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## **Loss and Damage to Ecosystem Services**

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### **Abstract**

Loss and damage has risen to global attention with the establishment of the ‘Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts’. While much of the discussion has focused on loss and damage to human livelihoods, climate change is also having a significant impact on ecosystems. The Intergovernmental Panel for Climate Change Fifth Assessment Report (2014) indicates that adaptation options for ecosystems may be more limited than for human systems and consequently loss and damage both to ecosystems, and to ecosystem services, may be expected. Ecosystem services underpin human livelihoods. It is therefore critical to better assess loss and damage to ecosystem services. This paper assesses current and expected losses and damages to ecosystem services through a survey of the Working Group II Fifth Assessment Report of the Intergovernmental Panel for Climate Change, and a detailed case study of the impact of glacial loss in Peru’s Cordillera Blanca. Evidence for changes to services is seen in the different phases of hydrological shift of glacial melt. While the impact of other stressors resulting from human activity on ecosystem services need to be considered, greater focus is needed on the relationships between climate change, loss and damage, ecosystem services and human well-being. Ultimately efforts to protect ecosystem services may help build resilience in human livelihoods and minimize loss and damage.

## A. Introduction

In the space of a few short years, a catalogue of climate change impacts has emerged around the globe, summarized by the Intergovernmental Panel for Climate Change (IPCC) Fifth Assessment Report (AR5) Working Group II, which assesses the vulnerability of social-ecological systems, finds that, “changes in climate have caused impacts on natural and human systems on all continents and across the oceans” (IPCC, 2014: 4). While some natural and human systems may be able to adjust to a changing climate, it is clear that, there are limits in the extent to which adaptation is possible (IPCC, 2014: 28). When environmental stress exceeds a system’s thresholds for adaptation, it is increasingly likely that irreversible negative impacts will be sustained (Adger et al., 2009; Dow et al., 2013). A range of empirical evidence now indicates that climate change, in conjunction with other anthropogenic pressures, may drive systems to limits at local, continental and planetary scales (Scheffer et al., 2003; Rockstrom et al., 2009). At these limits, loss and damage is increasingly likely.

Loss and damage from climate change occurs when the impacts of climate-related stressors have not been, or cannot be, avoided through mitigation and adaptation efforts (Warner and van der Geest, 2013). Scientific conceptualizations of loss and damage, and the definition in the United Nations Framework Convention on Climate Change (UNFCCC), have focused on impacts in economic systems (Warner and van der Geest, 2013; Wrathall et al., 2014). Very little attention has been given to non-

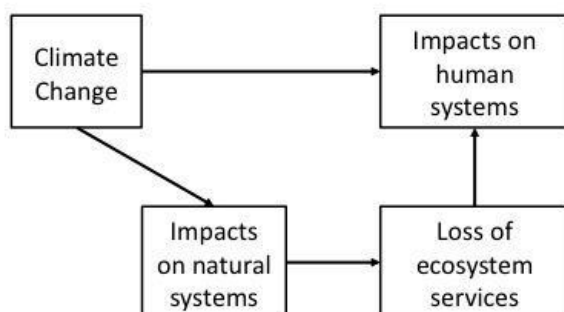
economic or ecological limits and impacts. Yet, “Evidence of climate-change impacts is strongest and most comprehensive for natural systems” (IPCC, 2014: 4). According to the IPCC, adaptation options for ecosystems are limited and focus on reducing pressures (IPCC 2014). In the case of successive, progressive, accelerating and permanent change, current measures are unlikely to prevent loss and damage to ecosystems and their services.

Ecosystem services are ecological processes or functions, which have monetary or non-monetary value to individuals or society at large. They are frequently classified as: (1) provisioning services, including food and water; (2) regulating services, including flood and disease control; (3) cultural services, including recreational and spiritual benefits; and (4) supporting services, such as nutrient cycling or productivity (IPCC 2014; MA, 2005). Each of these services supports different aspects of human well-being, providing among other things, security and material for life. Costanza et al. (2014) estimate the total value of global ecosystem services at US\$125 trillion per year. However, purely economic valuations do not capture the non-monetary value of services and their impact on human well-being.

Though ecosystem services are often measured at specific scales, they respond to changes in broader systems at catchment, landscape and climate system scales (DeGroot et al., 2010). Moreover, because ecosystem services are complex and interrelated, they are subject to non-linear thresholds of change and sudden degradation at local levels (Bennet et al.,

2009; Folke et al., 2004). Disturbances that impact specific species relationships, such as tree species, can produce changes in specific ecosystem services, like water provisioning (Larsen et al., 2005). The Millennium Ecosystem Assessment (2005) concluded that approximately 60 per cent of ecosystem services are being degraded. Loss of services due to land change alone could range from US\$4.3 trillion to US\$20.2 trillion per year (Costanza et al., 2014). It is critical to determine if, how and where climate change is pushing ecosystem services across tipping points and result in permanent loss and damage, and the relationship to increased risks of loss and damage to human systems (IPCC, 2014).

Climate change can impact human systems directly, for example when increasingly severe cyclones cause loss and damage to properties, infrastructure and economic supply chains, but impacts may also be mediated, positively or negatively, through natural systems and ecosystem services. This is the case when, for example, increasing temperatures cause glacial retreat, which affects river flows and can cause loss and damage to livelihoods of farmers who are dependent on river water for irrigating their crops. Figure 1 shows this schematically while chapter 18 of IPCC WGII AR5 has a much more elaborate figure, depicting how natural and human systems interconnect).



**Figure 1. Relationship between climate change, ecosystem services and human systems.**

This paper seeks to identify attention to loss and damage in ecosystem services by first conducting a qualitative data analysis (QDA) of the 32 chapters of IPCC WGII AR5. QDA software is used to extract sentences in which the words loss and damage occur, and the resulting list of almost two thousand sentences is analysed both quantitatively and qualitatively to find

out which climatic stressors, impact sectors, regions and ecosystems the report primarily associates with loss and damage. The central message of the Warsaw International Mechanism for loss and damage – that current mitigation and adaptation measures are not enough to avoid residual loss and damage – is stated firmly in the summary for policy makers: “Under all assessed scenarios

for mitigation and adaptation, some risk from residual damages is unavoidable (very high confidence)” (IPCC, 2014 p.14), and in more detail in the technical summary:

Adaptation and greenhouse gas mitigation are complementary risk management strategies, but residual loss and damage will occur from climate change despite adaptive and mitigative action. Opportunities to take advantage of positive synergies between adaptation and mitigation may decrease with time, particularly if limits to adaptation are exceeded. In some parts of the world, current failures to address emerging impacts are already eroding the basis for sustainable development. (IPCC, 2014, Technical Summary, p. 33)

By reviewing the report it is possible to identify evidence of climate change-induced losses and damages to human and natural systems.

This paper continues with an examination of a specific case study of glacial loss in Peru’s Cordillera Blanca, to identify the impact of loss and damage to ecosystem services on human well-being. According to the AR5 report, pro-glacier hydrologic systems are among the most affected by climate change. Their global volume is projected to decrease by up to 85 per cent this century (IPCC, 2014). Glaciers are important both to the ecosystems and populations of the tropical Andes, providing meltwater discharge during the dry season or in drought conditions. The complexities of glacier recession and shifting water resource management are context specific and highly

reliant on local and national policies for the governance of water resources.

Nevertheless, as glaciers continue to reduce in size, the provisioning of water, a critical ecosystem service, may be impaired with direct consequences for livelihoods (Mark and McKenzie, 2007).

## **B. Intergovernmental Panel for Climate Change (IPCC) Fifth Assessment Report (AR5) Working Group II Analysis**

This section reviews how loss and damage features in the Working Group II (WGII) contribution to the Fifth Assessment Report, with a focus on loss and damage to ecosystems and ecosystem services.

### **1. Methods**

In the first instance, qualitative data analysis software (QDA Miner/WordStat) was used to extract sentences from the thirty IPCC WGII AR5 chapters plus the summary for policy makers (SPM) and the technical summary (TS) containing the words loss(es), lost, losing, lose, loser(s), damage(s), damaged or damaging. The resulting 1,911 sentences were exported to a spreadsheet and screened for technical and formatting issues and to check whether the words loss and damage were actually used in a meaningful way (e.g. author name: ‘Scott R. Loss’ was excluded). The resulting document contained 1,886 sentences, in which loss, damage and related words occurred 2,177 times (in some sentences, the words occurred more than once).

After this step, the file with 1,886 sentences was subjected to qualitative analysis to explore the words most often used in

combination with loss/damage. A threshold was set at frequency 10, meaning that words that co-occurred with loss/damage less than ten times were excluded from the qualitative analysis. The QDA software automatically excludes words that convey little intrinsic meaning, such as able, about, above, according, across, etc. The resulting list contained 587 words used in relation to loss/damage. This list was cleaned by:

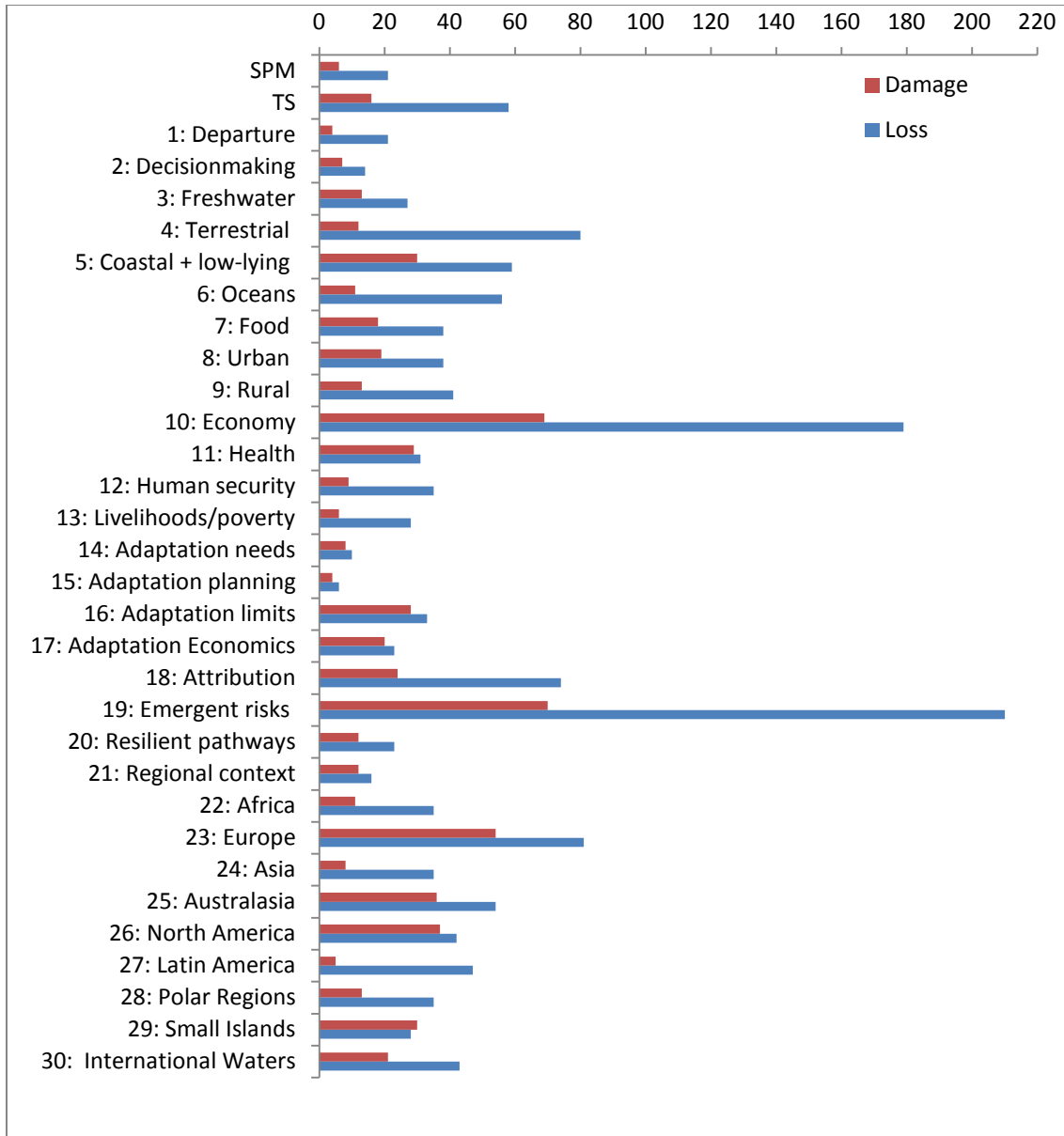
- Removing author names;
- Removing words that conveyed no intrinsic meaning in this context, but were not automatically excluded by the QDA software (e.g. chapter, section, common, IPCC, SPM, table, terms, important, related, report, role, similarly, etc.);
- Clustering words with the same root (e.g. agriculture and agricultural). We were conservative in clustering words because sometimes words with the same root have a different meaning (e.g. effects and effective were kept separate, and so were developing and developed). In case of doubt, the original text was consulted to verify whether words conveyed exactly the same meaning.
- In a few instances, words were combined (e.g. the word Zealand only occurred in New Zealand; sheet only in ice sheet, greenhouse only in greenhouse gas, etc.). When the other word (e.g. ice in ice sheet, sea

in sea level rise) also occurred independently, the frequency score was adjusted (i.e. frequency of ice sheet deducted from frequency of ice).

The cleaned word list contained 301 words that occurred at least ten times in the same sentence with the words loss(es) or damage(s). This list of words and their frequencies of occurrence were used for the analysis of how loss and damage features in IPCC WGII AR5, with a focus on loss and damage to ecosystems and ecosystem services.

## **2. Findings**

A review of the 32 IPCC WGII AR5 chapters indicates that losses and damages are most frequently mentioned in Chapter 19 (Emergent risks and key vulnerabilities) and Chapter 10 (Key economic sectors and services), indicating that loss and damage is mostly framed in economic terms and primarily seen as a future threat. The terms loss and damage are used more often in the chapters on Europe, North America and Australia than in chapters on Asia, Africa, Latin America, Small Islands and Polar Regions. This is surprising because loss and damage is mostly associated with vulnerable countries, such as small island development states and least developed countries (see Figure 2).



**Figure 2: Occurrence of words loss and damage by chapter. In this figure, chapter titles have been shortened. The words included in the analysis are loss (es), lost, loser(s),losing, damage(s), damaged or damaging.**

The most frequently used words in the same sentence with loss or damage are risk, economic, impacts, flood, coastal, adaptation, ecosystems, species, insurance, water, sea, ice, costs, coral, infrastructure, biodiversity and land. All these terms occur

at least 100 times in one sentence with loss and/or damage. In relation to ecosystems, the report reveals a particular concern about species and habitat, for example impacts of climate change on coral reefs; loss of ice cover and glaciers; loss of land due to



submergence and coastal erosion and; loss and damage to particular ecosystems, such as forests, mangroves and wetlands (see Figure 3). Impacts on human systems primarily involve economic losses and

damage to infrastructure. Substantially less attention is given to impacts on ecological bases for human wellbeing and development, such as food security, livelihoods and health.



**Figure 3: Tag cloud of words related to ecosystems and services used in one sentence with loss or damage. The threshold for inclusion in the Figure was set at 25. Words related to ecosystems are shown in green, and words related to ecosystem services and ‘constituents of well being’ in blue.**

IPCC WGII AR5 (2014) tends to frame loss and damage as either an issue for natural systems or economic systems (see also Carey et al., 2014), with only occasional recognition that loss and damage from climate change will disproportionately impact those who derive livelihoods from local ecosystem services. For example, in this quote from Chapter 14, page 8:

Climate change is expected to have a relatively greater impact on the poor as a consequence of their lack of financial resources, poor quality of

shelter, reliance on local ecosystem services, exposure to the elements, and limited provision of basic services and their limited resources to recover from an increasing frequency of losses through climate events.

To better understand the significance of loss and damage in ecosystem services, this paper turns to one of the clearest examples of the effects of climate change: glacier recession in the tropics and the accompanying shift in hydrologic resources.

### **C. Case study: Glaciers in the Cordillera Blanca**

The Cordillera Blanca-Callejon de Huaylas region in the Ancash department of Peru represents the densest configuration of tropical glaciers in the world. The Santa River, which forms the principal watershed in the Cordillera Blanca, drains a total area of 12,200 km<sup>2</sup> and is the second largest river along Peru's Pacific Coast. The upper watershed, the Callejon de Huaylas, is more than 5,000 km<sup>2</sup> and captures the majority of pro-glacier runoff from the Cordillera Blanca. According to historic and multiscale hydrologic modelling and remote-sensing analyses, a 22 per cent reduction in glacier area occurred across the Cordillera Blanca between 1970 and 2003, and a further 17 per cent loss occurred between 2003 and 2010 (Baraer et al., 2012). Hydrologic, ecosystem and social change associated with glacier recession were investigated in the Santa River based on an evaluation of nine sub-basins including Los Cedros, La Balsa, Colcas, Paron, Llanganuco, Chancos, Querococha, Pachacoto and La Recreta. The rapid, yet uneven deterioration of glaciers and reduction of water resources is associated with a number of social and ecological changes within the Canyon de Huaylas.

It bears reiterating that ecosystem services include (1) provisioning services, including food and water; (2) regulating services, including flood and disease control; (3) cultural services, including recreational and spiritual benefits; and (4) supporting services, such as nutrient cycling or productivity (IPCC 2014; MA, 2005).

Losses and damages in the functionality of specific services might manifest idiosyncratically according to the reliance of local populations for livelihood activities. To add clarity and reduce the complexity – which cannot be scrubbed completely— we consider the effect of hydrologic change on each of these services related to livelihoods in the Canyon de Huaylas. The aim of this section is to provide evidence that loss and damage in livelihood systems is mediated through ecosystem services, and requires further explicit attention.

#### **1. Methods**

The information presented is drawn from research by National Science Foundation - Coupled Human Natural Systems research, and is based on analyses conducted for UNEP's Global Environment Alert Series (UNEP 2013). Despite complex and widely differing social contexts within the Canyon de Huaylas, the various sub-catchments form the basis for comparative (or quasi-experimental) research on the effect of glacier recession on social-ecological systems.

#### **2. Findings**

Historical hydrological assessments and synoptic isotopic sampling in nine glacier tributary watersheds of the Santa River, indicate an evolution of glacier hydrology through four 'impact phases' of climate change (Baraer et al., 2012): Phase 1) increasing dry-season and yearly average discharges (as glaciers begin to recede); Phase 2) annual average discharges reaches a 'peak' (due to reduced glacier masses and diminishing dry season discharges); Phase

3) a pronounced decrease in discharges (as glacier recession stabilizes); and Phase 4) the end of the glacier influence on outflows.

This hydrological trend is already decades-old in some sub catchments. La Balsa, a Phase 3 watershed, likely crossed the threshold from Phase 2 in approximately 1970. The overall state of studied watersheds, determined with a linear regression-based assessment, indicates that, on average, glacier-fed rivers are experiencing an increase in discharge variability and a decrease in dry-season discharge (Phase 3), it is likely that the Santa River's 'peak' occurred around 1980 (Baraer et al. 2012).

The continued loss of glacier mass will have a significant impact on hydrologic systems in the basin and consequently on the associated ecosystems and human populations. The general spatial pattern of human settlement and livelihoods around the Cordillera Blanca is as follows. Population centres lie in the lower catchments, surrounded by privately-held agricultural fields and pasture which extend to the upper watershed. Meanwhile communally managed pastures, small-scale mining and agroforestry projects extend along glacial valleys into the upper catchments, which generally terminate in glacial lakes or moraines (Bury et al. 2013). The impact of changing hydrological phases on specific services and livelihood activities is discussed below.

### **(a) Provisioning Services**

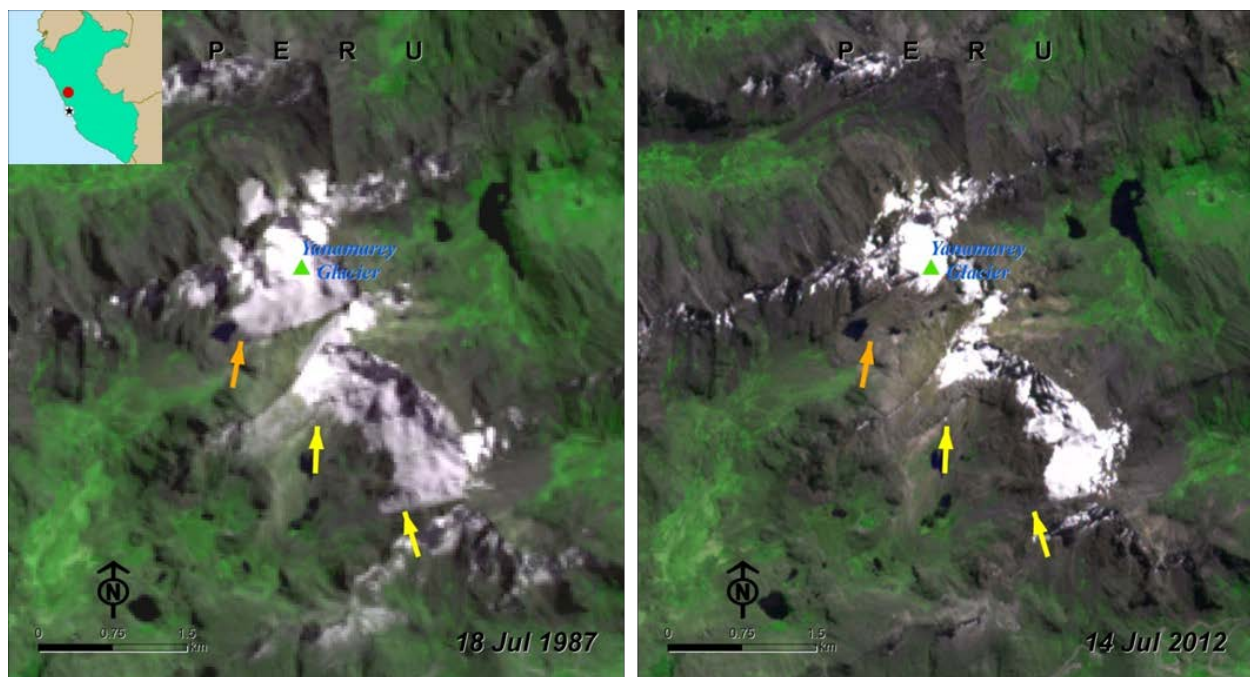
Glaciers feeding tributaries of the Santa River have buffered mountain hydrology

and regulated stream flow through a landscape with sharp seasonal oscillations in precipitation, with glacier runoff exceeding 40 per cent of stream flow during the dry season (Mark et al., 2005). Within rural communities of the Cordillera Blanca, livelihoods are largely dependent on access to water and are affected by private, communal and public institutions that delimit access to essential land and water inputs. The historical relationship between water availability and water use is not a simplistic, deterministic interaction because new technologies, laws, economic opportunities, natural resource extraction, cultural values, conservation practices, and recreation preferences shapes how people in the region have utilized glacier runoff over time (Carey et al. 2014). It is thus important to analyze glacier shrinkage and ecosystem services in dialogue not only with shifting hydrology but also shifting local, national, and international societal forces—that is, remembering to analyze the situation through the lens of global change rather than simply climate change (Lynch 2012; French 2014; Carey et al. 2012; etc.).

Provisioning services may be enhanced temporarily before diminishing during the process of glacier recession. Initially, as a glacier begins to retreat, water supply increases for a limited duration before later entering a period of declining water as glacier mass decreases. This may provide short-term boosts to water provisioning. Yet, this is only temporary, and at the same time, rapid melting contributes, in some cases, to the formation of high elevation lakes. While introducing risks, which are further described below, these lakes have some

regulating effect on water resources. However, many sub-catchments, such as Querococha, are already experiencing pronounced decreases in water. The surface area of Yanamarey glacier within the Querococha sub-watershed of the Rio Santa watershed lost more than half of its glacial area since 1948 (Baraer et al., 2012), with 85 per cent of the loss occurring between 1962 and 2008 (Huh et al., 2012). In addition to retreating it has also thinned, causing it to lose more than 88 per cent of its

volume (Huh et al., 2012) and decreasing its seasonal storage capacity (Bury et al., 2011). Melt water from Yanamarey contributes nearly 100 per cent of the stream flow to the upper watershed during the dry season months (June-September) but proportionately less downstream (~24 per cent to over 50 per cent depending on year and season) (Bury et al., 2011). Projected rates of deterioration suggest it may completely disappear by 2020 (Mark et al., 2010).



**Figure 4. Yanamarey glacier. The orange arrow indicates where the glacier has retreated and the yellow arrow point to other noticeable changes in snow and ice cover between 1987 and 2012 in surrounding glaciers. Source: Landsat visualisation by UNEP/ GRID-Sioux Falls**

Changing dry season flow has critical significance for crop irrigation. Expert interviews with a range of stakeholders and water users in 2012 identified some specific

agricultural areas within the Querococha watershed had shifted in recent decades from year-round irrigation to rain-fed irrigation only. While in specific sites, it has

not been determined whether the switch to rain-fed only irrigation is attributable to climate change and glacier recession, it is nevertheless consistent with the expected pattern of diminishing dry season discharge identified in the sub-catchment, just as the super abundance of water in irrigation channels in Llanganuco is consistent with early stages of glacier recession. The potential for changing water provisioning to influence livelihood trajectories is a compelling narrative, and indeed, between 1972 and 2008 cultivated area in the Callejon de Huaylas shrank by 19 per cent. Nevertheless, these livelihood changes are more likely to have resulted from increased competition for water and land resources, a shift toward cash crops over subsistence farming and the pull of urban labor markets rather than climate change (Bradley et al., 2006; Bury et al., 2011; Mark et al., 2010). This is a reminder that livelihoods are set within a social context, which can ultimately impose greater constraints to livelihood function than loss or damage to water provisioning.

### **(b) Regulating Services**

The new hydrologic equilibriums are impacting high altitude wetlands, known as *paramos*, and cloud forests (Bury et al., 2013; Poveda and Pineda, 2009). Between 2000 and 2011, wetlands in the Quilcayhuanca valley contracted by 17.2 per cent through two general stages: first fragmentation and then contraction. Wetlands perform a number of valuable ecosystem services, including maintaining consistency in stream flow in upper catchments, regulating stable

evapotranspiration cycles, and supporting pastures (Bury et al., 2012; Carey 2012; Young and Lipton 2006). Research is ongoing to establish a link between shrinking wetlands, a changing evapotranspiration cycle and increasing 24-hour temperature variability. Ethnographic and structured interviews almost universally suggest that dry-season days are becoming warmer and nights are becoming colder. The perception among growers is that increasingly variable temperatures threaten subsistence and smallholder agricultural production, as intense morning frosts are leading to increased crop mortality.

Rapid glacial loss can also increase the likelihood of disaster events. The Parón watershed, which contains the Artesonraju glacier, has experienced a loss of over 30 per cent of its glacier surface area since 1930. Retreat of Artesonraju and the neighbouring Artesoncocha glaciers have resulted in the formation of a new highland lake (denoted with a yellow arrow in Figure 5) that is characterised by overhanging ice and loose rocks, making the area vulnerable to landslides. In addition, the new lake sits above two previously formed lakes, including Lake Parón, the largest lake in the Cordillera Blanca, and Lake Artesoncocha, which caused two nearly catastrophic glacial lake outburst floods (GLOF) in 1951 that almost caused Lake Parón to overflow (Carey 2010). This positioning poses a threat for a catastrophic GLOF event should an avalanche or landside, triggered by additional melting into the new lake, occur (Chisolm et al., 2012). Throughout the Cordillera Blanca hundreds of new glacial lakes have formed at the foot of shrinking



glaciers. Because many of these glacial lakes are unstable—and some such as Lake Palcacocha above the city of Huaraz have triggered deadly outburst floods, including the 1941 flood that killed 5,000 people—the Peruvian government has had to partially drain and dam 35 Cordillera Blanca glacial lakes. The artificial security dams alter

downstream hydrology, especially when they have been fitted with floodgates to create high-elevation reservoirs such as at Lakes Parón, Cullicocha, and Rajucolta (Carey 2010). Both rapid melting, and the draining of lakes potentially impair the regulating services provided by *paramos*.



**Figure 5. Artesonraju glacier and new lake. Source: Landsat visualization by UNEP/GIRD-Sioux Falls**

Other side effects of glacial loss include decreased or decelerated flows of rivers used for hydropower. Vergara et al. (2007) derived an estimate for the impact of the reduction of glacial melt water on the power generation capacity of the Cañon del Pato hydropower plant on the Rio Santa, which contributes approximately 8 per cent of Peru's electricity generated by hydropower

(annual output from Vergara et al., 2007 divided by total annual hydropower generation from World Bank, 2010). They concluded that a 50 per cent reduction in glacier runoff would contribute to an approximate 10 per cent decrease in annual power output (from 1540 GWh to 1250 GWh). Further, if the glacier contribution were to disappear completely, annual power

output would be reduced to 970 GWh. Decreased reliance and use of hydropower would force countries to explore other energy options, with increased production costs from other sources and possibly requiring an increase in energy imports (UNEP, 2011). At the same time, these projections of loss and damage to power generation ignore the capacity for new arrangements that societies can choose, when facing resource constraints.

### (c) Cultural Services

Traditionally in the Cordillera Blanca, glaciers and glacier lakes hold specific religious and spiritual meaning and their disappearance has implications for cosmological interpretations of weather and seasons, causes of auspiciousness and misfortune, as well as sense of identity and place. The importance of these cosmological imaginaries for cultural self-replication cannot be understated. . There is a longstanding tendency in the Cordillera Blanca region to consider certain lakes as being enchanted, that is, possessing certain supernatural or spiritual forces. Often times local residents see these enchanted lakes as dangerous, not to be approached, and to be treated with respect. More broadly, the glacial lakes and the glaciers that feed them fit into local conceptions of place, history, community relations, and identity. They are imbued with meaning and value, even as many are feared. Glacier change and the formation of new lakes or bursting of unstable glacial lakes alters people's historical relationship with the Cordillera Blanca, demonstrating how climate change is altering the cultural services glaciers have historically provided. Loss of glacial ice—or more importantly, the instability in dynamic, melting glaciated regions—is

altering cultural services in other ways, too, because people are no longer eating *raspadillas* as much as they did previously. *Raspadillas* are like a snow cone in the United States: shaved ice with flavoring added. In the Cordillera Blanca region, residents have eaten *raspadillas* made with glacial ice for decades, probably centuries. But glacier retreat is making the mountains too unstable for ice collectors to visit glaciers for ice harvesting, thereby affecting a traditional food and festivity—not to mention community and kinship-based activity of collecting glacial ice—due to the shrinking glaciers. In other parts of the Peruvian Andes, such as at Mount Ausangate, tens of thousands of Andean pilgrims visit shrines at the foot of the mountain's glaciers in the annual *qoyllur riti* pilgrimage. Glaciers and glacial ice have since the pilgrimage began in the eighteenth century held medicinal and spiritual value for the pilgrims, who until recently carried blocks of ice back to their communities. With recent climate change impacts, authorities have forbidden people from taking the glacial ice, thereby affecting people's spirituality, their relationship with the mountain gods, their sense of place, and even their health given the lack of medicinal glacial water .

### D. Discussion

Loss and damage is framed in scientific reporting in the IPCC AR5 (2014) primarily as an issue for economic systems. If natural systems are mentioned, the focus is on species and habitat in particular ecosystems, mainly coasts and glaciers. However, the association with terms such as flood, health and agriculture indicates that widespread loss and damage to ecosystem services may also be occurring. As the case study indicates, areas fed by tropical glaciers are already experiencing changes in water

supply affecting provisioning, regulating and cultural services. This has the potential to impede livelihoods.

In the Cordillera Blanca, reduced water flow has implications for food production, water filtration by wetlands, micro climate, energy supply, migration and demography. Glacial melting has also resulted in increased risk of disasters, as short-term runoff surges from glaciers could trigger landslides or massive flood events (Chevallier et al., 2011; Chisolm et al., 2012). If glaciers continue to recede, then future impacts to cultural services might be anticipated. Social cohesion may be strained with increased competition, spiritual and aesthetic values may be compromised and revenue from tourism may decrease as glacial ice becomes less stable and riskier for mountaineering. But in the meantime local economies may benefit from glacier tourism, the *ruta cambio climatico*, a climate change circuit where people are going to see impacts of climate change on glaciers. Furthermore, with decreasing water supplies and competition for use, the interests of large and powerful stakeholders, including hydropower companies, municipalities and industrial agricultural producers, will likely have greater influence over water rights governance than smallholders (Bury et al., 2013; Vuille, 2013). Adaptation measures to reduce risk of high altitude pro-glacier lakes have corresponded with the resource needs of multinational agriculture, mining and hydropower companies, over those of local smallholders leading to several sustained resource conflicts in the Cordillera Blanca (Carey et al., 2012). These conflicts highlight how adaptation for one group, such as the more prudent regulation and use of increasingly scarce water, can be considered loss and damage to another group. This shows evidence of a political economy of loss and damage, where

difficulties will be concentrated among the least powerful.

Ultimately, findings suggest that greater emphasis on loss and damage to ecosystem services is needed. The dominance of economic, monetary and physical impacts reported in IPCC AR5 (2014) may result from lack of research in this area and a predominance of natural scientists and economist among IPCC authors (Carey et al., 2014), rather than from lack of change in ecosystems or their services. More attention should be paid to the relationship between loss and damage in ecological communities and ecosystem services. Climate change is already having an impact on ecosystems and on the individual species within them (IPCC, 2014). Phenological observation of species across a wide range of ecosystems indicates that “many terrestrial, freshwater, and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances, and species interaction” (IPCC, 2014). However, responses vary between species, with not all species responding at the same rate and in the same manner (Zavaleta et al., 2009). Shifts in geographic ranges vary, according to the species’ capacity to migrate, which is often constrained by physiology, competition, geography, anthropogenic pressures or competition. Rates of change may differ by region or even altitude. For example, changes in forest species composition in “lowland areas lag behind highland due to greater ability for local persistence as climate warms, reduced opportunity for escape and habitat fragmentation” (Bertrand et al., 2011 p. 518). Species’ specific responses to changing climatic conditions are likely to result in the creation of non-analogue communities – novel combinations of species that do not currently co-occur (Urban 2012). Altered species interactions



and biodiversity can in turn affect ecological communities and ecosystems processes, such as the cycling of material (Chapin et al., 1997; Worm et al., 2006; Walther et al., 2002; Zavaleta et al., 2009). However, greater elaboration of the specific mechanisms through which climate change impacts species, ecosystems and their services (the arrows in Figure 1) is needed.

The interaction between climate change and other stressors also needs to be assessed and the impact on ecosystem services evaluated. Noting the lack of evidence for climate mediated migration in trees, Walther et al., (2002 p. 395) conclude, “the modern landscape provides little flexibility for ecosystems to adjust to rapid environmental change...human activity has rendered increasingly impassible”. According to Chapin et al. (2000) land use change may have the largest global impact on biodiversity, followed by climate change, nitrogen deposition and finally, species introductions. This is supported in the Peruvian case study: Baraer et al. (2012 p. 142) note that the decrease in dry-season stream discharge from glaciers in Peru “Cannot be attributed fully to the change in glacial cover, as other factors (e.g. changes in land use, agriculture practices or population density) also might have affected regional river discharge regimes.”

## **E. Conclusion**

A review of the science in the IPCC AR5 report (2014) and data from a Peruvian case study indicate that loss and damage in ecosystem services is occurring with impacts for human livelihoods and well-being. Ecological complexity has thus far been overlooked in formulations of loss and damage. While it is hard to predict changes, it is clear that ecosystems are already experiencing impacts from climate change.

The impacts for ecosystem services may be both positive and negative. For example, in areas with glaciers, an accelerated rate of melting will bring a short-term surge in water supplies followed by long term declines. Mixed trends have been documented in ecosystem services in Europe, such as “increases in forest area and productivity while at the same time there have been declines in soil fertility and an increased risk of forest fires” (Schroter et al., 2005 p. 1335). These changes in services are characterized by complexity across space and time.

Loss and damage in ecosystems services is an improved starting point for better understanding the feedbacks between changes in ecosystems and human well-being and on possibilities for adaptation. Social, technological and economic factors have the potential to buffer the impact of declining ecosystem services on human well-being. For example, increased use of bed nets could help overcome the impact of decreased natural regulation of malaria vectors due to changes in temperature or rainfall. It could be possible to create highland reservoirs to stabilize the cycle of seasonal runoff in Peru (Bradley et al., 2006). Behavioural adaptation could also take place, as exemplified by the Proyecto Regional Andino de Adaptación initiative, which works towards increasing the resilience of the ecosystems and the local economy against the impacts of melting glaciers (Ordoñez et al., 2010). Fair and adequate policies should also be implemented to protect water rights, as there is likely to be an increasing reliance on mechanisms to capture and save water. Ultimately, minimizing loss to ecosystem services may provide a cost effective way to minimize loss and damage to human systems. Support for maintenance of ecosystem services should become a central

focus of the Warsaw International Mechanism. This would help to reduce risks,

build resilience and support human development.

## F. References

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Livelihoods are the lattice upon which all human organization hangs, and some of the worst-case scenarios of global change – displacement, migration, conflict and famine – all centrally concern the problems that people face in sustaining productive livelihoods.

The 2013-2014 Resilience Academy is a group of 25 international researchers and practitioners who have recognized that dangerous global change is a threat to the livelihood systems of the world's poor. The Academy met twice, in Bangladesh and Munich, Germany, and developed a set of working papers as an evidence base for the concepts and practices that we, as a cohort of colleagues, propose for addressing this pressing challenge.

