaten food production, an important ecosystem service.

Intra-annual variability is another issue. Within any growing season, large gaps in rainfall or extreme rainfall events can have important impacts on crop production—withering crops after they've sprouted or washing them away. The combined effects of decadal, inter-annual (between years), and intra-annual (within years) variability have important repercussions for food provisioning, which is an important ecosystem service.

Research on losses and damages from the 2004 and 2010 droughts in northern Burkina Faso showed that villagers have become less able to cope with droughts because of a decline in pastoralism and an increase in cropping (Traore and Owiyo 2013). Pastoralism has long been an important and well adapted livelihood strategy in the region; herders could move their cattle to areas where pasture was more abundant to accommodate localised water deficits. This was a way of life that brought resilience to droughts. With recent land use change policies and conflict, severe barriers to pastoralists' freedom of movement make them more vulnerable to droughts. Surveys found 96 and 87% of respondents felt the negative effects of droughts on crops and livestock, respectively, and that extreme droughts tend to have cascading effects. First, the water deficits affect seedling growth and crop yields, which then affects the availability of food for people and feed for livestock (Traore and Owiyo 2013).

At the geographic center of this large dryland region, for centuries Lake Chad—centred in Western Chad and straddling the Niger, Nigeria and Cameroon borders—was home to abundant fisheries and livestock herds. Temperature increase, rainfall unpredictability, and land use changes have negatively affected the Lake Chad basin. Once among Africa's largest lakes, the lake has shrunk from 25,000 sq. km in 1963 to around 1,000 sq. km (Fig. 9.5) (UNEP 2008).

A ridge that emerged during the drought in the 1970s and 1980s now divides Lake Chad in two. Despite the recovery of rainfall in the 1990s, the lake never fully recovered because irrigation withdrawals increased from the primary tributaries to the south, where rainfall is higher (Gao et al. 2011). The lake once supported a vital traditional culture of fishing and herding. As the lake receded, farmers and pastoralists shifted to the greener areas, where they compete for land resources with host communities (Salkida 2012). This has been compounded by violent conflict associated with the Boko Haram insurgency, which has spilled across the border from Nigeria (Taub 2017). Others have migrated to Kano, Abuja, Lagos, and other big cities. The decline of Lake Chad illustrates how changing climate patterns interacting with other anthropogenic modifications, conflict and poor governance result in losses and damages to ecosystems and societies.



This collection of maps has been sourced from a series of satellite images provided by NASA Goddard Space Flight Center:

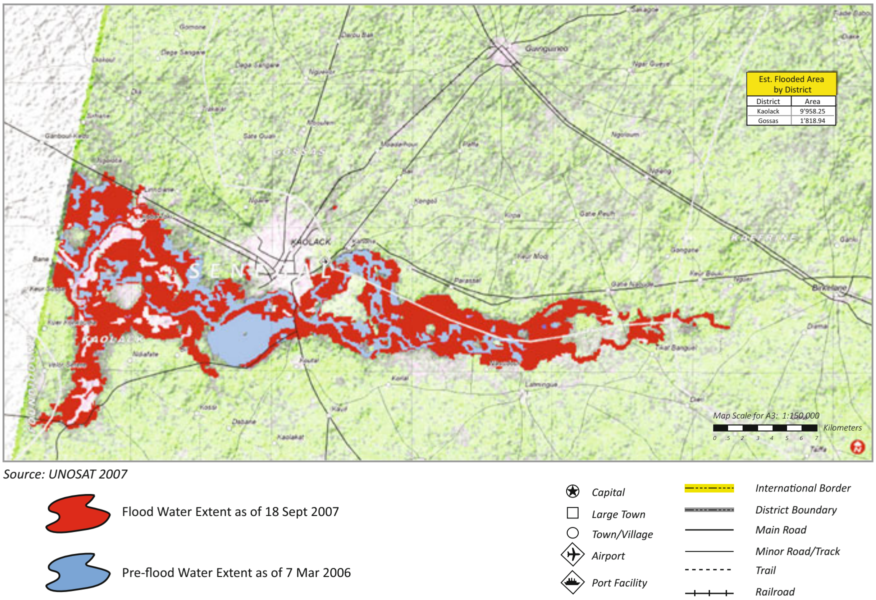
Source: UNEP GRID 2008

Fig. 9.5 The drying of Lake Chad. *Source* UNEP (2016)

In other parts of the Sahel, rainfall recovery in recent decades has brought flooding because the rainfall arrives in more intense cloudbursts rather than in a more evenly distributed manner (Giannini et al. 2013). In 2007, for example, rainfall extremes and consequent flooding in Senegal's peanut basin led to loss of property and crop loss because farmers often cultivate in and around natural depressions (Fig. 9.6).

Research in eastern Senegal on household perceptions of flood and drought indicate that climate variability brings crop, livestock and other economic losses (Miller et al. 2014). Over the decade preceding the survey, on average households reported experiencing 2.5–3 years of drought and 0.2–0.5 years with flooding, with higher incidence in the north than the south. It is unclear how climate change might influence the Sahel in future, with some climate change projections suggesting there might be a shift to wetter conditions while other projections suggest that conditions will become much drier (Druyan 2011). Despite the uncertainty about the potential influence of human-induced climate change in the region, there is ample evidence to demonstrate the vulnerability to climate shocks, as well as potential shifts in climate.

Adaptation measures implemented in the Sahel include crop-livestock integration, soil fertility management, planting of drought-resistant crops, water harvesting, dug ponds for watering animals, livelihood diversification, and seasonal or permanent migration. A number of these methods have been practiced for generations and are the norm for semi-arid regions. However, in a changing climate such practices will have to be scaled up and new methods developed, as adaption has not been sufficient to prevent losses. New methods may include breeding of more drought-resistant crops, or innovations such as index-based insurance. For the latter, payouts to participating farmers and herders are not made on the basis of actual losses but on the basis of changes in rainfall or drought indices, thereby reducing the overhead of



Source: UNOSAT 2007

Fig. 9.6 Flooding in the peanut basin south of Kaolack, Senegal (September 2007). *Source* UNEP (2016)

claims inspections (chapter by Schafer et al. 2018). This has been tested successfully in Senegal, Ethiopia, and Northern Kenya (Greatrex et al. 2015).

In the future, temperature changes may create genuine hard limits to adaptation, for example, where temperature increases are beyond the limit of crops during critical points in their life cycle (Ericksen et al. 2011). According to the IPCC, in Africa

Climate change combined with other external changes (environmental, social, political, technological) may overwhelm the ability of people to cope and adapt, especially if the root causes of poverty and vulnerability are not addressed (Niang et al. 2014).

This may lead to migration as an adaptive response (Mortimore 2010; World Bank 2018), as it has in the past (de Sherbinin et al. 2012; UNEP 2011).

9.5 Conclusions

This chapter tried to enhance understanding of how and when climate change threats to ecosystems and the services they provide result in losses and damages to people and society. In doing so it addressed serious gaps in the emerging research and debate on Loss and Damage from climate change. The first generation of empirical work on losses and damages has focused primarily on human systems and tended to overlook the mediating role of ecosystems and the services ecosystems provide to society. The chapter introduced a conceptual framework for studying the complex relations between climatic stressors, impacts on ecosystems, ecosystem services, adaptation opportunities, limits and constraints and residual losses and damages. A case study from West Africa illustrated how this works out in a real-world setting.

The case study showed that causal links between climate change and a specific event, with subsequent losses and damages, are often complicated. Oversimplification must be avoided and the role of different factors, such as governance or management of natural resources, should be explored further. For example, lack of investment in water related infrastructure, agricultural technology, or health care services also increase the risk of losses and damages. In the Sahel, variability in rainfall patterns influences primary productivity, but barriers to pastoralists' freedom of movement have also increased their vulnerability to droughts.

The case also shows that while some adaptation measures have been implemented, losses and damages have nevertheless occurred. For instance, adaptation measures in Dryland West Africa include crop-livestock integration, soil fertility management, planting of drought-resistant crops, water harvesting, dug ponds for watering animals, livelihood diversification, and seasonal or permanent migration. A number of these methods have been practiced for generations. However, as climate change intensifies, promising practices will have to be scaled up and new methods will have to be devised. A win-win solution will be to invest in ambitious mitigation action to avoid the unmanageable, and comprehensive and holistic adaptation action to manage the unavoidable–including better management of ecosystems and their services, improved governance, and economic policies that support sustainable development.

Ultimately, a range of approaches is needed to address climate change impacts and to ensure that resilience building efforts and sustainable development can continue. This includes policy options to avert losses and damages, and to address losses and damages that have not been or cannot be averted through enhanced mitigation and adaptation. These options include risk transfer, which can be used to both avoid and address losses and damages; risk retention, such as social protection policies; migration, recovery, rehabilitation and rebuilding in the wake of extreme events; and tools to address non-economic losses and damages. Approaches to avert and limit losses and damages as well as to address the residual impacts of climate change will be more successful if they incorporate inclusive decision-making, account for the needs of a wide range of actors, and target the poor and vulnerable.

As Loss and Damage is a new and emerging topic in science and policy, there are more unanswered questions than answers at present. We identify two important areas for future research and evidence gathering. First, there is a need to increase understanding of how losses and damages to human well-being is mediated through losses and damages to ecosystem services and of the specific policy entry points. This includes more study of the adverse impacts of climate change, including climate extremes, on ecosystem functioning. Examples may include the effects of extreme heat and drought on forest ecosystems, the consequences of sea level rise and storm surge for coastal ecosystems ranging from sea grasses and marshes to mangroves, and the implications of glacier loss on downstream hydrology and riparian ecosystem functions.

Second, it is important to document and evaluate the effectiveness of efforts to avert losses and damages and identify how the efficacy of tools and measures can be improved, including how non-economic losses and damages associated with the loss of ecosystem services can be better addressed. This includes gathering evidence on the potential for, and the limits to, ecosystem-based adaptation in a number of areas. Examples may include the ability of intact mangrove ecosystems to limit coastal erosion from sea level rise and storm surge, the potential for wetlands to reduce flood damage by absorbing runoff from heavy rainfall and releasing water gradually, or the potential and the limits for greening urban areas to reduce heat stress and consequent remediation of health risks. In such evaluations of adaptation and risk management efforts, it is of paramount importance to include the views of beneficiaries, particularly when the intended project beneficiaries are vulnerable people with limited political capital (see also Pouw et al. 2017).

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