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NOTE AND COMMENT

Loss and Damage and limits to adaptation: recent IPCC insights and implications for climate science and policy

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Abstract
Recent evidence shows that climate change is leading to irreversible and existential impacts on vulnerable communities and countries across the globe. Among other effects, this has given rise to public debate and engagement around notions of climate crisis and emergency. The Loss and Damage (L&D) policy debate has emphasized these aspects over the last three decades. Yet, despite institutionalization through an article on L&D by the United Nations Framework Convention on Climate Change (UNFCCC) in the Paris Agreement, the debate has remained vague, particularly with reference to its remit and relationship to adaptation policy and practice. Research has recently made important strides forward in terms of developing a science perspective on L&D. This article reviews insights derived from recent publications by the Intergovernmental Panel on Climate Change (IPCC) and others, and presents the implications for science and policy. Emerging evidence on hard and soft adaptation limits in certain systems, sectors and regions holds the potential to further build momentum for climate policy to live up to the Paris ambition of stringent emission reductions and to increase efforts to support the most vulnerable. L&D policy may want to consider actions to extend soft adaptation limits and spur transformational, that is, non-standard risk management and adaptation, so that limits are not breached. Financial, technical, and legal support would be appropriate for instances where hard limits are transgressed. Research is well positioned to further develop robust evidence on critical and relevant risks at scale in the most vulnerable countries and communities, as well as options to reduce barriers and limits to adaptation.

Keywords Climate risk · Loss and Damage · Limits to adaptation · Transformation

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Introduction: Paris agreement and climate-related risks

The recent Intergovernmental Panel on Climate Change (IPCC) special report on 1.5 °C global warming (SR1.5) (IPCC SR1.5-IPCC 2018) suggests that achieving the 1.5 °C goal as stipulated by the Paris Agreement (UNFCCC 2015) will significantly reduce projected risks and further rises in observed climate change-related impacts compared to current warming of 1.1 °C above pre-industrial global temperature. These risks and anticipated impacts include increases in the frequency and/or intensity of heavy precipitation, high temperature, heatwaves, and sea-level rise, and are expected to lead to continuous and widespread impacts on human, natural, and managed systems. The SR1.5 demonstrates that each (half) degree of warming increases the magnitude of risks from anthropogenic climate change across sectors and regions, and that disadvantaged and vulnerable populations are at disproportionally higher risk from both present and future warming. In principle, the IPCC finds the achievement of the 1.5 °C target possible, even with current mitigation technologies; however, massive upscaling and quick operationalisation are required.

Yet, given omnipresent debates around the climate crisis and emergency, what evidence exists with respect to impacts and risks that may be irreversible, existential, and that already breach adaptation limits – today and in a future world that is warmer by 1.5 °C and more? The SR1.5 (IPCC 2018), additional recent IPCC reports- the Special Reports on Climate Change and Land (SRCCL) and on the Ocean and Cryosphere in a changing climate (SROCC) (IPCC 2019a, b), and other research, including two recently published multi-authored books (Filho and Nalau 2018; Mechler et al. 2018), for the first time summarize such evidence with important implications for research, implementation, and policy, including for the international climate policy debate under the United Nations Framework Convention on Climate Change (UNFCCC) and the Warsaw Mechanism on Loss and Damage associated with Climate Change Impacts (WIM). With the WIM's 2019 review of its achievements carried out and expert groups created to facilitate the move from debate to action, it is timely to review relevant insights from these and other scientific publications and their implications for science and policy.

Loss and Damage—a first time for the IPCC

Over the last three decades, Loss and Damage (L&D)[1] has become increasingly relevant for international climate policy and advocacy. The discourse began during the establishment of the UNFCCC in the early 1990s with a proposal by the Alliance of Small Island States (AOSIS) on compensation and insurance for losses linked to sea-level rise (INC 1991). The subject matter is complex and controversial—some consider it to be about liability and compensation, while others suggest climate risk insurance should be largely ramped up. Hence, it took more than two decades and increasingly robust evidence on climate change impacts and risks, as synthesised by the IPCC (e.g. through the 5th Assessment Report, IPCC 2014) for L&D to be recognised institutionally by the UNFCCC. In 2013, negotiators at the 19th Conference of the Parties (COP19) to the UNFCCC established the WIM (UNFCCC 2013), while at COP21 in 2015, the Paris Agreement generated Article 8, which provided the L&D Mechanism with a permanent legal basis (UNFCCC 2015). Although L&D began as a political concept, multi-faceted scientific research now contributes to an increased understanding of its complexity.

A three-page cross-chapter box in the IPCC SR1.5 on 'Residual Risks, Limits to Adaptation and Loss and Damage' (Roy et al. 2018) marks the first time that the IPCC reviews the scientific literature on L&D. Originally not considered in the outline, inclusion into the report was advocated for half-way through the process by some IPCC member countries spurred by advances in the physical and social sciences, as well as growing scientific evidence regarding increasing climate-related impacts. This heightened attention builds on a socially engaged science of losses and damages that assesses what people in various geographic and cultural contexts value and to what extent climate change puts these life aspects at risk (Barnett et al. 2016). Among others, the two multi-authored review volumes mentioned above and a number of other papers (e.g., McNamara and Jackson 2018) published almost concurrently with the SR1.5, highlight the state-of-the-art in research and practice on L&D across multiple disciplines, provide insight into policy contexts and salient policy options, and present evidence on limits to adaptation and adaptive capacities across the globe.

Views on L&D vary widely with some convergence

The SR1.5 synthesizes L&D aspects that so far, have been controversial as well as some that are now relatively widely accepted. There is consensus that L&D refers to adverse climate-related impacts and risks from both sudden-onset events, such as floods and cyclones, and slower-onset processes, including droughts, sea-level rise, glacial retreat, and desertification. Impacts and risks have been discussed predominantly with a view towards vulnerable developing countries, and have been considered to include both economic (e.g., loss of assets and crops) and

[1] A distinction made here and elsewhere is to distinguish between capitalised letter *Loss and Damage* to refer to political debate vs. lowercase letter *losses and damages* to broadly relate to (observed) impacts and (projected) risks (see Mechler et al. 2018).

non-economic types (e.g., loss of biodiversity, heritage, and health). At the same time, in the L&D debate under the WIM, it remains controversial to what degree losses and damages would need to be rigorously attributable to anthropogenic climate change, or whether all climate-related risks are to be reckoned with to be considered relevant under the WIM. The policy-remit of L&D, and its distinct nature from adaptation policy and practice, has remained particularly contested, mainly along two lines of inquiry: What to consider? Only today's impacts, future risks, or both; and what the scope and potential for avoiding impacts and risks may be (James et al. 2018).

Some analysts and stakeholders have suggested that the WIM should deal with liability for unavoided impacts that are already manifest today, suggesting that North–South financial compensation is to follow (Verheyen and Roderick 2008; Roberts and Huq 2015). Others have argued that the debate should focus primarily on drawing attention to future unavoidable losses and existential risks (Hoffmaister et al. 2014; Roberts and Pelling 2018). Still others claim that donor-supported insurance for significant residual impacts will help to avoid and manage future risks in vulnerable communities and countries (Boyd et al. 2017; Mechler 2017; Linnerooth-Bayer et al. 2019). Given these competing perspectives and, as some would argue (Lees 2017; Calliari et al. 2019), deliberate policy ambiguity, it is not entirely surprising that the UNFCCC has not yet put forward an official definition of L&D. Thus, the policy space for L&D with all its policy and financial implications remains somewhat vacant. The SR1.5 synthesis presents the first, albeit partial, assessment of the evidence that relates L&D to residual (after adaptation) climate-related risks and limits to adaptation. This provides the basis for understanding, on the one hand, unavoided and unavoidable climate-related losses and damages and, on the other hand, the scope for avoiding and reducing future risks.

Emerging evidence on residual risks and soft and hard adaptation limits

IPCC's 5th Assessment Report (AR5) recognizes important biophysical, institutional, financial, social, and cultural barriers to adaptation, which, particularly when compounded, can lead to soft and hard adaptation limits. The IPCC definition considers *hard limits* to occur when adaptive actions become infeasible to avoid risks, and hence impacts and risks become unavoidable. *Soft limits* arise when technological and socioeconomic options are not immediately available to avoid risks through adaptive action, meaning that impacts and risks remain unavoided for the moment (Dow et al. 2013; Klein et al. 2014).

The SR1.5 builds on these definitions of (future) adaptation limits to, for the first time, assess evidence on soft and hard adaptation limits as identified in the report for systems, sectors and regions, as well as impacts and risks under 1.5 °C and 2 °C of global warming (Roy et al. 2018). For hard limits, the report provides robust evidence with respect to natural systems, including the projected irreversible loss of up to 90% of tropical coral reefs by mid-century under 1.5 °C warming (and nearly total loss under the 2 °C scenario); many irreversible losses of biodiversity; and sea-level rise combined with increased aridity and decreased freshwater availability rendering several small atoll islands uninhabitable (IPCC 2018). Examples of soft limits identified in the SR 1.5 include populations driven into poverty traps due to climate-induced shocks, heatwaves affecting megacity dwellers, and coastal livelihoods rendered unsustainable in low-lying islands and along coastlines. Depending on the context, some soft limits may become hard limits if exposed populations have no means and space to move, which is particularly the case when intangible types of harm are considered. Table 1 below synthesizes evidence reported across the SR1.5 and presents types of limits (natural, technological, and socioeconomic) with further information on key risks, regions, impacts at (current) 1.1 °C, 1.5 °C, and 2 °C warming levels, as well as the scope for anticipated adaptation actions.

Finally, the SR1.5 documents proposed approaches and policy options to address residual risk and L&D. It assesses a growing body of legal literature and litigation, concluding that "litigation risks for governments and businesses are bound to increase with an improved understanding of impacts and risks as climate science evolves (*high confidence*)" (Roy et al. 2018 p. 456). The report also lists a selection of policy options that are being considered or implemented, including international support for experienced losses and damages; support for addressing climate-induced displacement; and donor-supported implementation of regional public insurance systems. The Summary for Policymakers, which is the synthesis and most policy-relevant part of any IPCC report, does not mention L&D explicitly; it does, however, identify "limits to adaptation and adaptive capacity for some human and natural systems at global warming of 1.5 °C with associated losses (*medium confidence*)" (IPCC 2018 p. 12). In addition, the assessment finds risks of irreversible loss of marine and coastal ecosystems to become more pronounced with increasing warming with an uncertainty statement of high confidence.

IPCC's SRCCL and SROCC assessments published in 2019 also report on Loss and Damage, adaptation limits, and transformation (IPCC 2019a, b). For instance, the SROCC suggests that climate change-driven ocean and cryosphere

Table. 1 Evidence on climate-related risks, adaptation, and limits synthesized from the IPCC's SR1.5

System/sector (RFC*)	Regions	1.1 °C (current warming)	1.5 °C	2 °C	Adaptation options	Scope for adaptation-type of limit (system)
Coral reefs (1)	Tropics	50% Loss	70–90% Loss	99% Loss	Artificial reefs, water clean-up	Very limited Hard limit (natural)
Terrestrial and wetland ecosystems (1)	Global	Species ranges have started to shift to track climate space (no estimate)	Climatically determined geographic range losses: 6% of insects, 8% of plants, 4% of vertebrates lose over 50% of their ranges	18% of insects, 16% of plants and 8% of vertebrates with range losses of over 50%	Water and vegetation management, increased connectivity	Limited Hard limit (natural)
Human health (2, 3, 4)	Global, part. tropics	No estimate	+350 million people exposed to deadly heatwaves in megacities by 2050	Annual occurrence of heat-waves similar to deadly 2015 heat-waves in India and Pakistan	Hydration, cooling zones, green roofs	Medium—low in tropics. Soft and hard limit (e.g. for outdoor work) (technological)
Coastal livelihoods and islands (2, 3)	Global, Asia, SIDS in Pacific and Caribbean	No estimate	31–69 million people at risk. Sea level rise and increased wave run up, increased aridity and decreased freshwater availability leave several atoll islands uninhabitable	32–79 million people at risk	Coastal defences, ecosystem-based adaptation, reef restoration	Low-medium Soft and hard limit (technological, socio-economic)

Source: Hoegh-Guldberg et al. (2018); de Coninck et al. (2018); Roy et al. (2018)

*RFC (IPCC Reason for Concern)[2]: 1 = unique and threatened systems, 2 = extreme events, 3 = unequal distribution of impacts, 4 = global aggregate impacts (economic + biodiversity), 5 = large scale singular events. For current warming levels, estimates are only available for tropical coral reefs

[2] IPCC developed the so-called Reasons For Concern (RFC) to scientifically address the question of 'dangerous interference with the climate system' as stipulated by the UNFCCC (UN, 1992). The RFC summarize and visualize IPCC evidence for a number of broad and representative risk classes and for different levels of warming (Smith et al. 2001, 2009).

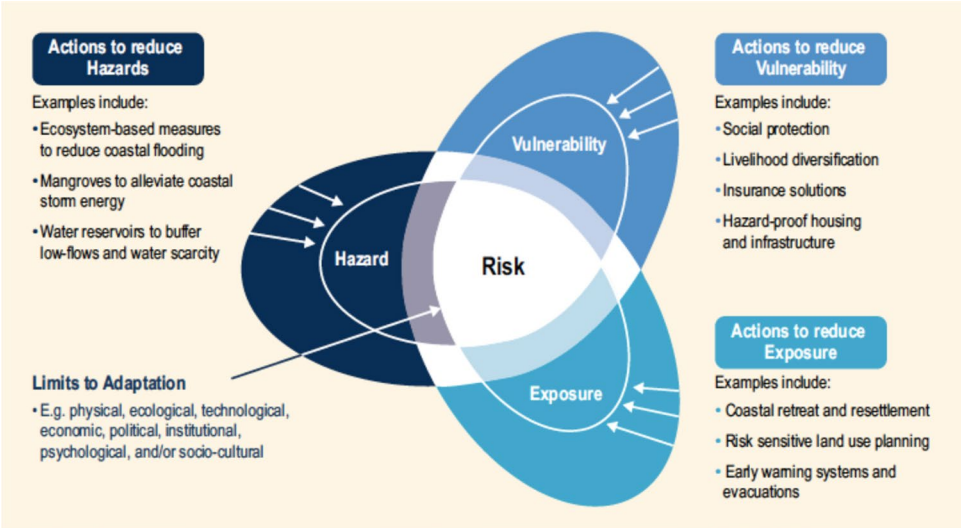

Figure. 1 IPCC risk framework as updated for the SROCC including a representation of adaptation limits. Source: Abram et al. (2019)

changes will render some island nations uninhabitable, although assessments of habitability remain challenging due to a lack of relevant literature. In addition, marine heatwaves, which for the majority are caused by anthropogenic climate change, are now considered a major new threat to marine ecosystems and associated livelihoods. Importantly, the 'limits' framing has been well anchored into IPCC's risk perspective. The SROCC updates the risk framework, with risk understood as a function of hazard, vulnerability, and exposure, and now explicitly consider limits to adaptation (see Fig. 1).

Implications for science and policy

Climate research has responded to demands for evidence-based insights relevant to the L&D debate. The IPCC and other recent publications present a broadening body of scientific literature on concepts, perspectives, methods, and evidence relevant to L&D. IPCC's 6th Assessment Report scheduled to be released in 2021/22 can be expected to include further insight, also as limits and barriers to adaptation (not however L&D) are mentioned several times in the plenary-approved outline for Working Group II- and thus need to be assessed by the IPCC to fulfill its mandate. Advances in research thus inform the complex and contested policy debate and provide an opportunity to further stimulate mutual understanding of the remit of L&D among negotiation parties.Clearly, this is a major challenge as the policy discourse remains characterized by substantial controversy as witnessed again at COP25 in Madrid in late 2019. Some progress has, however, been made. In Madrid, the WIM was for the first time comprehensively reviewed, including with regard to its effectiveness, and steps to take the WIM forward were decided (at COP22, a first review had remained incipient as it coincided with the ratification of the Paris Agreement, which thus overshadowed the review deliberations). The COP25 final decision emphasizes the need for international institutions to further support measures for averting and minimizing (i.e., avoiding), as well as addressing (i.e., dealing with unavoided and unavoidable) climate change-related impacts and risks. Consensus text suggested that scaled-up finance for L&D was indeed urgently needed. Yet, it remained unclear who is to provide funding and whether this would be additional to current pledges for adaptation (and mitigation). While COP25 did not deliver on concrete guidance and agreements, such as on a stand-alone financial mechanism for addressing and dealing with losses and damages as demanded by many developing country parties, the negotiations established an expert 'action' group. This group, inter alia, is to further help coordinate among parties inside the UNFCCC, such as with the standing committee on finance (SCF), as well as outside the convention with the Green Climate Fund (Climate Analytics 2019).

Climate negotiations are now turning towards COP26, the first COP with the Paris Agreement in effect, where parties are expected to present their ramped-up climate ambitions through updated Nationally Determined Contributions (NDCs). Emerging evidence on critical risks 'beyond adaptation' as well as on hard and soft limits in hotspot systems, sectors and regions, may hold potential to further build momentum in line with the Paris ambition and UNFCCC's overall objective of avoiding "dangerous interference with the climate system" (UNFCCC 1992). This is particularly important in the context of UNFCCC's global stocktake and national adaptation plans that countries have agreed to prepare and submit. Together, these documents may well provide up-to-date information on how and where particular adaptation limits are being approached and losses and

damages occur. Building on such information, adaptation and L&D policy may want to consider supporting actions on removing soft limits and spurring transformational, that is, non-standard risk management or adaptation, so that limits are not breached. Financial, technical, and legal support would be appropriate for instances where hard limits are transgressed.

While more work is essential, research has increasingly become capable of providing evidence-based insight through detection and attribution analysis, risk assessment, and the identification of diverse response portfolios for avoiding and managing losses and damages. A domain of research that is critically relevant for L&D is the systematic assessment of lived experiences of losses and damages across the globe (see e.g., Tschakert et al. 2019) as a rigorous basis for a global synthesis on non-economic and intangible harm. In addition to informing L&D policy, improved scientific understanding of the broad range of losses and damages would be of use in economic, insurance, and legal actions to ensure greater and urgent accountability for climate change and its consequences. There is also increasing engagement of researchers in WIM expert groups to support consensus and compromise-seeking among negotiators, representatives of international organizations. As the science perspective on L&D is maturing, it is overdue for climate policy to follow suite and clarify the remit of the debate, as well as adopt policies that truly reflect the challenges imposed by climate change.

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