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Essay

Loss and Damage from Climate Change: Knowledge Gaps and Interdisciplinary Approaches

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Abstract: Loss and damage from climate change have risen to a prominent position on the international agenda. At COP27 in 2022, the Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) ratified a decision to establish a loss and damage fund to compensate low- and middle-income countries that are suffering negative impacts from climate change. The fund is meant to address the Global Adaptation Gap, which describes the rising cost of adaptation needed to cope with climate change impacts due to delayed action to curb greenhouse gas emissions and remove greenhouse gases from the atmosphere. This essay highlights issues around loss and damage from climate change from a variety of natural and social science perspectives. From three months of discussions, an interdisciplinary perspective and research agenda on this topic have crystallised, which is outlined here. Given that the implementation of the loss and damage fund still needs negotiation and commitment from signatories to the UNFCCC, it is timely now to address some important knowledge gaps on how loss and damage can be measured, quantified, valued, understood, communicated, and adapted to. Hence, it is necessary to understand the complex interactions between people, politics, nature, and climate in this interdisciplinary context.

Keywords: loss and damage; climate change impacts; climate change adaptation; interdisciplinary; global adaptation gap; loss and damage fund; COP27

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1. Introduction

In 2006, the Stern review into the Economics of Climate Change [1] concluded that there was still time to "avoid the worst impacts of climate change, if we take strong action now", that "the costs of stabilising the climate are significant but manageable', and that a 'delay [in reducing greenhouse gas emissions] would be dangerous and much more costly". Sixteen years later, in 2022, Tuvalu was the first nation to draw up a national adaptation plan that foresees the creation of a landless nation that exists only in augmented reality in the metaverse after all its islands will have been submerged by the sea [2]. The example of Tuvalu highlights the issue of the significant global 'adaptation gap' to deal with the unavoidable consequences of committed climate change. The United Nations Adaptation Gap Report from 2022 [3] estimates that accounting for inflation, estimated annual adaptation costs will be 'in the range of USD 160–340 billion by 2030 and USD 315–565 billion by 2050', which is approximately 5–10 times higher than available adaptation finance, and the adaptation finance gap continues to widen.

However, adaptation finance is only one aspect of inadequate climate adaptation. The Adaptation Gap Report concludes that 'adaptation actions remain largely incremental in nature, typically do not address future climate change, and may reinforce existing vulnerabilities or introduce new risks, particularly for the most vulnerable'. The main reasons identified in that report are inadequate involvement of stakeholders and exclusion of marginalised groups, inadequate attention to local contexts and ownership, retrofitting development activities as adaptation actions, short-term focus and neglect of future climate risks, narrow definitions of adaptation success, and inadequate metrics of success.

The COP27 climate conference in Sharm El-Sheikh in 2022 resolved to set up a global fund to compensate low and middle-income countries for loss and damage from climate change impacts [4]. The idea behind that fund is that high emitters of greenhouse gases have historically contributed the most to the causes of climate change and have economically benefitted from them. Low and middle-income countries are on the receiving end of many of the impacts of climate change but also have the lowest coping capacity to deal with climate change impacts such as crop failures or rising sea levels. At previous COP events, industrialised nations blocked attempts by low and middle-income countries asking for financial support with their climate adaptation plans. However, at COP27, the agreement to compensate countries for loss and damage from climate change was signed, and that was seen by many as a major breakthrough [5,6].

Now that the principle to create a Loss and Damage Fund has been agreed upon, the international community faces the challenge of how to fully understand the complexity of loss and damage and how to monitor and implement the fund in a fair manner. This paper sets out an interdisciplinary perspective and research agenda on loss and damage from climate change established via three months of discussion with a team of researchers from across different Schools and Colleges at the University of Leicester. Why should one adopt an interdisciplinary perspective on loss and damage? Historically, the disciplinary specialisation of research evolved in order to deepen the understanding of particular phenomena or problems. Without this disciplinary specialisation, science would not have advanced the in-depth knowledge of the subjects of study as much as it has done. The trade-off is that the more differentiated research becomes, it becomes harder for specialists from different disciplines to communicate with experts from other disciplines [7]. The problem of understanding the effects of climate change on humankind (and, correspondingly, the identification of the best response strategies) is interdisciplinary by their nature, as it arises from the interplay between many individual disciplines such as geophysics, oceanography, biology, ecology, economy, sociology, and psychology [8,9]. Arguably, it is the most complex problem that science has ever dealt with. The value of interdisciplinarity is thus to re-integrate the deep understanding and ways of thinking of specialised research fields into a systems perspective. The authors believe that this is necessary to understand the complex interactions between people, politics, nature, and climate in the context of loss and damage from climate change.

2. Understanding Loss and Damage

2.1. Evidence Needed

'Loss and damage refers to the adverse effects of climate-related stressors on natural and human systems that cannot be, or have not been, avoided through mitigation or managed through adaptation efforts' [10]. Loss and damage include impacts from extreme weather events and slow-onset events such as rising sea-levels and glacial retreat [11,12]. With the rapid increase in the manifestation and awareness of climate-related risks and impacts from climate change worldwide, the world has realised that climate mitigation and adaptation may not be enough to manage the effects of anthropogenic climate change [13]. The Warsaw International Mechanism on Loss and Damage was set up in 2013 as a climate policy mechanism to deal with climate-related effects in highly vulnerable countries and was endorsed in 2015 by the Paris Agreement. Yet, as described in the book on the topic published in 2019 [13], the concepts, methods, tools, and directions for policy and implementation of loss and damage have remained contested and vague.

Loss can be understood as irreversible harm caused by climate change, for example, through the complete destruction or permanent reduction in the functioning of assets, infrastructure, or resources, the complete submergence of small island nations due to sea-level rise, the irreversible extinction of a species, or the permanent loss of cultural heritage sites due erosion caused by extreme weather events. Damage refers to harmful effects and costs associated with climate change that can be quantified and potentially compensated (including economic, social, and environmental costs). Damage can be temporary or partially reversible, and it often involves repair, restoration, or compensation, for example, the destruction of infrastructure by hurricanes, economic losses due to crop failure caused by drought, or the costs of relocating coastal communities due to erosion and rising sea levels.

As highlighted by Zommers et al. [10], the extent of loss and damage will ultimately depend on future climate mitigation actions, which will determine the intensity of extreme weather events and on the level of climate adaptation. Both of these influencing factors are within human control and entirely depend on priorities, how we spend our financial and other resources, and what level of priority is given to achieving net zero greenhouse gas emissions and adapting to already committed climate change. This conceptual link between mitigation, adaptation, and loss and damage is very difficult to address by modelling tools and requires integrated assessment models [14].

There is a clear need for evidence on the likely magnitude and reach of the already measurable and future anticipated impacts of climate change. This must include geophysical, geochemical, biological, and socio-economic evidence because climate change impacts by their very nature will disrupt physical, biological, and socio-economic systems due to their interconnectedness.

Moreover, because of the wide variety of climate change adverse effects, there is a need for a "common currency" that would allow comparison of the costs resulting from losses and damage of a qualitatively different origin. For example, while the costs arising from a loss of agricultural land because of rising sea levels can be estimated using well-defined economic indicators, how can one estimate the "costs" of a biodiversity loss or "costs" of cultural damage due to a loss of important historical site? The need "to compare the incomparable" will require new, multifaceted approaches going beyond a purely monetary value of loss and damage, similar to those that are used in land use decision-making [15].

Zommers et al. [10] argue that, to date, studies of loss and damage have focused primarily on human systems while overlooking the mediating role of ecosystem services. The ecosystem services lens offers a more holistic framework towards assessing loss and damage because it considers a whole range of ecosystem services and their functioning and does not adopt a narrow view of human loss and damage only. The Paris Agreement on Climate Change urges its signatories to enhance their understanding of the "resilience of communities, livelihoods and ecosystems" [10]. What can we currently learn from observations and models? The following sections shed some light on this question.

2.2. Observations

From an observational perspective, ecological surveys, earth observation measurements from space, meteorological stations, ocean buoys, and targeted mapping of the impacts of so-called natural disasters all contribute to the available evidence of measurable impacts. Observations have been crucial for leading the Intergovernmental Panel on Climate Change to conclude that climate change impacts are already measurable in all continents [16].

Biodiversity loss and gain are detected by the repeated and systematic monitoring of species populations and comparison with baselines. This is achieved using a variety of methods, from manual counts of populations to acoustic monitoring, to newer techniques such as environmental DNA (eDNA) analysis. However, biodiversity monitoring has historically been focused on vertebrate species, particularly birds and mammals [17], and there is greater data availability for temperate over tropical regions [18]. This taxonomic and geographical bias is present regardless of the methodology used, perpetuating the existing knowledge gap if it is not recognised, addressed, and solved specifically [19,20].

Global efforts are being implemented to improve biodiversity monitoring in lower and middle-income countries [21] and for previously poorly studied groups [22]. The challenges facing biodiversity monitoring are different in different regions. In the Global North, documented declines in the ability of the general population to identify common species and evidence of a growing disconnect from nature can present challenges. In the Global South, biological monitoring can face an array of difficulties ranging from lack of infrastructure and necessary equipment [23], changes in both formal and informal (including family-based) education, to violent opposition where monitoring may conflict with powerful social or economic interests [24]. Nevertheless, globally there are huge opportunities to improve data collection through community involvement, exploiting, e.g., mobile phones for data collection and even gamification. It is also important to incorporate information about the uses of biodiversity and use new approaches to assessing anthropogenic [25], particularly climate-related, pressure on plant biodiversity at both species and community levels. Overcoming these challenges, analysing the interests of stakeholders and the scientific objectives for monitoring will provide a better decision-making instrument and a more refined loss and damage calculation [26].

Earth observation from space plays a vital role in monitoring a wide array of environmental processes and features, ranging from the size of polar ice caps and biomass of forests to atmospheric greenhouse gas concentrations and ocean phytoplankton. In the context of quantifying loss and damage resulting from climate change impacts, such satellite-derived datasets and information products can inform on impacts that have already occurred. For example, sea level height variations, carbon losses from forest fires, agricultural crop failures due to drought conditions, and the extent of urban flooding can all be mapped from space. Satellite Earth observation data have several advantages over other data sources: they provide spatially explicit maps of where loss or damage has occurred, and they can be updated with new imagery to show the duration of the damage and the recovery period after the event. Such data sources also provide observational records in countries or regions where there are no other observation systems in place, either because they are too remote or inaccessible or because the country does not have the resources to collect data by other means.

However, satellite data have some limitations: they show phenomena at a specific spatial and temporal scale. These scales are determined by the spatial resolution of the images and the repeat cycle of the satellite orbiting around the Earth. Earth observation data have some remaining uncertainties in the data (random and systematic errors) and data gaps (e.g., from cloud cover), and they are phenomenological in that they show the current state of the land, ocean, or atmosphere, but they do not indicate the drivers and pressures leading to that state, and do not capture intangible qualities that may be extremely important in social and political cohesion. The role of Earth observation data in monitoring loss and damage can take several forms:

(i) Earth observation of biophysical parameters can be used to initialise, constrain, and validate computational models [27].
(ii) Spatial mapping can be used to verify the extent and severity of loss and damage and is used by insurance companies to verify compensation claims.
(iii) Time-series of spatial data can be used to detect temporal variability, seasonality, anomalies, and trends in the environment [28], which can lead to a more quantitative and spatially explicit understanding of loss and damage.

In agriculture, data collection, whether on-farm, from trading, or Earth observation, is already transforming production systems with the integration of decision-support tools [29]. These can go beyond identifying problems, enabling planning and forecasting and optimizing agronomy. With appropriate access to the tools and training of farmers, suppliers, and agricultural extension experts, they can both identify loss and damage and suggest mitigation strategies.

Climate scientists monitor the frequency, intensity, and spatial extent of extreme weather events that can cause loss and damage. Climate monitoring can also include long-term assessments of climate patterns and trends to identify potential risks and vulnerabilities, such as a one in 1000 years flooding event. These observations of extreme events provide important data on the occurrence of 'rare events' under current climate conditions. Climate models can predict the likelihood and severity of future changes in extreme weather events, such as floods, storms, and heat waves that may cause loss and damage.

2.3. Modelling

Evidence from the natural sciences includes climate model scenarios from atmospheric and climate models such as those used in the subsequent Climate Model Intercomparison Projects (e.g., CMIP6 [30]). Importantly, all these physical models are driven by socio-economic and policy scenarios that make assumptions about future greenhouse gas emissions to and removals from the atmosphere. Mechanistic, process-based models have a significant potential to link a biodiversity loss or even a mass extinction to a specific environmental trigger and/or to trace the effect of a particular environmental perturbation through a cascade of secondary processes [31]. Integrated Assessment Models [14,32–35] explicitly link the socio-economic and policy systems to the geophysical and biophysical models in order to simulate feedback between the two.

Climate impact modelling is contributing vital information to the anticipated future magnitudes of impacts. For example, sea level height models inform climate adaptation policies [36], but they are sensitive to assumptions about ice melting processes underneath the Antarctic ice sheet [37,38]. Species distribution models are used by ecologists to simulate the suitability of habitats and environmental conditions for biological species or groups of species. They can ingest gridded data on future climate states to inform the scenarios, as was demonstrated for liverfluke disease in cattle in Nigeria under future climates [39]. A geographical perspective on climate change impacts brings forward the question of which spatial and temporal scales the impacts are measurable on. It is well known that certain phenomena in the natural world are only detectable (or statistically significant) when data of a well-defined spatial and temporal resolution or granularity are available. For example, temporal scales of variability in global gridded climate data show specific spatial patterns and only become visible when scale-sensitive methods such as multi-scale sample entropy are used to identify them [40]. Similarly, insufficiently resolved spatial data can result in wrong conclusions about the population dynamics, community, or ecosystem properties, e.g., either overlooking a tendency or sometimes apparently revealing a property or phenomenon that, in reality, does not exist [41].

Climate attribution models [42] are an important field of research that needs to be considered in the implementation of loss and damage policies and financial mechanisms. The important question that these models need to answer is how much of the observed loss or damage is due to the anthropogenic contribution to extreme climatic events.

2.4. Legal and Policy Aspects

Litigation is viewed by Pihl et al. [43] as an essential tool to urge action. They summarise the ways in which litigation has been used in relation to climate cases in recent years. They identify public interest litigation against governments, claims against private actors (e.g., oil companies), and proceedings brought to domestic, international courts, tribunals, or human rights treaty bodies or non-compliance mechanisms. Interestingly, while they recognise the State as the primary vehicle by which to develop and enforce climate policy, they also acknowledge the absence of adequate climate action and enforcement, which results in the courts becoming lawmakers. Consequently, power balances are challenged, and scientific evidence is often directly involved in adjudication.

In developing countries, climate change cases are frequently related to human rights violations. This has resulted in a more focused debate on the role of the state in avoiding "dangerous climate change" and raises issues around due diligence and the implications of national climate plan policies and laws.

International courts and tribunals have also been used for settling international environmental legal disputes. These could be dealing with issues of extra-territorial emissions or harm caused by one State's water management strategy, which have direct consequences for an adjacent State downstream, for example.

A particularly interesting facet of climate litigation relates to future harm or harm to future generations, and there are cases that have been brought before the United Nations Committee on the rights of the child by children [43]. There are also important claims that decentralise humans and bring to the forefront the legal rights of nature. These and other issues surrounding reparation for loss of environmental goods and services internationally are highly contentious, and cases have highlighted the challenges of these sorts of environmental disputes.

According to the European Commission [44], in many countries, different institutions or ministries deal with climate change in relation to cultural heritage. This is seen by the European Commission as an obstacle to cultural heritage protection since cultural heritage policies and laws tend to reflect climate change issues more than the other way around; many countries do not even have a legal framework for heritage and climate change.

Coastal erosion and recession, as well as rising sea levels resulting in the submergence of large areas of land, are likely to have a significant impact on global heritage assets [45]. International migrations foreseeable as a result of climate change and rising sea levels are also likely to result in the loss of traditional knowledge and related intangible heritage. The laws applicable to such subjects are diverse and multifaceted, particularly since there is tension here between conventions dealing with underwater or maritime law versus laws applicable to heritage on land. Rising temperatures and increasing salinity, for example, may also have direct impacts on the physical condition of cultural heritage assets.

UNESCO has developed a special relationship with the IPCC over the last 3 years. This includes the first Focus Group on Culture and Climate Change to discuss the role of culture in climate adaptation resulting in the UNESCO, IPCC, and International Council on Monuments and Sites (ICOMOS) Cultural Heritage and Climate Change Initiative, and three White Papers were commissioned in December 2021 on the impact of climate change on cultural heritage, intangible heritage, and climate change [46]. The first of the three White Papers covers intangible cultural heritage, diverse knowledge systems and climate change, and focuses on diverse knowledge systems and intangible cultural heritage and their relationship with climate change [47]. The second White Paper is on the role of cultural and natural heritage in climate action and lays out various ways in which culture and heritage are interconnected with climate change resilience and advancing climate action [48]. Last but not least, the third White Paper addresses impacts, vulnerability, and understanding of risks, focusing on the effects and consequences of climate change on cultural and natural heritage and the creative economy [49].

2.5. Participatory Approaches

Social sciences, arts, and humanities offer perspectives on who is suffering the consequences of loss and damage, who benefits from the anticipated payments by the Loss and Damage Fund, and who has a voice in the process. These perspectives include how different socio-economic and minority groups are represented in the process of quantifying and compensating for loss and damage, equality, and gender issues.

Participation by volunteers and communities in the gathering of biodiversity data (often referred to as citizen science) can provide extensive and valuable information which can be used for monitoring [50]. However, these data are subject to the same biases in the collection, as previously mentioned [51]. Indices such as the Living Planet Index (LPI) attempt to combine vertebrate population trend data into a global indicator of percentage biodiversity change and are used to model projected future biodiversity changes [52]. The LPI has previously been used by the Convention on Biological Diversity (CBD) as a global indicator of progress towards biodiversity conservation targets. However, the bias in such indices is a significant problem with population trends in groups representing the greatest sources of global biodiversity, such as invertebrates and fungi, being poorly documented and, where evidence is available, such groups show little congruence with trends documented for vertebrates [53].

Participatory approaches should be adopted in the very design of climate adaptation action plans and other policy measures to make the process much more democratic and give a voice and political relevance to underrepresented groups. Local populations, particularly indigenous groups, often have a strong link with their local environments and their natural cycles, which can be important for data collection beyond usual scientific methods. Indigenous knowledge can strongly affect climatic justice scenarios and should be included when discussing the role of participatory approaches in loss and damage monitoring and evidence building.

2.6. Social and Psychological Loss and Damage

Economic models can estimate the monetary value of loss and damage, such as the cost of property damage, loss of income, and the cost of adaptation measures. The UN Adaptation Gap Report presents financial figures for loss and damage that are estimated based on some economic assumptions and assessments. Perspectives from experts in the Global North and South may well diverge when these assumptions are explicitly reflected on. Social, psychological, and behavioural research can provide insight into the social and psychological impacts of loss and damage, such as displacement, trauma, and mental health issues. The autonomy of communities has a value in itself and is often not addressed in assessing loss and damage.

The social and psychological impacts of loss and damage can be documented through surveys, interviews, and other social science research methods. The establishment of a Loss and Damage Fund at COP 27 of the UNFCCC represents an important milestone in addressing existing financial gaps for addressing losses and damages. It is anticipated that once operational, the Loss and Damage Fund will effectively respond to the needs of frontline countries in the climate crisis and potentially enable amelioration efforts. The disproportionate impacts of climate change on frontline countries in the Global North and South have long been a part of the policy discourse on loss and damage and are anticipated to be a central and contentious element in the operationalisation of the Loss and Damage Fund.

National-level socio-economic indicators and metrics can highlight the differential exposure of frontline countries to climate change and their needs for Loss and Damage Fund. To be equitable and fair, the Loss and Damage Fund must be able to clarify which countries have the greatest need for loss and damage finance. Integrated analysis of national-level socio-economic indicators and climate risks is a useful tool to help prioritise countries' needs for Loss and Damage Fund. Although national-level socio-economic indicators/metrics have been used in the past by researchers to determine whether Global

South countries are more vulnerable to natural hazards than Global North countries, it is not clear how such assessment may be applied to the funding of loss and damage. It is not clear how integrated national-level socio-economic indicators and global-scale climate hazards can be used to balance the needs of countries with the lowest socioeconomic indicators with those of countries facing existential threats, such as Small Island Developing States, irrespective of their socio-economic indicator level when making decisions on Loss and Damage Fund finance [54]. Further progress is thus required to understand how socio-economic impact assessment can be applied to the Loss and Damage Fund. In spite of sharp divisions in terms of how to understand and operationalise the Loss and Damage Fund, the principle of prioritising countries with high vulnerability and low capacity to finance their own climate action could well be applied to the funding of loss and damage [54]. However, the application of this principle may require a newly adapted approach to the use of national-level socio-economic impact assessment in loss and damage.

Cultural and natural heritage at risk from climate change includes tangible and intangible heritage, and different community groups may have diverging ideas of the value of different types of heritage. Methods such as oral histories and storytelling can be deployed to gain knowledge of intangible heritage. Cultural and social cohesion and family structures, place names, and festivals are examples of assets that are often overlooked but can be severely disrupted if people are displaced by climate change impacts such as floods or famine.

3. Adaptation Strategies

In order to promote adaptation strategies and reduce the likelihood of loss and damage, effective use of the funding for climate change risk reduction is essential. There are a variety of concepts that might be guided to efficient use of funding for climate change risk. One of the key principles is that investments in areas where it will have the biggest impact should be prioritised. This can include protecting the most vulnerable groups, helping in the building of climate-resilient infrastructure, and advancing sustainable development practices. Innovation can be another principle to address climate change risk and more effectively use funds. For instance, using innovative techniques for collecting and analysing climate data can help to identify investment priorities and identify high-risk areas. In addition to that, accountability is an essential part of the effective use of funds. To achieve this, financing must be managed in a transparent and accountable manner, with precise criteria for measuring the impact and reporting on progress. Lastly, promoting cooperation between government institutions, NGOs, and private sector actors to make sure money is spent efficiently and effectively to mitigate the risks associated with climate change.

The history of multilateral partnerships beyond the UN's recent pledge to provide a Loss and Damage Fund due to 'unavoidable risks of climate change' (UNEP) provides some guidance on understanding how best to proceed, with research emphasis on efforts undertaken through the UN Security Council, the Millennium Development Goals, and the Global Compact. Through successes and failures throughout the UN's most recent history, we find four essential components in a variety of successes, agency-centered participatory processes [38], interdisciplinary collaboration [55–57], asymmetrical autonomy [58], and commitment [56,59,60]. With limited space to direct each feature of various successful implementations of UN projects and goals, it should be noted that the capacity of the UN to mediate numerous external stakeholders into a framework that drives operational investment while also disincentivising or disempowering the naturally unequal and asymmetric capacity existent between nation states, private enterprise, NGOs, and community stakeholders is core to understanding how the Loss and Damage Fund may successfully operate.

Understanding loss and damage beyond the UN's statement of 'unavoidable risks of climate change' (UNEP) requires an awareness of how efforts to tackle the consequences of climate change while establishing a fund can drive new potential responses to these unavoidable risks, it can also easily be overwhelmed without interest in collaboration,

autonomy, and agency. As is often the case, naturally existing organisational disparities in capacity that produce asymmetry in partnerships mediated by the UN have complicated past efforts in the partnership development, as seen in the 2002 Partnerships for Sustainable Development (PFSDs), where America saw partnerships as an opportunity to avoid additional, specifically binding, sustainable development targets [61]. The same is true for participatory efforts that, without an interest in autonomy and agency, resulted in a diversion of commitment to the larger purpose, as seen in the cannibalising privatisation that resulted from Official Development Assistance payments diverging in purpose from the UN's Millennium Development Goals [62]. This disparity and contradictory interaction with funding partnerships can also be seen through public–private partnerships that have become more common across multiple branches of the UN (UNDP, UNICEF, UNEP, and the World Health Organization), effectively giving greater influence and access to private enterprise that was previously inaccessible, further deepening globalised privatisation outside the impetus of the various Public/Private Partnerships [63].

Finally, it should go without saying that while funds and other financially viable methods of UN-mediated partnerships will have a natural amount of external cooperation because of that financial potential, a lack of space, or removing agency and autonomy from our attempts to identify and rectify climate change loss and damage, will only result in a slow death of the whole project due to disinterest and exodus of the most committed partners.

4. A Focus on Agricultural Loss and Damage and Food Insecurity

Crop failures caused by changes in the frequency and intensity of extreme weather events triggered by climate change [64] are one of the major areas of loss and damage in the agriculture sector, as was highlighted by a recent meta-analysis [65]. Extreme weather disasters impact food supply chains around the world [66] and have recently attracted greater attention in the media as regional crop harvest failures have led to occasional shortages of certain commodities such as tomatoes in the UK: food systems need resilience and flexibility [67]. Agricultural loss and damage can therefore be understood as (i) the difference in current yield and the long-term average yield of a crop, (ii) the difference in the current yield and the expected yield for that site, and (iii) the difference in current yield and the optimum yield globally.

In the agriculture sector, loss and damage are caused by biotic stresses such as weeds, insects, and other animals, fungal, bacterial, and viral disease [68], and by abiotic stress such as available water (too much/too little), temperature (too hot/too cold), soils, and wind damage [65]. Measurement and monitoring of crop yields are important to gather information on global food security [66]. Local food prices can be highly sensitive to supply chain failures, and climate change impacts have certainly contributed to recent soaring food price inflation and the cost-of-living crisis, even though other factors such as trade barriers and the behaviour of commodity traders also influence these.

New genetic crop varieties may offer more resilience against extreme weather events and some of the biotic and abiotic factors leading to agricultural loss and damage. A great challenge for the farming sector is that industrialised farming requires substantial investments and access to capital (e.g., for new machinery or buildings) in order to change farming practices and adapt to climate change. The new Loss and Damage Fund could be used to an extent to provide that capital to farmers, especially in the Global South, where adaptive capacity is lacking and climate impacts are expected to be severe.

5. Discussion

The implementation of the mechanisms for the new Loss and Damage Fund requires interdisciplinary working across research disciplines in order to identify, understand, quantify, and address all relevant aspects of climate change impacts and how they affect people. Usually, such research findings are communicated through the publication of technical reports or academic papers with a focus on actionable points and evidence-

based interventions. Often, the main findings are also communicated to stakeholders and policymakers through high-level technical summaries, case studies, presentations with infographics, and media interviews. New and less conventional ways of engaging the wider public with issues around climate change involve the arts and humanities. Media such as art exhibitions, public performances, theatre plays, and interactive, participatory methods can reach people who would not normally want to engage with the topic of climate change. Living Labs are another great way of involving people in practical research. They can be understood as open innovation ecosystems in real-life settings and often adopt iterative stakeholder or user feedback to the research team.

This essay has identified some important open research questions. How well can models predict loss and damage from extreme events caused by climate change? Extreme events are, by their very definition, relatively rare and can therefore be difficult to model. Robust statistical modelling approaches are needed in order to refine models of extreme events. Under climate change conditions, the distribution and frequency of extreme events are also changing, which makes them harder to model as it renders current model assumptions less reliable. Another question is what the power relations are that have led to the COP27 resolution on loss and damage? How have international political factors such as having a Democrat president in the US, mounting tensions between Europe, the USA and China, Russia's war in Ukraine, and other factors played into this resolution?

A successful model for dealing with peacebuilding processes has been the concept of 'Truth and Reconciliation Councils' [69], which aim to bring the facts and truths to light whilst also seeking mechanisms for setting aside previous conflicts in order to move on into a better future. Would a 'Truth and Reconciliation Council for Climate Change Impacts' provide a pathway towards global environmental justice?

How can existing inadequacies in climate adaptation plans be overcome to make the use of adaptation finance from the Loss and Damage Fund more effective? Climate change impacts have manifested themselves much more quickly and with greater damages than anticipated by many. This raises the question as to whether current thinking about effective climate adaptation is sufficient to cope with the climate crisis. There are existing barriers towards quantifying adaptation finance needs, especially for low- and middle-income countries. Only a small number of countries have so far submitted national climate adaptation plans and financial details at the point of writing this essay. It is unclear as to whether this is due to a lack of capacity to write those plans, a lack of political will, or other factors. How can these barriers be overcome? Valuation of loss and damage is, after all, highly culturally specific, especially concerning the cultural and psychological damages caused by climate change. Climate adaptation plans should be co-created together with local communities and not exclusively by nation-states in a top-down approach in order to adequately represent a diversity of losses and damages from climate change in different groups of the population. Climate adaptation plans need to be inclusive.

After climate adaptation plans have been written in anticipation of future payments from the Loss and Damage Fund, consideration has to be given to the distribution and use of those funds. Who is likely to benefit from future loss and damage payments eventually, local communities, businesses, and national governments? Additionally, how do we evaluate the effectiveness of the use of these funds?

Our discussions highlighted several principles as to how the Loss and Damage Fund can be set up in an impactful and effective manner:

- Prioritisation: Loss and Damage Funds should be distributed to regions and communities that are most vulnerable to the impacts of climate change based on an evaluation of the potential risks and impacts.
- Integration: Loss and Damage Funds should be incorporated into existing disaster risk reduction and disaster management programs to ensure that they are successfully integrated into local planning and decision-making processes.

- Partnership: Loss and Damage Funds should be used to build partnerships between governments, communities, the private sector, and international organisations to make better use of available resources, knowledge and expertise.
- Evidence-based decision-making: Loss and Damage Funds should be used to support evidence-based decision-making by investing in research and data collection to guide the design and implementation of risk reduction strategies.
- Capacity building: Loss and Damage Funds should be used to increase the capacity of communities, governments, and other stakeholders to implement effective risk reduction strategies by providing training and technical assistance.
- Monitoring and evaluation: Loss and Damage Funds should be used to monitor and evaluate the effectiveness of risk reduction strategies and make required adjustments based on what has been proven to work and what has not.
- Long-term planning: Loss and Damage Funds should be set aside for long-term planning to ensure that risk reduction strategies can be sustained and scalable over time.

Establishing a Loss and Damage Fund within the UN requires a complex of toolboxes, best practices, monitoring systems, and international cooperation between community stakeholders, private enterprises, NGOs, members, observers, and unrecognised States, including the wide range of possible stakeholders not indicated above. The breadth of the foundational organisation and technical implementation necessary to accomplish the task set before the Loss and Damage Fund must also occur before a single compensatory payment is delivered.

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