

Slow-onset Processes and Resulting Loss and Damage – An introduction



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List of abbreviations

| | |
|---------------|---|
| AR4 | IPCC Fourth Assessment Report |
| AR5 | IPCC Fifth Assessment Report |
| COP | Conference of the Parties to the United Nations Framework Convention on Climate Change |
| ENDA | Environment Development Action Energy, Environment and Development Programme |
| ESL | Extreme Sea Level |
| GDP | Gross Domestic Product |
| GMSL | Global mean sea level |
| GMSLR | Global mean sea level rise |
| IOM | International Organization on Migration |
| IPCC | Intergovernmental Panel on Climate Change |
| LECZ | Low-elevation coastal zone |
| OCHA | Office for the Coordination of Humanitarian Affairs |
| RCP | Representative (Emission) Concentration Pathway/Scenario |
| SIDS | Small Island Developing States |
| SLR | Sea level rise |
| SR1.5 | IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels |
| SRCCCL | IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems |
| SREX | IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation |
| SROCC | Special Report on the Ocean and Cryosphere in a Changing Climate |
| UNCLOS | United Nations Convention on the Law of the Sea |
| UNDRR | United Nations Office on Disaster Risk Reduction |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNHRC | United Nations Human Rights Council |
| UNU | United Nations University |
| USAID | United States Agency for International Development |
| USD | US Dollar |
| WIM | Warsaw International Mechanism for Loss & Damage |

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SUMMARY OF KEY FACTS AND DEFINITIONS

What is a slow-onset process?

The effects of climate change can be divided into two categories according to the temporal scale over which they occur and the differing speed of manifestation of their impacts: slow-onset processes and rapid-onset events. To date, in the climate context, no officially acknowledged definition of slow-onset processes has been established. For this paper, slow-onset processes are understood as phenomena caused or intensified by anthropogenic climate change that take place over prolonged periods of time – typically years, decades, or even centuries – without a clear start or end point (see UNFCCC 2012, UNU 2017, UNHRC 2018, IPCC 2007 and 2012). Slow-onset processes evolve through gradual transformations - creeping or incremental changes that can generate severe, cumulative and potentially irreversible impacts on ecological and human systems. Impacts take place at

all levels up to the global scale. Slow-onset processes' characteristics can be well understood when compared with rapid onset events, in the climate context typically referred to as extreme weather events. Rapid-onset events are single, discrete events with a clearly identifiable beginning and/or end and that occur or reoccur in a matter of days or even hours at a local, national, or region scale (UNHCR 2018).

This paper considers increasing mean temperatures, sea level rise, ocean acidification, glacial retreat, permafrost degradation, salinisation, land and forest degradation, and desertification, as well as loss of biodiversity, as slow-onset processes (see UNFCCC 2017, UNU 2017). The paper puts a special emphasis on the distinct slow-onset process of sea level rise, which is one of the most urgent such

Which phenomena fall under the category of slow-onset processes?

processes in Senegal, our case study country. Droughts are a special case and not included in the list of these processes. Droughts result from a pattern of extreme weather that persists for some time (e.g. a season) and can be classified as an extreme climate event (IPCC 2014c).

What losses and damages do slow-onset processes cause?

Loss and damage is understood as “adverse impacts of human-induced climate change that cannot be avoided by mitigation or adaptation, or that will not be avoided in the future by adaptation due to insufficient resources” (Mace/Verheyen 2016: 198). A main distinction can be made between economic loss and damage (including [a] physical assets and [b] income) and non-economic loss and damage (including [a] material and [b] non-material forms). The analysis for this paper (see section 3) showed that all slow-onset processes cause a high number of different losses and damages; sea level rise and land and forest degradation lead to the greatest number of losses and damages. This includes economic damage to physical assets (e.g. infrastructure and property) and income (e.g. losses for fisheries and aquaculture, losses in livestock and agriculture production, and losses for tourism). It also includes non-economic loss and damage in its material form (e.g. damage to ecosystems and their services, and loss of land area or territory) and non-material form (e.g. loss of heritage, identity, health, and local and indigenous culture). In the analysis the selected slow-onset processes caused

a higher number of non-economic than economic losses and damages.

Slow-onset processes are interlinked and mutually reinforcing. They all lead to a damage and/or loss of ecosystems and their services, leading to a decrease and loss of biodiversity. Slow-onset processes and the losses and damages they cause can be drivers of human mobility (Rigaud et al. 2017). Migration as an adaptation strategy or way of dealing with loss and damage, however, can lead to further non-economic losses, such as loss of culture and traditions, language, social networks, identity and community cohesion (Campbell/Warrick 2014). Research showed that slow-onset climate changes are more likely to induce increased migration and displacement than rapid-onset changes (Kaczan / Orgill-Meyer 2020). Research also hints that, similar to rapid-onset events, slow-onset processes and resulting losses and damages particularly affect vulnerable people in countries of the Global South (Warner/van der Geest 2013, Zorn 2018). This is also partially due to the fact that slow-onset processes, as well as climate-related rapid-onset events, and related hazards perpetuate collective and individual vulnerabilities (van der Geest/Schindler 2017). These parts of the population are more vulnerable to a hazard’s damaging effects (because, for instance, their livelihood depends on fewer assets and their consumption is closer to subsistence levels) but have lower coping capacity (because, for instance, they cannot rely on savings to buffer the impacts and may need longer to rebuild and recover).

INTRO DUCTION

What is the background of this paper and the series?

The effects of climate change can be divided into two categories according to the temporal scale over which they occur and the differing speed of manifestation of their impacts. There are rapid-onset events, typically referred to as extreme weather events in the climate context (e.g. cyclones and heatwaves). Meanwhile, there are slow-onset processes unfolding slowly and gradually over years, decades, or centuries (e.g. sea level rise, ocean acidification, and desertification). Both types of events substantially impact people's lives, cause loss and damage, hinder enjoyment of human rights, and drive human mobility. The first priority should therefore be to prevent or minimise this potential damage through effective mitigation, adaptation, and risk-reduction measures. Prevention or minimisation of all loss and damage is, however, no longer possible; climate change is already leading to unavoidable losses and will increasingly do so in the future. Taking this into account, it appears essential to address the unavoidable residual loss and damage, especially those for countries particularly vulnerable to climate change impacts.

In contrast with extreme weather events, addressing losses and damages caused by slow-onset processes is still neglected in the climate change context, both at the national and international levels.

Neglecting the issue undermines the scale of the challenge. Scientists conclude that in the long term, more people will be affected by slow-onset processes than by extreme weather events. The example of sea level rise (SLR) effectively illustrates the problem's global dimension. By 2050, sea level rise will threaten 300 million people living in low-lying coastal areas as they live on land below projected annual flood levels (Kulp/Strauss 2019). Estimates of global economic losses from coastal flooding due to SLR amount to > 4 % of world GDP (Schinko et al. 2020). For low-lying developing countries and Small Island Developing States (SIDS), however, its effects will be particularly severe, and in some cases existential. Based on current greenhouse gas emissions, researchers assume most atolls will become uninhabitable before the mid-21st century. Already today, SLR is causing substantive non-economic losses. In Senegal, our case study country, the effects of sea level mixed with other anthropogenic factors are threatening the World Heritage Site of Saint-Louis. Other communities are already submerged, despite adaptation measures. Thousands of people have already been displaced, and many more will follow in the future. Of Saint-Louis territory, 80 % will be at risk of flooding by 2080 and 150,000 people will have to relocate (Government of Senegal/World Bank 2013). Most of West Africa's coastal cities, home to 105 million people, face a similar threat.

Despite this urgency, the political Loss and Damage^[1] debate on national and international level and related measures to address losses and damage often still have a focus on dealing with the impacts of extreme

weather events. A number of gaps and challenges in coping with and managing slow-onset processes and related loss and damage can explain this. These include a lack of common understanding of the terminology related to slow-onset processes, and a lack of data and knowledge on the losses and damage slow-onset processes cause (particularly at the local level). These also include a lack of clarity about the question of how countries currently deal with these losses, and finally a lack of clarity regarding adequate measures to deal with losses and damage from slow-onset processes. The IPCC Special Report on the Ocean and the Cryosphere thus states that, '[m]ore work is needed to explore the range of activities available to respond to L&D [loss and damage] resulting from slow onset processes in the scope of the SROCC report (...)' (IPCC 2019a: 630).

What is the objective of the paper series on addressing loss and damage from slow-onset processes?

This series responds to the above-described challenges. This first paper introduces slow-onset processes and resulting losses and damages. The second analyses the status quo, challenges, and gaps in addressing losses and damages from slow-onset processes at the national and international levels. Finally, the third paper analyses financial tools and instruments to address losses and damages from slow-onset processes. Through the analyses, we seek to foster awareness of the urgency to act in this area, and provide input for processes at the national and international levels. This is with the aim of finding tangible and feasible solutions to address loss and damage from slow-onset processes. The series is prepared in the context of the 'Multi-Actor Partnership on Climate

¹ We use the term 'loss and damage' or 'losses and damages' (lowercase letters) to refer to harm from adverse effects of climate change and 'Loss and Damage' (capitalized letters) for the political debate, particularly under the UNFCCC (see e.g. IPCC 2019a). For a definition of 'loss and damage' see section three.

and Disaster Risk Financing'^{2]} project. It includes a case study from the partner country Senegal and contains insights from the other partner countries of Malawi, Madagascar, Laos, the Philippines, and Sri Lanka.

What does this first part, 'Slow-onset Processes and Resulting Loss and Damage – An introduction,' cover?

This part starts the series by navigating the maze of words that emerged in the context of slow-onset processes. It clarifies the questions of: What are slow-onset processes? What are other relevant terms for the terminology around slow-onset processes? and Which

phenomena fall under the category of slow-onset processes? A separate box describes how the IPCC uses the terminology. Subsequently, it summarises key characteristics of slow-onset processes, also in comparison with rapid-onset events. The introduction to these characteristics is deliberately kept detailed, as they form the basis for analysis of potential financial tools and instruments for dealing with loss and damage under the specific consideration of these characteristics in the third part of the series. In a second step, this paper presents losses and damages due to slow-onset processes. It details the different types of losses and damages (economic and non-economic) resulting from slow-onset processes in general and for the special case of SLR. The final section gives insights on the losses and damages in Senegal due to SLR.

2 The Multi-Actor-Partnership on Climate and Disasters Risk Financing in the Context of the InsuResilience Global Partnership project is carried out by a consortium of civil society organization. The main focus of the project is capacity development and the establishment/expansion of multi-actor dialogue platforms at national and global levels in order to promote the development and implementation of gender-equitable, poverty-oriented and human rights-based approaches to climate risk financing. The project is carried out in Malawi, Madagascar, Laos, Philippines, Sri Lanka, Senegal, Caribbean by implementing partners from the project countries. The overall coordination is led by CARE Germany with Germanwatch and Munich Climate Insurance Initiative (MCII). The project is supported by Engagement Global with funding from the German Ministry for Economic Cooperation and Development. For more information and a detailed project summary see: <https://careclimatechange.org/multi-actor-partnership-climate-and-disaster-risk-finance-in-the-context-of-the-insuresilience-global-partnership-igpp/>.

SLOW- ONSET PROCESSES

AND THEIR KEY CHARACTERISTICS

What is a slow-onset process?

Climate change causes and/or exacerbates natural hazards that pose a threat to, among other things, human security, sustainable development, and human rights (Schäfer, Künzel & Jorks 2020). Climate change's adverse impacts can be divided into two categories based on their temporal rate of occurrence and the differing speed at which their impacts appear. There are rapid-onset events, in the climate context typically also referred to as extreme weather events. These include cyclones or heatwaves. The duration of these discrete events is typically measured in hours, days, or months (UNHRC 2018). There are also climate change effects unfolding slowly and gradually over years, decades, or centuries (UNFCCC 2012). These include e.g. sea level rise and are referred to herein as slow-onset processes. This categorisation stems from the original terminology used in the Bali Action Plan (2007), which classifies direct climate impacts either as 'acute' or 'chronic' (UNFCCC 2008). While 'acute' impacts are described as 'short-term' and 'highly severe,' 'chronic' impacts are characterised as 'entirely anthropogenic' and 'gradual.'

No official definition of slow-onset processes has been established to date in the climate context. International organisations, including the Intergovernmental Panel on Climate Change (IPCC), the United Nations Framework Convention on Climate Change (UNFCCC), the International Organisation for Migration (IOM), and the United Nations Office for Disaster Risk Reduction (UNDRR), have used several terms to describe the climate change-related phenomenon of slow-onset processes and related impacts. They include: slow-onset events, creeping changes, slow incremental changes, slow-onset hazards, slow-onset perils, slow-onset effects of climate change, chronic climate impacts, and slow-onset impacts (see IPCC 2012, IPCC 2007, UNFCCC 2008 & UNHRC 2018, IOM 2020, UNU 2017). Even in IPCC reports, the term is not used consistently. In relevant IPCC reports and special reports since 2007, 13 different types of slow-onset terminology can be identified as having been used without a definition and often used without a description of the phenomena the term encompasses (see box ‘Slow-onset processes in IPCC reports’). The following paragraphs will therefore provide a detailed description of the characteristics of slow-onset processes, concluding with a definition of the phenomenon.

What are key characteristics of slow-onset processes?

Slow-onset process’ characteristics can be approached through comparison with those of climate-related rapid-onset events. Rapid-onset events are single, discrete events with a clearly identifiable beginning and/or end and that occur or reoccur in a matter of days or even hours at the local, national, or regional scale (UNFCCC 2012, IOM 2020). Slow-onset processes, however, lack a clearly identifiable start or end and are of a gradually evolving, creeping, or incremental nature (IOM 2020). Their severity only manifests through environmental transformation or degradation over a long period – usually years, decades or even centuries (UNHRC 2018). Impacts take place at all levels up to the global scale. Beyond the timeframe and level of

impact, rapid-onset events and slow-onset processes differ in a large number of characteristics.

Table 1 summarises the key characteristics of slow-onset processes compared to those of rapid-onset events. Beyond these key characteristics, which distinguish slow-onset processes from rapid-onset events, there are further typical attributes and features of slow-onset processes important for understanding their nature.

a) Interlinked and mutually enforcing nature of different slow-onset processes

The progress of one slow-onset process is often highly interlinked with that in others, such as SLR and salinity intrusion, leading to loss of soil fertility and a change in delta ecosystems. Slow-onset processes, thus, are highly interconnected and sometimes exacerbate or trigger one another. Temperature rise and glacier retreat, for instance, are two slow-onset processes that are simultaneously among the main contributors to SLR (Carbon Brief 2019). SLR, however, is a major contributor to land degradation and loss of biodiversity. For example, marine intrusion at just 1 m of sea level would severely impact protected areas (0–58.3 % loss), ecoregions (0–90.0 % loss), and endemic species (41–50 % loss) across New Guinea (Legra 2009).

b) Interlinked nature of rapid-onset events and slow-onset processes

Slow-onset processes can occur coincidentally, simultaneously, or sequentially with rapid-onset events. This leads to even more substantial disruption of natural and human systems due to simultaneous manifestation of multiple hazards and impacts. Consequences include increased rates of SLR together with increases in severe rainfall, storm surges, and associated flooding (IPCC 2019a: 624). Other examples are SLRs’ relationship with so-called extreme sea level (ESL) events, which (excluding tsunamis) result from tropical or extra-tropical cyclones, as a combination of high tides and storm surges, and in many cases a dynamic wave component. Little et al. (2015) acknowledge this dual role of regional SLR and tropical cyclone frequency and intensity changes for future flood risk

Table 1: Key characteristics of climate related slow-onset processes and rapid-onset events

| | Rapid-onset event | Slow-onset process |
|---------------------------|--|---|
| Type of event/ process | Single, discrete events | Gradual, creeping, incremental process |
| Timeframe | Occur within days or hours | Slowly unfolding over years, decades, or centuries Might accelerate over time (e.g. SLR) Gradual manifestation |
| | Clearly identifiable start and end point | Creeping and gradual, no clearly identifiable start and/or end point |
| Predictability | Not foreseeable regarding their frequency and intensity | Slow-onset processes, per se, are foreseeable phenomena, but: (1) they interact with anthropogenic parameters and external stressors, resulting in uncertainty about concrete impacts; (2) their manifestation differs at the local level |
| Impacts | Highly visible impacts Major damage in a very short time Limited to a specific geographical area | Damage through creeping environmental transformation or degradation Gradual impact over a longer period of time |
| Level of impacts | Appears at local, national, and regional scale | Potentially spread out over larger geographical areas up to the global level |

Source: Author, based on information from IOM 2020, UNFCCC 2012, UNHCR 2018, Staube-Delgado 2019

(IPCC 2019a: 624). Buchanan et al. (2017) addressed this issue across different level of extremes, focusing on the United States. Importantly, they found SLR would result in stronger increases in the number of moderate (or high-frequency) events in some places, such as the East Coast cities of Charleston or New York. Other areas, such as Seattle on the West Coast, would experience a more rapid increase in the number of rare extreme (or low-frequency) events. On average, across all study sites, there would be a 25-fold increase in

the expected annual number of present-day 100-year events (i.e. events currently with a 1 % chance of occurrence in any given year) by 2050 under a moderate SLR scenario (representative concentration pathway [RCP] 4.5)^[3]. This highlights how SLR and, in particular, the accompanying changes in ESL, will lead to a rapid increase in flood risk over the next few decades. Other interrelations of SLR with other physical processes include decadal-scale variability in ocean circulation (e.g. Firing et al. 2004), often associated

³ The IPCC described RCP 4.5 as an intermediate scenario. Emissions in RCP 4.5 peak around 2040, then decline. According to the IPCC, RCP 4.5 requires that carbon dioxide emissions start declining by approximately 2045 to reach roughly half of the levels of 2050 by 2100.

with large-scale climatic patterns such as the Pacific decadal oscillation (Bromirski et al. 2011), as well as interannual variability, such as occurs during phases of the El Niño–Southern Oscillation (NOAA 2017).

c) Cascading nature of slow-onset processes

As stated, changes in one of an ecological system's components (e.g. sea level) can cause cascading impacts and bring about numerous consequences, such as food insecurity or displacement. It must further be noted that one slow-onset processes impact (e.g. SLR) may trigger a multitude of hazardous impacts (e.g. coastal erosion, salinity intrusion, leading to soil fertility loss and delta ecosystem change). Additionally, as described under the above points a and b, slow-onset processes are highly interconnected and are interrelated with rapid-onset events. Owing to these interdependencies, slow-onset processes can be described as underlying cascading effects,^[4] which are complex, multi-dimensional, and constantly evolving over time. An example of such an effect is that mean temperature rise leads to biodiversity loss in coral reefs. Since corals also fulfil the function of protecting coasts from waves, their loss due to bleaching-induced mortality also increases flooding risk, which SLR already exacerbates (IPCC 2019a: 624).

Slow-onset processes also lead to risks to and impacts on ecosystems, people, human activities, and the built environment (IPCC 2019a). According to the IPCC's conceptual framework, hazards, vulnerability, and exposure are the major drivers of changes in disaster risks and of impacts when risk is realised (IPCC 2014, 2016). The severity of impacts therefore depends strongly on the level of vulnerability^[5] and exposure to certain slow-onset processes. With SLR, one potential chain of effects is the intensification of coastal hazards such as enhanced flooding, and the salinisation

of soils, groundwater, and surface waters. These hazards can lead to direct impacts, such as damage or loss of coastal ecosystems and their services due to land being permanently underwater. They can also lead to indirect impacts, such as loss of health due to loss of a source of calories from coastal ecosystems.^[6] Figure 1 displays the chain of effects for SLR.

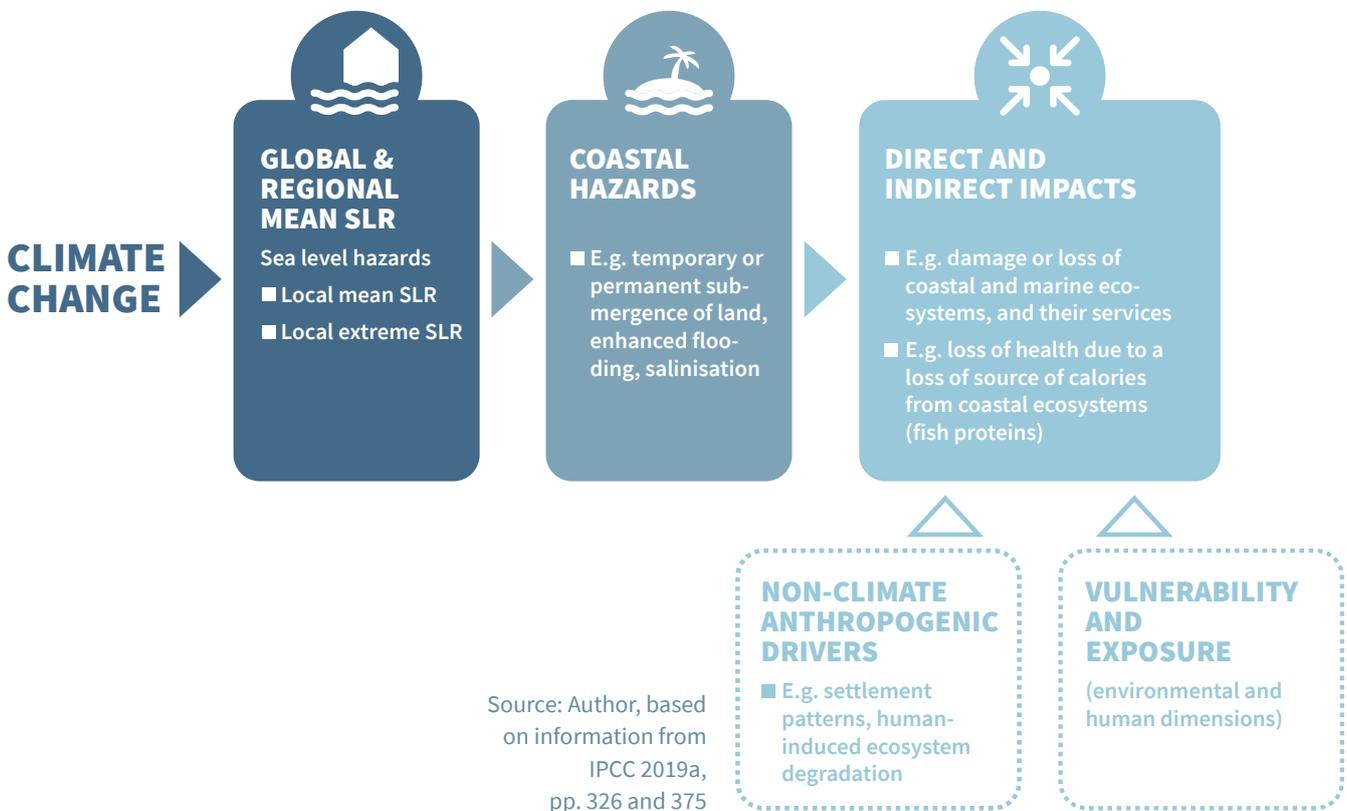
d) Hybrid nature

Most slow-onset processes-induced impacts cannot be solely attributed to these processes; rather, they are simultaneously influenced by other anthropogenic parameters (Raymond et al. 2020). Slow-onset processes therefore can be shaped by internal characteristics of the different systems and external confounding factors, such as longstanding stressors (e.g. overexploitation of natural resources). These factors' interaction with slow-onset processes shows the complexity of managing the associated risks. A literature review (Matias 2017) identified natural resource extraction and exploitation, pollution, land use change, industrialisation, and force majeure, among others, as external factors exacerbating slow-onset processes' impacts (Matias 2017: 8). For example, floods due to rising sea levels may be exacerbated by both natural and anthropogenic vertical land movement due to, for instance, overexploitation of groundwater or post-glacial rebound (see NOAA 2017, NASA 2020). However, studies of trend attribution have provided relevant information about the influence of climate change on some slow-onset processes including SLR, and increasing temperatures (James et al. 2019). It was demonstrated that anthropogenic activity has influenced global warming, and also regional warming on six continents. On top of that, the global increase in SLR has also been attributed to anthropogenic greenhouse gases (Bindoff et al. 2013).

4 A 'cascading effect' is an overall impact scenario timeline in which initial impacts can directly or indirectly trigger other unforeseen, adverse phenomena and sequences of events that lead to consequences of significant magnitude and damages inflicted on elements at risk, such as physical, social, or economic disruption (cf. Pescaroli & Alexander 2015).

5 According to the IPCC (2018: 67) 'vulnerability and exposure are dynamic, varying across temporal and spatial scales, and depend on economic, social, geographic, demographic, cultural, institutional, governance, and environmental factors.'

6 'Risk' refers to potential negative impacts of climate change where something of value is at stake, recognising the diversity of values. Risks depend on hazards, exposure, vulnerability (including sensitivity and capacity to respond), and likelihood. (IPCC 2018).

Figure 1: Slow-onset processes' chain of effects for sea level rise

e) Tipping points and permanent shifts

Slow-onset processes and their impacts span a broad range of natural systems. Failing to manage their associated risks may lead to the ecological thresholds or tipping points of systems being crossed (IPCC 2012). This can result in nonlinear instabilities in a system and domino-like, potentially irreversible damages, because ‘once an ecological threshold is crossed, the ecosystem in question is not likely to return to its previous state’ (CCSP 2009). Two examples of major SLR-related tipping points are the potentially irreversible retreat of the Greenland Ice Sheet, which could lead to ≤ 7 m of SLR, and the West Antarctic Ice Sheet, which could lead to 3 m. There is also some indication that interactions among rapid-onset and slow-onset events may result in thresholds being crossed. For example, a study in the US state of Florida found that once sea level reached a critical level, the transition from a landscape characterised by upland forests and

freshwater wetlands to one dominated by mangroves occurred suddenly, following a single storm surge event (Ross et al. 2009).

Based on the previous application of terminology in differing contexts, as well as further characterisations such as those mentioned above, for this paper, slow-onset processes are understood as phenomena caused or intensified by anthropogenic climate change that take place over prolonged periods of time – typically years, decades, or even centuries – without a clear start or end point. Slow-onset processes evolve through gradual transformations – creeping or incremental changes that can generate severe, cumulative, and potentially irreversible impacts on ecological and human systems at all levels (see, for example, IOM 2020, UNFCCC 2012, UNU 2017, UNHRC 2018, IPCC 2007 & 2012).

What are other relevant terms for the terminology on slow-onset processes?

As mentioned, a number of different terms are applied in the context of slowly, gradually evolving climate-related phenomena. Another term frequently used synonymously with slow-onset processes as used in this paper is ‘slow-onset events’ (see Cancun Adaptation Framework 2010). From our perspective, use of the term ‘event’ is misleading and inadequate, as it suggests a ‘discrete occurrence of a single phenomenon that can be clearly identified in time’ (UNU 2017), as opposed to the gradual natural and human-induced changes. We therefore do not use the term in this publication series.

The areas of disaster risk reduction and humanitarian action also deal with slowly evolving processes (both climate-related and non-climate-related), but with a focus on their impacts. This is reflected in the terminology used. UNDRR uses ‘slow-onset disaster’ and this is also established in the Sendai Framework. UNDRR understands it as a disaster “that emerges gradually over time. Slow-onset disasters could be associated with, for example, drought, desertification, sea-level rise, epidemic disease” (UNDRR 2015: 12). The IPCC defines disasters as “severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.” (IPCC 2012: 558). Based on this understanding, slow-onset processes do not cause a disaster by themselves. They can result in a slow-onset disaster when combined with societal vulnerabilities and lack of preparation and response measures.

The term ‘slow-onset emergency’ is frequently used in humanitarian action. It is defined as an emergency that “does not emerge from a single, distinct event but one that emerges gradually over time, often based on a confluence of different events” (OCHA 2011: 3).

The Office for the Coordination of Humanitarian Affairs (OCHA) uses this term for drought, and notes that broader global challenges such as climate change, urbanisation, food and energy price spikes, and irregular migration can, in combination, ultimately result in more slow-onset emergencies.

Which phenomena fall under the category of slow-onset processes?

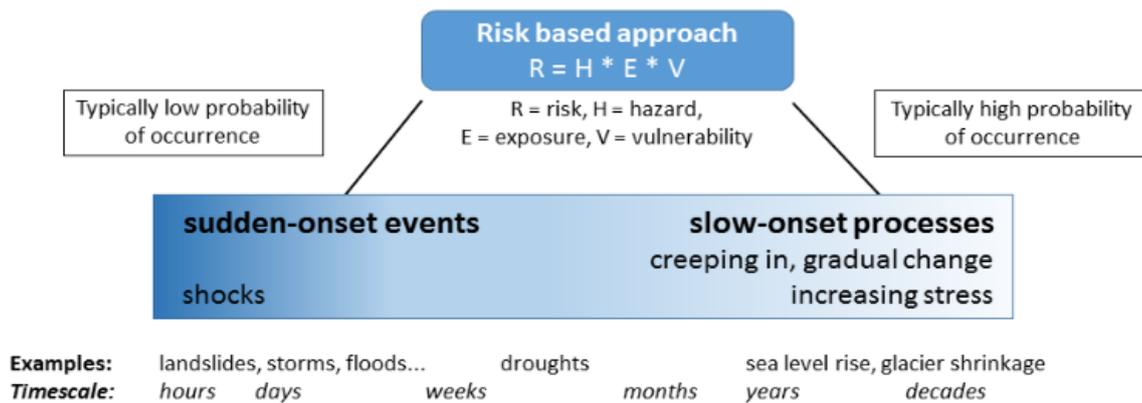
For slow-onset processes, there is neither an official definition nor a list of phenomena grouped under this category of climate change impacts. The following classifications exist:

- IPCC reports (2019, 2018, 2014, 2012) group the following phenomena under the terminology of slow-onset processes/slow-onset climate impacts/slow-onset perils/slow-onset hazards: ocean changes, SLR, glacier retreat, mountain and polar cryosphere changes, ocean acidification, permafrost thaw, rising mean temperatures and variability in temperature and water, desertification, precipitation changes, ecosystem changes, land degradation, and drought (see box ‘Slow-onset processes in IPCC reports’ for details.)
- The Conference of the Parties to the United Nations Framework Convention on Climate Change (COP) Decision 1/COP.16 contains a list of slow-onset processes considered particularly relevant for the UNFCCC’s mandate, including, ‘sea level rise, increasing temperatures, ocean acidification, glacial retreat and related impacts, salinization, land and forest degradation, loss of biodiversity and desertification’ (UNFCCC 2012: 3).
- UNU includes SLR, coastal erosion, salinisation, ocean acidification, temperature rise, desertification, and changing rainfall patterns in its categorisation. Droughts are categorised as a special case, since their manifestation and respective response measures often resemble sudden-onset events (UNU 2017).

For this paper, we consider increasing mean temperatures, sea level rise, ocean acidification, glacial retreat, permafrost degradation, salinisation, land and forest degradation, and desertification, as well as loss of biodiversity, as slow-onset processes. The Annex gives a detailed definition for each of these events. This paper particularly emphasises the

distinct slow-onset process of SLR, which is one of the most urgent process in Senegal, our case study country. Droughts are a special case and not included in the list. These result from a pattern of extreme weather that persists for some time (e.g. a season) and can be classified as an extreme climate event (IPCC 2014c).

Figure 2: The continuum of slow-onset processes and sudden-onset events



Source: Huggel 2016

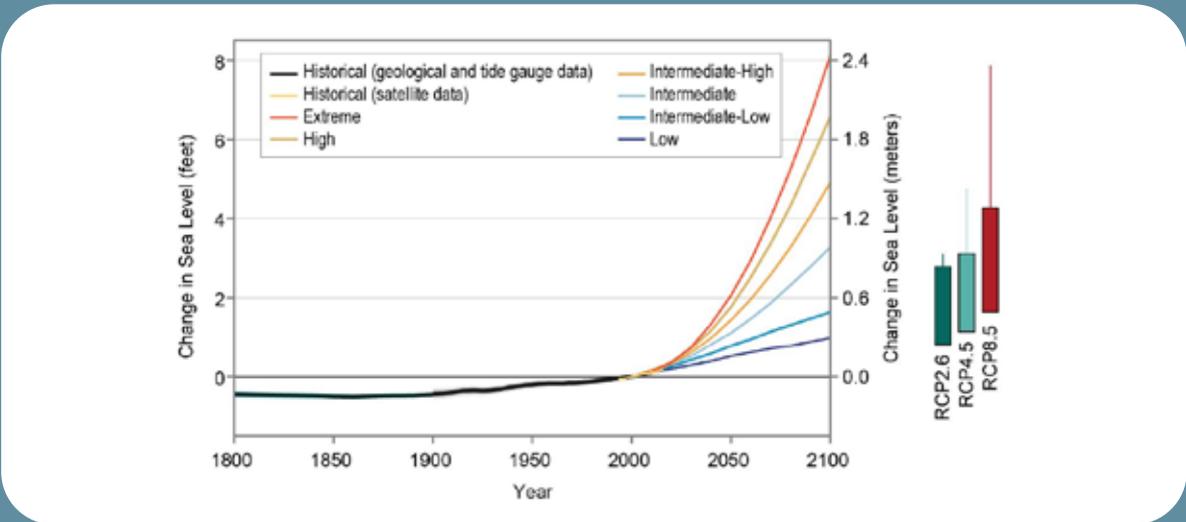
BOX: SEA LEVEL RISE

Global mean sea level rise (GMSLR) refers to the worldwide average rise in mean sea level (UNFCCC 2012). Sea level change can be both global and local (relative sea level changes). It is caused by different processes, such as a change in ocean volume (e.g. through melting glaciers and ice sheets or expanding volume due to temperature increase), or by salinity changes (IPCC 2018). The sum of glacier and ice sheet contributions is now the dominant source of GMSLR (IPCC 2019a). During the last 3 million years, the global mean sea level (GMSL) has exceeded 5 m above present levels, when global mean temperature was $\leq 2^\circ\text{C}$ warmer than in pre-industrial times (IPCC 2014c: 1140). The rate of GMSLR since 1900 has been faster than during any comparable period over at least the last 2,800 years (Kopp et al. 2016a).

Future SLR is highly dependent on the RCP followed. However, it is projected to be faster

under all RCPs at the end of the 21st century, including those compatible with achieving the Paris Agreement’s long-term temperature goal of well below 2°C . The IPCC (2019a) projected the GMSL will rise between 0.43 m (RCP2.6) and 0.84 m (RCP8.5) by 2100 relative to 1986–2005. Beyond 2100, sea level will continue to rise for centuries due to continuing deep ocean heat uptake and mass loss of the Greenland and Antarctic ice sheets, and will remain elevated for thousands of years. The IPCC scenarios are based on rather conservative calculation models. Vermeer and Ramsdorf (2009) published a semi-empirical estimate of 1.00–1.40 m for the period 1990–2100, depending on the RCP. This is significantly more than the IPCC’s corresponding values. Recent publications even recognised that a GMSLR $> 2\text{ m}$ is possible even if global mean temperature rise is limited to 2°C by the end of the 21st century (Bamber et al. 2019).

Figure 3: Historical and projected global average sea level rise



Source: USGCRP 2018

The rate of SLR varies spatially across the world, owing to a variety of factors (Church et al. 2004; Nicholls/Cazenave, 2010). Thermal expansion, ocean dynamics, and land ice loss contributions will generate regional departures of about $\pm 30\%$ around the GMSLR (IPCC 2019a). Temperature and salinity changes can contribute significantly to regional sea level change (Church et al. 2010). Gravitational and rotational effects from changes in ice masses and ocean circulation also influence the rise's regional distribution. These effects lead to the rise being higher in the tropics than at high latitudes (Hinkel et al. 2014).

Moreover, changes in local relative sea level substantially vary because of biophysical and geological processes such as vertical land movements and changes in ocean circulation patterns. Human activities such as extraction of groundwater or oil, mining, and changes

in sediment supply from rivers due to dam building also influence local relative sea level. These activities are more relevant to SLR than global climate change in some areas (Ericson et al. 2006). Densely populated deltas are particularly vulnerable to such activities due to their geological nature (Hinkel et al. 2014). Human-induced local relative changes in sea level can therefore be a key source of uncertainty about the risks coastal areas face (ibid.).

BOX: SLOW-ONSET PROCESSES IN IPCC REPORTS

Unlike extreme weather events, slow-onset processes as a category are not defined in IPCC reports. A comparison of different reports finds a variety of slow-onset-related terminology. The terms, however, are not used consistently

throughout the reports and are often used without a description of types of processes grouped under them. The following table summarises the varying terminology used in relevant IPCC Reports and Special Reports since 2007.

Table 2: Slow-onset-related terminology used in relevant IPCC reports since 2007

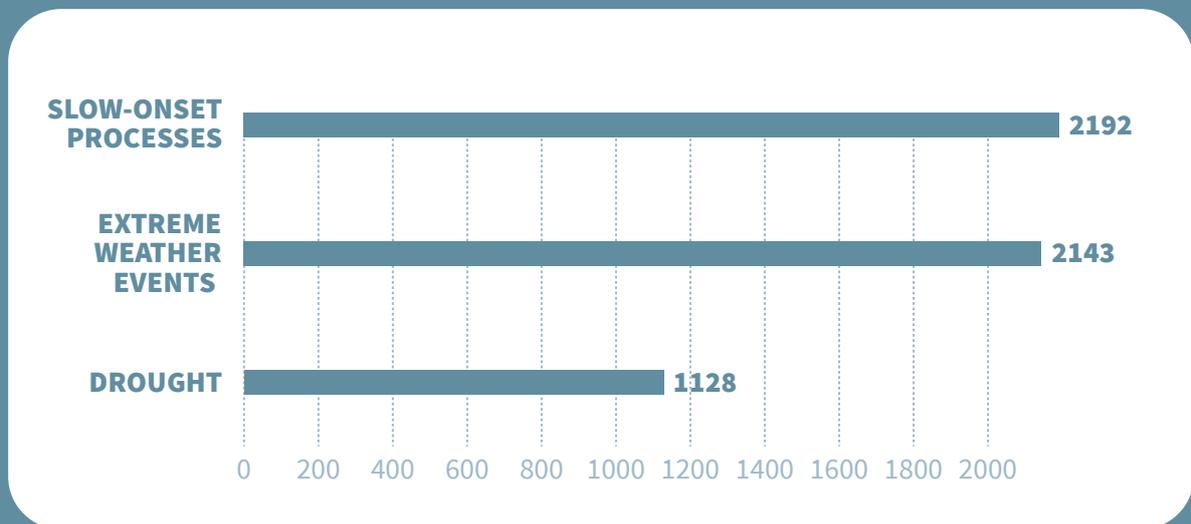
| Term | Types of processes described under term | IPCC Report |
|--|--|---|
| Slow-onset processes | Ocean changes, sea level rise, glacier retreat, mountain and polar cryosphere changes, as well as ocean acidification | SROCC, p. 88 |
| Slow-onset perils | Sea level rise, drought, and permafrost thaw | AR5, WG II, p. 1445 |
| Slow-onset hazard | Rising temperatures and variability in temperature and water (AR5) Drought, desertification (SREX) | AR5, WG II, p. 115 SREX, p. 80 |
| Slow-onset events/ Slow-onset climate events | Recurrent droughts (AR5, SREX) “(…) slow-onset events may lead to increased displacement, disrupted food chains, threatened livelihoods (high confidence), and contribute to exacerbated stresses for conflict” (SR Land) Term used without description of processes in SRCCL and SR 1.5 | AR5, WG II, p. 809 SR 1.5, p. 67 SRCCL, pp. 16, 513, 755 SREX, p. 88 |
| Slow-onset disaster | Term used without description of processes | AR4, WG II, p. 382 |
| Slow-onset impacts/ Slow onset climate impacts/ Impacts of slow-onset climate change | Changes in precipitation, changes in ecosystems, land degradation, desertification (SR Land) ‘Slow onset climate impacts and risks can exacerbate or otherwise interact with social conflict corresponding with movement at larger scales’ (SR Land) Term used without description of processes in SRCCL | AR5, WG II, pp. 885, 553 SR 1.5, p. 456 SRCCL, p. 690 |
| Slow-onset climate change | Term used without description of processes | SRCCL, p. 513 |
| Slow-onset problems | ‘Climate change is typically viewed as a slow-onset, multigenerational problem’ | SREX, p. 452 |
| Creeping changes | ‘The disaster risk research has paid more attention to sudden-onset hazards and disasters such as floods, storms, tsunamis, etc., and less on the measurement of creeping changes and integrating the issue of tipping points into these assessments (see also Section 3.1.7).’ | SREX, pp. 88, 94 |
| Slow incremental change | Sea level rise | AR4, WG II, p. 798 |

SROCC (IPCC 2019a), SRCCL (IPCC 2019b), SR 1.5 (IPCC 2018), AR5 WG II (2014a+b), SREX (IPCC 2012), AR4, WG II (IPCC 2007)

For this paper, a word analysis was conducted to understand how slow-onset processes are reflected in the IPCC Fifth Assessment Report (WG II: Impacts, Adaptation, and Vulnerability) and the IPCC Special Report Global Warming of 1.5 °C (2018). The first graph shows the total number of mentions of slow-onset processes^[7] compared with that of extreme weather events^[8] and drought as a special case. In the IPCC Fifth

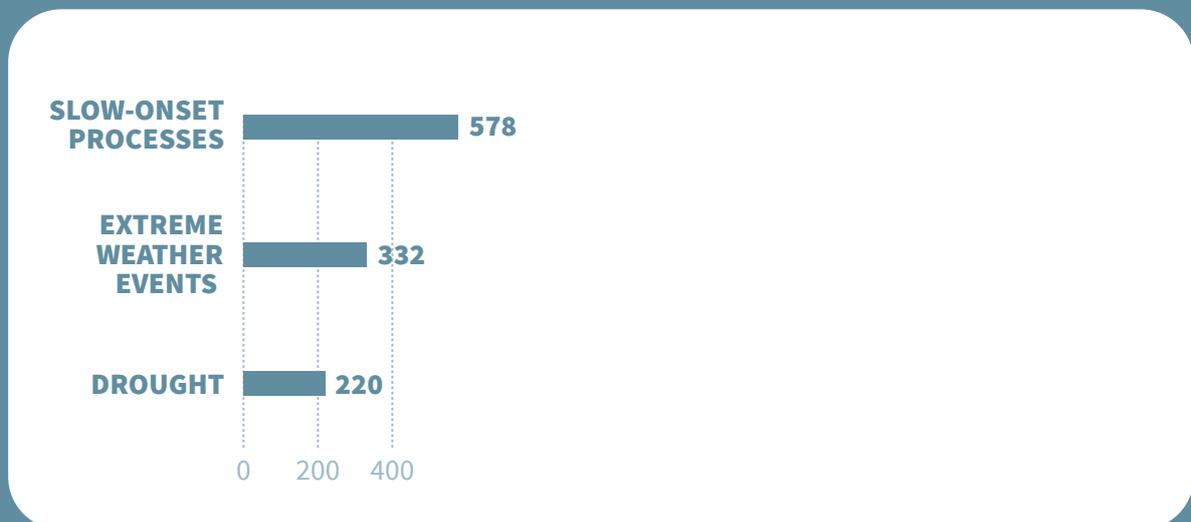
Assessment Report, both types are mentioned at a similar frequency (extreme weather events = 2,143; slow-onset processes = 2,192). In the IPCC Special Report, slow-onset processes (578) are mentioned slightly more often than extreme weather events (332). In comparing these types of events/processes, we must note only four types of extreme weather events are counted, while there are nine types of slow-onset processes.

Figure 4: Total number of mentions of slow-onset processes, extreme weather events, and drought in IPCC AR5, WG II



Source: Author, based on IPCC 2014a and b

Figure 5: Total number of mentions of slow-onset processes, extreme weather events, and drought in IPCC SR 1.5 °C



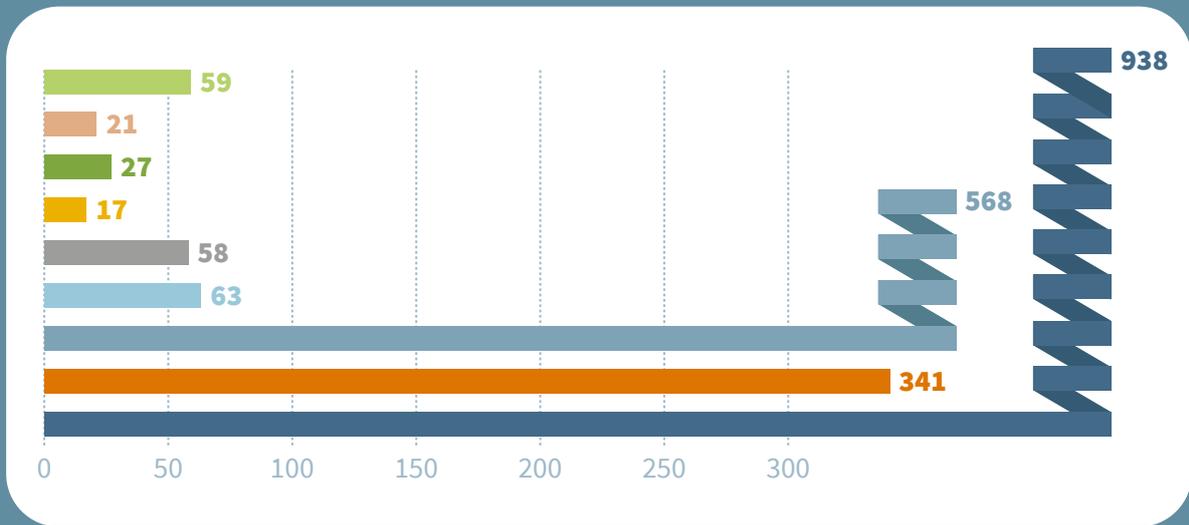
Source: Author, based on IPCC 2018

7, 8 See list of specific processes at the end of this box.

Regarding the number of mentions for specific slow-onset processes, both IPCC reports show a broad coverage of SLR, followed by ocean acidification and/or increasing temperature. All other processes receive minimal mention.

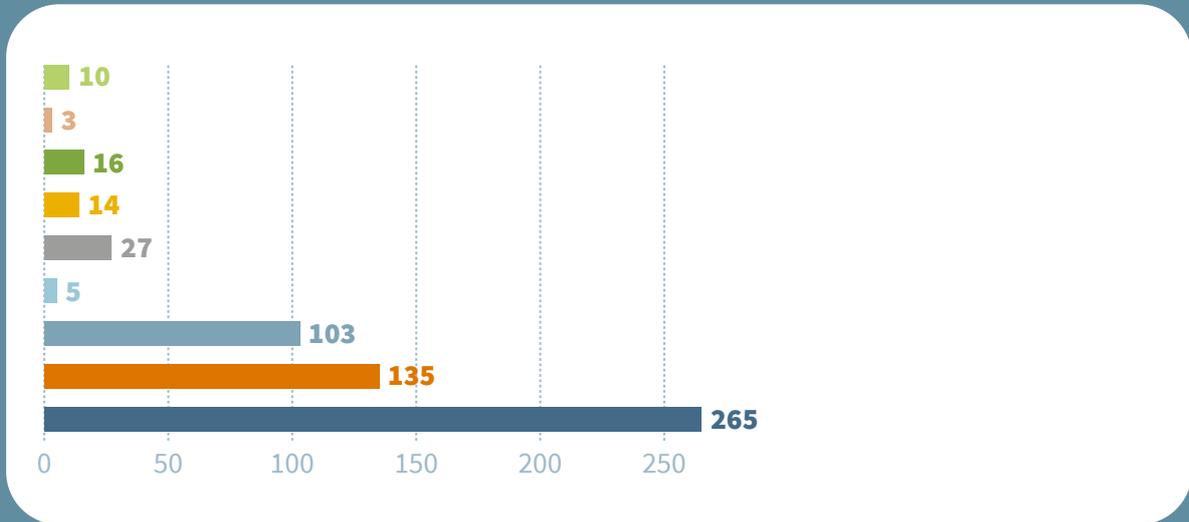
-  **BIODIVERSITY LOSS**
-  **SALINISATION**
-  **LAND AND FOREST DEGRADATION**
-  **DESERTIFICATION**
-  **DEGRADATION OF PERMAFROST**
-  **GLACIAL RETREAT**
-  **OCEAN ACIDIFICATION**
-  **INCREASING TEMPERATURE**
-  **SEA LEVEL RISE**

Figure 6: Mentions of specific slow-onset processes in the IPCC AR5, WG II



Source: Author, based on IPCC 201 a and b

Figure 7: Mentions of specific slow-onset processes in IPCC SR 1.5 °C



Source: Author, based on IPCC 2018

We must note that, since 2019, the IPCC published two reports that particularly address slow-onset processes: the IPCC Special Report on the Ocean and Cryosphere (2019a) and the

Special Report on Climate Change and Land (2019b). A more detailed analysis would be needed to look into what exactly is discussed for the different areas.

REGARDING THE IPCC WORD ANALYSIS

The following terms were used for slow-onset processes and extreme weather events.

SLOW-ONSET PROCESSES

- **Sea level rise** (also: SLR)
- **Increasing temperature** (including temperature increase, temperature rise)
- **Ocean acidification**
- **Glacier retreat** (including glacier shrinkage, glacier melt, glacier mass loss)
- **Permafrost degradation** (including decreases in the extent of permafrost, thawing of permafrost, permafrost thawing, permafrost melting, permafrost loss)
- **Salinisation**

- **Land and forest degradation** (including land degradation, forest degradation)

■ Desertification

- **Biodiversity loss** (including loss of biodiversity)

EXTREME WEATHER EVENTS

- **Tropical cyclones and other extreme storms** (including cyclone, hurricane, typhoon, tropical storm, extreme storm)
- **Heat wave** (including extreme heat [event]), heat event)
- **Floods** (including flooding [not including coastal flooding due to SLR])
- **Heavy rainfall** (including extreme precipitation)

LOSS AND DAMAGE

DUE TO SLOW-ONSET PROCESSES

What is loss and damage?

The impacts of slow-onset processes, such as SLR, can already be felt around the globe. Science clearly shows these impacts will substantially worsen with further global warming (IPCC 2018). While the first and most essential step to avoid future climate change impacts is to effectively reduce greenhouse gas emissions, historical greenhouse gas emissions and locked in investments in fossil fuel industries have already committed us to a certain level of climate impacts. Moreover, not all climate change impacts can be successfully prevented or minimized by adaptation or risk reduction measures, whether because of financial, technical, or physical constraints.^{9]} Hence, climate change will lead to losses and damages induced by slow-onset processes as well as extreme weather events.

9 The IPCC (2014) differentiates between hard adaptation limits (those that will not change, for instance, thresholds in physical systems or exceedance of the physiological capacity of individual organisms or communities to adapt to changes), and soft adaptation limits (which could change over time, for instance, economics, technology, infrastructure, laws and regulations, or broader social and cultural considerations).

With no official definition, this paper understands loss and damage as, “adverse impacts of human-induced climate change that cannot be avoided by mitigation or adaptation, or that will not be avoided in the future by adaptation due to insufficient resources” (Mace/Verheyen 2016: 198). According to Verheyen (2012), there are three types of loss and damage: avoided, unavoided, and unavoidable. This reflects that the extent of loss and damage considerably depends on mitigation and adaptation efforts that can avoid loss and damage, or lead to unavoided loss and damage due to technical, financial, or political constraints and limits. Yet there is also loss and damage that cannot be averted via mitigation or adaptation measures; including loss and damage due to slow-onset processes that have already begun, such as SLR (Schinko et al. 2016).

Loss and damage can be caused by extreme weather events (e.g. typhoons or floods) and slow-onset processes (e.g. glacial melting), as well as events triggered by a combination of the aforementioned (e.g. glacial melting leading to glacial lake outburst floods). This paper focuses on unavoided and unavoidable loss and

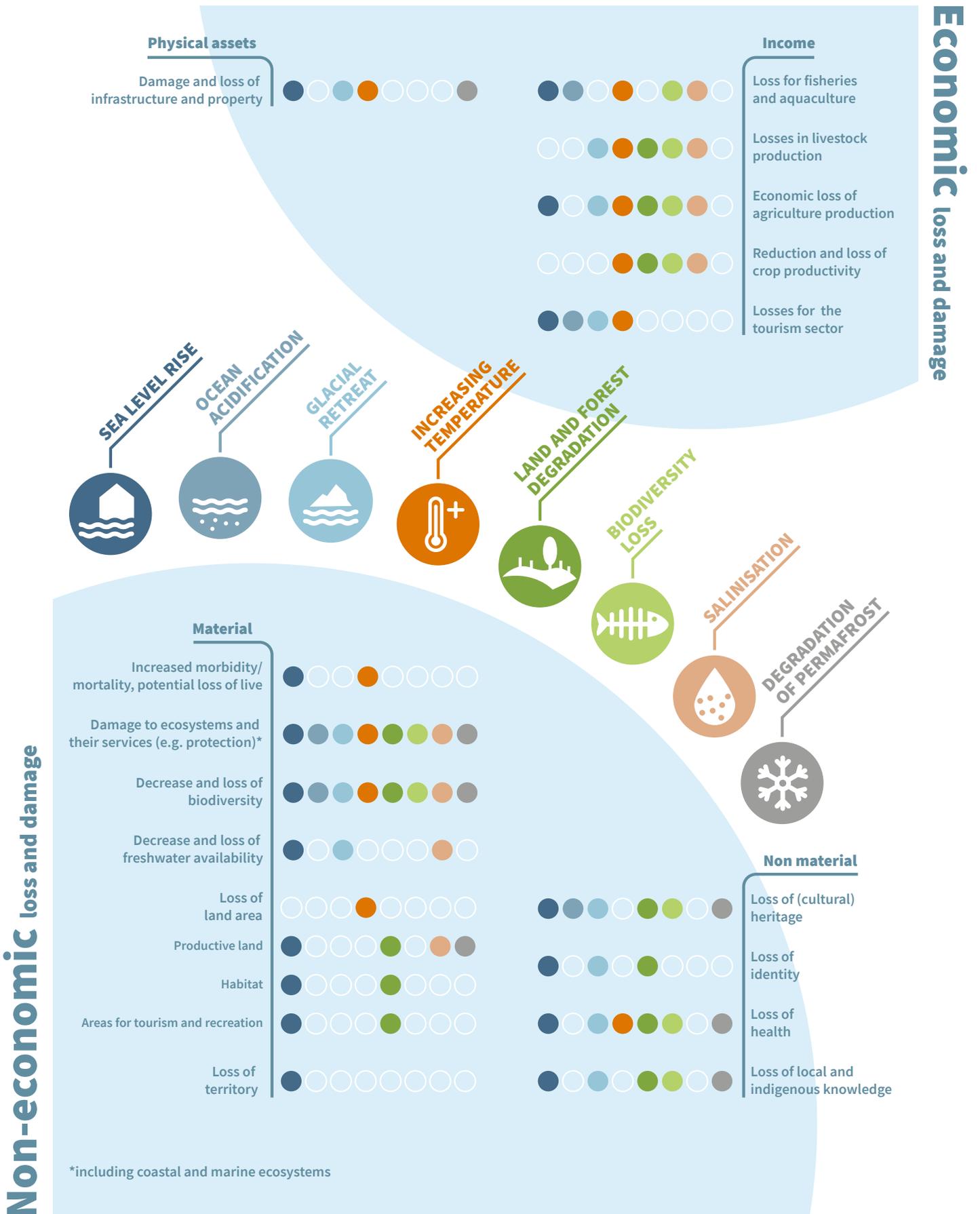
damage due to slow-onset processes. In this context, it must be noted that multiple factors contribute to a specific loss or damage. Besides anthropogenic emissions, natural modes of climate variability, as well as other drivers that influence exposure and vulnerability, need to be considered.

A main distinction can be made between economic and non-economic losses and damages. Climate change hazards cause loss and damage of items (resources, goods, and services) that are commonly traded in markets. Examples include property and infrastructure. Affected people, however, also experience loss of material and non-material items that cannot be traded (Serdeczny 2018). Examples include loss of cultural identity, human health, and lives. Non-economic loss and damage can take material (e.g. lives, biodiversity, and territory) and non-material (e.g. identity and physical and mental health) forms (Morrissey/Oliver-Smith 2013). For this paper, we differentiate between economic loss (including [a] physical assets and [b] income) and non-economic loss (including [a] material and [b] non-material forms).

What losses and damages can result from slow-onset processes?

Slow-onset process will cause a wide range of economic and non-economic losses and damages. The following figure is based on a literature review conducted for this paper. It provides a comprehensive overview of the potential losses and damages resulting from the slow-onset processes including increasing mean temperatures, SLR, ocean acidification, glacier retreat, permafrost degradation, salinisation, land and forest degradation, desertification, and biodiversity loss. Annex 1 gives details specific loss and damage for each slow-onset process.

Figure 8: Overview of loss and damage due to slow-onset processes



Source: Author – see Annex for full list of literature

The figure makes no claim of completeness and although it is based on an extensive literature review, slow-onset processes might lead to loss and damage not yet covered by research; thus no scientific evidence is yet available. Based on the current status quo of research on slow-onset processes and resulting loss and damage, the figure shows:

- different slow-onset processes cause a high number of different losses and damages – economic and non-economic types
- the different slow-onset processes analysed cause a higher number of non-economic than economic losses and damages
- the interlinked and mutually enforcing nature of different slow-onset processes, in that all slow-onset processes lead to a damage and/or loss of ecosystems and their services, leading to a decrease and loss of biodiversity
- sea level rise and land and forest degradation lead to the highest number of losses and damages

Research alludes to the fact that, similar to rapid-onset events, slow-onset processes and resulting losses and damages particularly affect vulnerable people in countries of the Global South (Warner/van der Geest 2013, Zorn 2018). These people are more vulnerable to the damaging effects of hazards (because, for instance, their livelihood depends on fewer assets, their consumption is closer to subsistence levels) yet they have lower coping capacity (because, for instance, they cannot rely on savings to buffer the impacts and may need more time to rebuild and recover). This is also partially due to the fact that slow-onset processes, as well as climate-related rapid-onset events, and related hazards perpetuate collective and individual vulnerabilities (UNU 2017:37). These processes exert continual pressure on people and their livelihoods, so that even less-severe events can propel them more quickly into a situation of acute humanitarian need. If livelihoods are not restored or strengthened through recovery and development activities, smaller hazards can overwhelm households, resulting in a vicious cycle and manifested slow-onset disasters (OCHA 2011). For SLR and drought (the latter of which we do not classify as a

slow-onset process), Birkmann and Welle (2015) show that, owing to societies' higher vulnerability and low adaptive capacities, an overwhelming majority, 90 %, of low-income countries face a high or very high risk of loss and damage due to slow-onset processes, while only 5 % of high-income countries face such risks.

Slow-onset processes can hinder enjoyment of internationally guaranteed human rights, such as adequate food, water, health, and housing, as well as the right of self-determination and to take part in cultural life and enjoy one's culture. Hindrance comes in ways such as loss of land, which particularly harms indigenous communities (HRC 2018: 16). Consequently, slow-onset processes put those already in vulnerable situations at the greatest risk of suffering human rights harms as a result of the process' adverse effects (HRC 2018: 17).

Slow-onset processes and the losses and damages they cause can be drivers of human mobility. Migration as an adaptation strategy or way of dealing with loss and damage, however, can lead to further non-economic losses, such as loss of culture and traditions, language, social networks, identity and community cohesion (Campbell/Warrick 2014). Climate change is by now recognised as a key driver of human mobility (e.g. 2016 United Nations Summit for Refugees and Migrants, Global Compact on Migration, Global Compact for Refugees, and UNFCCC Task Force for Displacement). This applies to both rapid-onset events and slow-onset processes. There is, however, still a knowledge gap regarding climate change's direct influence on human mobility. We must note that migration is a multi-causal phenomenon and the impacts of SLR or extreme weather events are only some of the many factors relevant in households' or individuals' decisions to move (Stapelton et al. 2017). A limit for voluntary individual or collective decisions to migrate is, however, reached when a place or country becomes uninhabitable, such as when rising sea levels necessitate it. A recent review (Kaczan/Orgill-Meyer 2020: 283) found that regarding elevated temperatures and drought (which we do not classify as a slow-onset processes), "slow-onset climate changes are more likely to induce increased migration than rapid-onset

changes”. Kaczan and Orgill-Meyer (2020) suspect the different impacts of the events on households capabilities needed for migration as reasons for this difference between rapid-onset events and slow-onset processes. While floods quickly deplete households’ capabilities, including resources for costly migration, slow-onset processes creates an “adjustment period” (ibid.: 284) allowing households to make a decision over the best mix of adaptation strategies and gather resources as precondition for migration activities. We must also note that, compared with rapid-onset events, which now primarily cause short-term migration for escaping impacts of extreme weather events^[10], slow-onset process will primarily lead to households’ and individuals’ permanent relocation.

Despite this substantial difference, research on migration has focused on rapid-onset events and disasters (Kaczan/Orgill-Meyer 2020). This also leads to a gap in tracking the number of people who have moved in response to slow-onset processes and their impacts, as no global dataset is available. A World Bank report projects that without effective climate and development action, in Sub-Saharan Africa, South Asia, and Latin America, 143 million people – 2.8 % of these regions’ population – could be forced to move by 2050 to “escape the slow-onset impacts of climate change” (Rigaud et al. 2017: xix). These figures reflect internal migration flows and the general recognition that climate-induced migration usually occurs within countries (Kaczan/Orgill-Meyer 2020).

Dealing with climate- and environment-related flight and migration under international law is not easy. This is especially true because climate and environmental change can rarely be identified as specific reasons for displacement. The Geneva Refugee Convention, the foundation of international refugee law, only protects against discriminatory

persecution. Refugee status is not accorded to people displaced because of climate change impacts. Although some Pacific Islanders seeking protection have been granted legal residence, this has not been done without recognising climate change as a decisive reason for displacement (Künzel/Wirsching 2017). The Nansen Initiative, which has been working for three years on transboundary environmental and climate-related displacement in the context of severe weather disasters as part of a voluntary government consultation process, has identified a large number of potential protections under international law. Using them to a greater extent would contribute to closing the existing protection gap. The political will of the potential host countries is, however, lacking (ibid.).

What losses and damages can result from sea level rise?

Coastal locations have always had many advantages for people, yet at the same time they pose a danger to people and assets because of coastal hazards such as storm surges. Climate change-induced SLR acts as a risk multiplier for existing coastal hazards. As the risks posed by SLR increase, so will the associated economic and non-economic losses and damages. A literature review for this paper identified different coastal hazards and types of loss and damage due to SLR. Table 4 summarises the results in a simplified overview aimed at listing the relevant losses and damages. We note that besides the hazard, exposure and vulnerability are key determinants of impacts. Non-climate anthropogenic factors (e.g. human-induced ecosystem degradation) are an additional driver of impacts (see IPCC 2019a). A presentation of the chain of effects for SLR, including these additional factors, is on page 13.

10 We note that this might change in the future with increasing frequency, intensity, and duration of extreme weather events.

Table 3: Loss and damage from sea level rise

Sources: Author, based on information from IPCC 2019a; IPCC 2018

¹¹ Submergence and flooding can be permanent or temporary. They are temporary through increased frequency of ESL events (more extreme water levels), such as caused by extreme wave heights. Local sea levels that historically occurred once per century (historical centennial events) are projected to occur at least annually in most locations by 2100, and by 2050 in low-lying megacities and small islands. Mean sea level rise projections under RCP8.5 are likely to extend beyond 1 m in 2100 because of a larger projected ice loss from the Antarctic Ice Sheet (IPCC 2019a: 20).

Table 3 clearly shows the wide range of economic and non-economic loss and damage caused by SLR and associated coastal hazards, and which will affect millions of people. Nearly 10 % of the global population (around 680 million people) is living in low-lying coastal zones (with more than 1 billion projected by 2050) (IPCC 2019a). By 2050, sea level rise will threaten 300 million people living in low-lying coastal areas as they live on land below projected annual flood levels (Kulp/Strauss 2019). Despite this, not all regions are equally exposed and vulnerable to SLR's impacts. Dasgupta et al. (2007) identified Brunei, Cambodia, China, Indonesia, North Korea, South Korea, Malaysia, Myanmar, Papua New Guinea, the Philippines, Thailand, and Vietnam as countries where the 'impact of sea level rise will be particularly severe.' That study estimates that a 1-m SLR would lead to approximately 74,000 km² at risk of permanent inundation, and displacement of 37 million people in the 12 countries. Other studies also include India, Bangladesh, and Nigeria as countries particularly vulnerable to SLR, as they are among the countries with the largest populations living in low-elevation coastal zones (LECZ) and the 100-year floodplain (Neumann et al. 2015).

The different economic and non-economic losses and damages resulting from SLR are detailed below.

Economic loss and damage

A recent study (Schinko et al. 2020) notes that global economic losses from coastal flooding due to SLR can amount to > 4 % of world GDP (in RCP45-SLR) without further adaptation and assuming high ice melting. SLR particularly affects economic growth and welfare through loss of land, loss of infrastructure and physical capital, loss of social capital, and additional costs from extreme events, as well as an increase in expenditure for coastal protection (Hallegatte 2012). Besides 'construction' and 'energy intensive industries,' 'agriculture' is one of the economic sectors particularly hit by SLR (Schinko et al. 2020).

The sector is mainly affected by land submergence, salinisation of soil and fresh groundwater resources, and land loss due to permanent coastal erosion.

Decreased agricultural production owing to these processes is already visible for rice, oilseed, sugarcane, and jute (IPCC 2019a). This has consequences on production, livelihood diversification, and food security, particularly in coastal agriculture-dependent countries such as Bangladesh (Khanom 2016). Also already visible are the negative effects of SLR on fisheries and aquaculture that are caused through adverse impacts on habitats (e.g. coral reef degradation, reduced water quality in deltas and estuarine environments, and soil salinisation) and facilities (e.g. harbour damage) (IPCC 2019a). Two additional areas prominently mentioned in the IPCC Special Report on the Ocean and Cryosphere (2019a) are damage to infrastructure and property (e.g. damage to coastal protection works, public facilities, harbours, airports, and housing) along with losses for the tourism sector via SLR's impact on landscapes (beaches) cultural features, and critical transportation functions such as harbours and airports, and tourism facilities (e.g. hotels).

Non-economic loss and damage

Non-economic loss and damage due to SLR is even more diverse. It includes that for coastal and marine ecosystems and their services because of habitat contraction and the loss of plant and animal species (e.g. mangroves, sea grasses, salt marshes, and hatcheries), leading to lost functionality of these ecosystems (IPCC 2019a). These impacts are "exacerbated by direct human disturbances, and where anthropogenic barriers prevent landward shift of marshes and mangroves (termed coastal squeeze)" (IPCC 2019a: 13).

Coastal ecosystems are vital for protecting coastlines from storms and erosion, and are important carbon stores. Nearly 50 % of coastal wetlands, however, have been lost over the last 100 years as a result of the combined effects of localised human pressures, SLR, warming, and extreme climate events (IPCC 2019a). Particularly impacted are SIDS where over 80 % of the population lives near the coast. Based on current greenhouse gas emissions, researchers assume most atolls will become uninhabitable before the mid-21st century (e.g. Roi-Namur in the Marshall Islands) (Storlazzi et al. 2018). This particularly owes

to exacerbation of wave-driven flooding by SLR, compromising soil fertility and the integrity of freshwater lenses (ibid.). Kiribati, which is composed entirely of atolls, is one of the states at risk of being entirely inundated by the century's end (Boncour/Burson 2010). Already, well before the islands are completely submerged, SLR impacts are increasing socio-economic and environmental problems, and threaten to render Kiribati uninhabitable.

SLR's impacts on marine ecosystems and their services "put key cultural dimensions of lives and livelihoods at risk" (IPCC 2019a: 26). This includes loss of culture as well as local and indigenous knowledge, and impacts on food security (e.g. through loss of a source of calories – fish proteins). Graham et al. (2013) identified five social values specifically at risk from SLR: health, feeling of safety, belongingness, self-esteem, and self-actualisation. This also includes loss of connection, community, and/or sense of place as a consequence of migration as well as changing landscapes.

Migration and displacement

Many of the losses and damages SLR causes have high potential for leading to displacement of large parts of the population. Migration and displacement are already occurring (see section 4 with examples from Senegal). Moreover, rapid population growth in many coastal settlements will cause the number of people at risk will further increase in the future (McLeman 2018). Permanent inundation of areas, making land uninhabitable and unavailable for livelihoods, is the key factor behind migration patterns, yet there are also hazards, and losses and damages, associated with SLR (ibid.). Saltwater intrusion, coastal flooding, and erosion can contribute to destroying coastal agriculture and drinking water supply (ibid.). SLR also negatively impacts livelihoods that depend on coastal ecosystem services – including tourism, fisheries, and coastal aquaculture – and thus has adverse impacts on job security and indirectly pressures migration (ibid.). Also noteworthy is that migration from SLR is multicausal and also influenced by political, economic, social, and demographic factors (Hauer et al. 2020).

Estimating SLR-inflicted human displacement is challenging, as it considerably depends on emission pathways, adaptation measures, and other factors that drive migration. Estimates therefore vary substantially. These are often based on the number of people living in the LECZ or the 100-year floodplain. The LECZ is a contiguous zone of land along the coast worldwide, and that is <10 m above sea level. By 2000, 10.9 % (625,000,000) of the world's population lived in this area, with the majority (83 %) of the global LECZ population living in developing countries (Neumann et al. 2015). By 2060 it could be inhabited by 12 % of the world's population (1.4 billion) under high rates of population growth (ibid.). By 2050, sea level rise will threaten 300 million people living in low-lying coastal areas (Kulp/Strauss 2019). By 2100, up to 4,6 % of the global population are estimated to be flooded annually because of rising sea levels, without adequate adaptation (Hinkel et al. 2014). For Bangladesh, a country highly impacted by and vulnerable to SLR, Davis et al. (2018) estimated that direct inundation could displace 0.9 million people (by year 2050) to 2.1 million people (by year 2100) could be displaced by direct inundation. They note that almost all of this movement will occur locally within the southern half of the country, and not internationally.

Based on these estimates, SLR poses a substantial threat to people's entitlements, such as the right to self-determination (HRC 2018). People become forced to migrate if land is lost because of rising sea level. Considering that states such as Kiribati and Tuvalu already face the threat of disappearance, slow-onset processes' implication for statehood and sovereignty of territory are also important. In this context, Article 1 of the Montevideo Convention establishes that any entity must meet four requirements to be acknowledged as a state: permanent population, defined territory, effective government, and the capacity to enter into relations with other states (Montevideo 1993). Based on these criteria, SIDS, among others, will lose their statehood as their territories and lands are submerged. Since no international law exists concerning involuntary state extinction, this has strong potential to lead to severe loss and damage for entire

populations that become stateless in such a case. Additionally, long before states' territories submerge, international law indicates they could very likely lose their exclusive economic zones (Powers 2012, Sefrioui 2017), which is the zone where coastal nations have jurisdiction over natural resources (e.g. it allows countries to regulate the natural resources in the water, which greatly impacts whether countries can regulate fish stocks within their 'boundaries'). The United Nations Convention on the Law of the Sea

(UNCLOS) implies that States only have these exclusive economic rights in an area that extends ≤ 200 nautical miles from their coastlines (Articles 56 and 57 UNCLOS). UNCLOS Article 121(3) further provides that '[r]ocks which cannot sustain human habitation or economic life of their own shall have no exclusive economic zone or continental shelf.' This regulation leaves room for interpretation, but could mean the loss of a state's economic entitlements, even before it becomes uninhabitable.

LOSS AND DAMAGE IN SENEGAL DUE TO SEA LEVEL RISE

Senegal, listed among the lower middle income countries group, in 2019 had per-capita GDP of US \$23.578 trillion.^[12] Although the country has seen development progress in recent years, nearly 70 % of Senegalese live in multidimensional poverty (Zamudia/Terto 2016). Moreover, the country's economy largely depends on climate-sensitive sectors, including agriculture, livestock, and fisheries (ibid.). These factors combined increase Senegal's climate change vulnerability. In the Notre Dame Global Adaptation Index, Senegal is ranked among the countries with a high vulnerability score and low readiness score for adaptation actions.^[13] SLR, temperature increase, ocean acidification and related impacts, salinisation, land and forest degradation, biodiversity loss, and desertification are the key slow-onset processes observed in the country. The following focuses on the impacts of SLR in Senegal.

Senegal is particularly vulnerable to coastal hazards. It is a coastal country, with 531 km of mainly sandy and

12 <https://data.worldbank.org/country/senegal>

13 <https://gain-new.crc.nd.edu/country/senegal>

low-lying coastline. Most of the country's population (60 %) is concentrated in its littoral, which contributes up to 68 % to GDP (DEEC 2020). The country is also situated in the West Africa Sahelian bioclimatic domain, which is characterised by its high temperature and its precipitation variability. Senegal's particular vulnerability owes to its geographical location, which exposes it to slow-moving hazards and to fragility of its coasts in the face of the erosive power associated with SLR. The predominantly sandy nature and low altitude of most of its long coastline directly expose it to the actions of several climatic hazards. Coastal erosion, inundation, extreme swell events, and soil and water salinisation pose significant threats (World Bank 2018). Low coastal topography, strong waves and winds, and weak soils are among the natural causes of erosion. However, human activities such as sand mining, rapid population growth, and unplanned development have exacerbated risk to coastal population, infrastructure, and ecosystems (ibid.). The coastal zone is the country's main socioeconomic driver, as it hosts 80 % of economic activities (horticulture, seaside tourism, fishing, services) and is home to diverse ecosystems providing vital services upon which local economies are highly dependent (USAID 2017). Coastal infrastructure, including 74 % of housing, is at risk from SLR-induced coastal erosion and inundation. Rapid erosion (due to both the climate and human activities) affects almost every major coastal town in Senegal, leading to losses of physical and financial assets (ibid.).

SLR is projected to be as high as 1 m by the end of the 21st century, which could result in the disappearance of 55–86 km² of the country's beaches, and flood 6,000 km² of low-lying areas (World Bank 2018). By 2080, an estimated 75 % of the shoreline could become at high risk of erosion because of SLR, which has already been substantial over the recent decades. Sand extraction and beach-top urbanisation, however, accelerate erosion phenomena (Government of Senegal and World Bank 2013). Recent simulations show Senegal may lose up to 8 % of its GDP by 2030 because of climate change effects (World Bank 2018). The bottom 40 % is likely to be most affected, with its incomes reduced by > 9 %

(ibid.). The coastal area is characterised by low-lying, rapidly expanding, and high-population suburbs, high water tables, and poorly planned drainage systems. Even small amounts of rain can flood entire neighbourhoods. In addition to extreme events, rising sea levels place much of the coastal population, infrastructure, and ecosystems at risk of flooding and erosion (USAID 2017). Researchers estimate that SLR could lead to displacement of more than 100,000 people (Niang et al. 2010).

Tourism and fisheries are two sectors particularly impacted by SLR. In Senegal, fisheries employ 17 % of the labour force, contribute 2.5 % of the GDP, and supply a main source of animal protein in the Senegalese diet (USAID 2017). Fisheries, already stressed from overfishing, are expected to be negatively impacted by climate change, as rising surface water temperatures and ocean acidification alter species reproduction and migration (ibid.). This, in turn, affects biodiversity and livelihoods, incomes, and nutrition that depend on fisheries (ibid.). Most of the country's tourism infrastructure lies along the Petite Côte, which already faces the impacts of erosion, losing 1–2 m of sandy beachfront a year. Rising sea levels threaten shallow coastal groundwater sources through increased salinisation. In summary, SLR's key impacts on Senegal are (based on USAID 2012):

- Damage/erosion of human settlements, infrastructure, industry, natural features, and beaches
- Salinisation of soil, coastal aquifers, and other groundwater and surface water sources
- Flooding of low-lying coastal areas
- Loss of coastal wetlands, lagoons, mangroves, and other coastal habitats
- Higher risk of pollution from coastal hazardous waste sites
- Higher cost of maintenance and expansion of coastal erosion controls
- Changes in the structure and composition of marine communities

Already, the impacts of SLR are particularly visible in several areas along the Senegalese coastline, such as Saint-Louis, Bargny, Saly, and Palmarin Niodior. Studies have revealed that average retreat rates of the shoreline between Mbao and Bargny in 1954–2006 ranged 0.41–1.51 m/year (UEMOA 2010). At Palmarin, the sea level has advanced by several dozen metres over the last four decades (ENDA Energy 2016). Destruction of residential and hotel infrastructure, ecosystems, and cultural sites, such as in Palmarin, are among the major effects of this sea advance. In 10 years, in the Guet Ndar district on the Langue de Barbarie, nearly 800 m of coastline has disappeared. Erosion and marine submersion have now destroyed or directly threatened all the dwellings along the beach. These neighbourhoods' populations are therefore in extremely precarious situations (AFD 2018). In the framework of a study on vulnerability to climate change, conducted in Palmarin and Niodior in 2014–2015, ENDA Energie had a discussion with Buuba, a Palmarin resident, on the losses and damages caused by climate risks. The following is Buuba's story on slow-onset hazards' biophysical and economic impacts.

'The sea's advance entered its active phase, in Palmarin, really from 1992. (...) I recorded the loss of two buildings with eight bedrooms, one kitchens and bathrooms and toilets, now occupied by the sea. The whole is estimated US \$25,000 to 33,300. I also lost personal assets: beds, chairs, utensils, two agricultural and carpentry machines. In terms of working days in agriculture and fishing due to weather extremes, the estimated working days lost is ten, which is estimated at US \$4,900. The increase in saltwater intrusion has led to a loss of 12 ha of my arable land, a drop in household yields estimated at 25 %, food insecurity in millet and rice and a lack of financial resources to support the costs of education, health, etc.' (ENDA Energy 2016).

The advancing sea's effects have also been observed on the economy, as fishermen's incomes have fallen following the destruction of landing sites (ENDA Energy 2016). This has led to migration of fishermen to other parts of the country or abroad, through clandestine emigration (ibid.).

The effects of sea level mixed with other anthropogenic factors are well illustrated by the example of the historic city of Saint-Louis, a registered UNESCO World Heritage Site. Over time, the city has progressively encroached upon the Langue de Barbarie, resulting in both populations settling in high-risk areas and reducing the sand dunes' natural protective barrier functions (World Bank 2018). The city is highly vulnerable to rising sea because nowhere within it is higher than 4 m above sea level (Ahedor 2019). UN-Habitat has called Saint-Louis the city most threatened by rising sea levels in all of Africa (BBC 2008). Rising tides have led to serious coastal erosion and forced schools, mosques, and hundreds of houses to be evacuated. Seawater has decimated crops that once thrived on the freshwater flow from the Senegal River (Ahedor 2019). The city experiences frequent extreme storm surges, which have displaced a number of families because of extensive flooding and coastal erosion along the Langue de Barbarie. The most recent and notable events that caused widespread damage took place in August 2017 and February 2018. Several houses located along the shoreline, as well as households and livelihood assets, were completely destroyed (World Bank 2018). The August 2017 storm surge displaced 199 families (about 2,000 people). Most of the families involved are currently living in a relief camp at the Khar Yalla site set up by the government, initiated by its emergency response mechanism (ibid.). The location, however, is in a flood-prone area and families in the camp are living in crowded tents with no sanitation services and inadequate access to water, electricity, and transport. It is also expected that more families may lose their homes (ibid.). Some communities on the outskirts of Saint-Louis have already been submerged. Doun Baba Dieye, a fishing community, 'has been wiped off the map, with only the tree and crumbling walls of an abandoned school remaining as

testament to its existence. Everything else is 1.5 metres under water' (Pronczuk 2020). Rare bird species that nest in the area's parkland are threatened and salt-water intrusion killed coconut trees and destroyed allotments of cabbages, manioc, and onions further inland (Yeung 2019). Yeung (2019) reports that 'Labourers can at least harvest the newfound salt reserves, but precious stocks of mullet and sardines that once populated the surrounding mangroves are dying out'. According to a study commissioned by the Senegalese government, 80 % of Saint-Louis territory will be at risk of flooding by 2080, and 150,000 people

will have to relocate. Most of West Africa's coastal cities, home to 105 million people, face a similar threat (Government of Senegal and World Bank 2013).

SLR has also led to salinisation of land and water resources in Senegal, as a result of saltwater intrusion. This situation is more marked in regions such as Fatick, Kaolack (central-western zone), and Ziguinchor (south-western zone), as well as the Niayes zone. The Centre Suivi Ecologique estimated that up to 1,700,000 ha will be affected by salinization (Centre Suivi Ecologique 2003).

OUT LOOK

This first part of the paper series on losses and damages due to slow-onset processes provides detailed explanation on slow-onset processes, their characteristics, and the phenomena that fall under this category. The descriptions are deliberately detailed, as they form the basis for an analysis of possible financial tools and instruments for dealing with loss and damage in specific consideration of these characteristics in the third part of paper series. The analysis conducted for this paper shows that all slow-onset processes cause a high number of varying losses and damages, SLR, and land and forest degradation, leading to the highest number of losses and damages. This includes economic damage to physical assets (e.g. infrastructure and property) or to income (e.g. losses for fisheries and aquaculture, losses in livestock and agriculture production, and losses in tourism). It also includes non-economic loss and damage in its material form (e.g. damage to ecosystems and their services, and loss

of land area or territory) and non-material form (e.g. loss of heritage, identity, health, and local and indigenous culture). In the analysis the selected slow-onset processes caused a higher number of non-economic than economic losses and damages. Slow-onset processes and the losses and damages they cause can be drivers of human mobility. Research also alludes that, similar to slow-onset events, vulnerable people in countries of the Global South are particularly affected by slow-onset processes and their resulting losses and damages.

Based on this analysis, the second paper in this series provides an overview of different approaches and measures to address loss and damage due to slow-onset processes. It also assesses the status quo of addressing such loss and damage at the national and international levels, and analyses gaps and challenges in doing so.

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