

Theme: Theme: Global challenges for water governance

# Loss and damage debate and the global footprint

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## Abstract

Climate change induced natural disasters are increasing, and more than three out of four of all kinds of natural disasters are water related ((Guha-Sapir, Below et al. 2009). Loss and damage from the water-related disasters are common, however, what is uncommon is the accelerated intensity and frequency of the disasters that the world is experiencing over the last few decades. IPCC's Assessment Reports (SREX and AR5) confirms that it is virtually certain that the frequency and intensity of the natural disasters will be more intense in the coming years (IPCC 2012, IPCC 2014). However, there are uncertainties associated with the magnitude, spatial and temporal scale of projection; as well as there are limits to the traditional methods, i.e., adaptation and mitigation, for managing negative impacts from climatic norms and stressors or extremes (Klein, Midgley et al. 2014). United Nations Framework Convention on Climate Change (UNFCCC) established a work programme on loss and damage in the seventeenth session of the Conference of the Parties (COP), with an overall objective of minimising the loss and damage through appropriate assessment, addressing loss and damage, and identification of the role of the Convention (United Nations 2011). This paper assesses the global footprint of the water related (climatological, hydrological and meteorological) disasters in terms of loss and damage. It also explores deep into the global loss and damage debate for identifying the commonalities and differences of loss and damage with the conventional adaptation and mitigation approaches.

**Keyword:** climate change, loss and damage, natural disasters, water resources, frequency, intensity, economic loss, non-economic loss

## Introduction

Climate change induced loss and damage is evident and increasing (IPCC, 2014). Hydrospheric components and hydrological processes are affected by any perturbation in the climatic processes, i.e., changes in the air temperature, imbalance in the bio-geo-chemical cycles, transformation in the land use, etc. (Bates, Kundzewicz et al. 2008). However, it is imperative that the anthropogenic responses or human contributions are the keys to the recently observed climatic changes and variability. The global disaster

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database shows that more than two third of all kinds of disasters are hydrological, climatological and meteorological (Guha-Sapir, Below et al. 2009). It is also evident that the frequency and magnitude of natural disasters are mounting in all dimensions of spatial and temporal scale (IPCC, 2014). Global climate models are also projecting that the situations will be far more aggravated in the coming future. Loss and damage, both in economic and non-economic terms, is also trending, and the global projections are depicting the same (Morrissey and Oliver-Smith 2013).

It is realized persistently that the current efforts for controlling the root causes of climate change, i.e., mitigation based approaches for reducing the greenhouse gas concentrations, or the adaptation based approaches to adjust or to minimize the exposure of the natural disasters are not enough to avoid the risk of loss and damage from natural disasters (United Nations 2012, Roberts, Geest et al. 2014). Even though the perceived level of preparedness was adequate, the coast of California in the United States experienced the economic damage of USD 96 billion only from one incidence of the cyclonic storm, the Katrina (Townsend, Rapuano et al. 2006). Similar to that, incremental magnitude of loss and damage resulting from global incidences of slow onset disasters like salinity intrusion, monsoon flood, etc. and incidences of rapid onset disasters like storm surges, flash flood, etc. has becoming evident in all around the globe with far more unprecedentedness than ever (IPCC 2012).

However, the global policies that directly or indirectly addresses climate change and disaster management have not adequately addressed the importance of water management as one of the principle adaptation for combating the climate change induced loss and damage. Although the United Nations Framework Convention on Climate Change (UNFCCC; (United Nations 1992)) is enacted to minimize the negative impacts of climate change, however, the implementation focus has been given much on mitigation based approaches despite their effectiveness is questionable when the global scale evidence of persistently increasing level of loss and damage is evident. Adequacy and appropriateness of the current initiatives, mostly focusing on mitigation, is also dubious when the global projections are depicting certain level of increase in the temperature (e.g., 1.5 degree Celsius) and propagation of negative impacts even we stop emitting and go back to the pre-industrial level. Other global agreements concerning sustainable development, disaster management and achieving the global targets for providing the basic necessities for living indirectly address climate change, but not addressing the management of water resources for minimizing the negative impact of climate change.

It is also increasingly realized that the current scale of risk reduction based approaches are not enough to address the current future scale of vulnerability and exposure (United Nations 2013). Transformation is needed, both in terms of retrofitting of structurally based approaches and mainstreaming climate change related considerations in the policy and non-structural disaster management approaches. Other approaches for disaster management may be found useful in managing the unprecedented risk paradigms. At the same time, ecosystem-based adaptation approaches with very low level of residual impacts may render the multiple benefit of adaptation and mitigation need to be explored through the lens of water resources management.

This paper sets the premise by discussing the novelty of the concept of loss and damage in the UNFCCC process. Then it provides the quantitative evidence for demonstrating the vulnerability of the water resources of climate change induced natural disasters. This paper also identifies the gap in the global agreements to address the importance of water resources management. Finally, a section is dedicated to

some generalized approaches to address loss and damage from natural disaster affecting the water resources.

## Objective and research questions

The principle objective of this paper is to provide quantitative evidence for demonstrating the risk of climate change induced loss and damage from hydro-meteorological disasters. It is imperative that the loss and damage from water-related disasters are also increasingly evident due to inaction, i.e., not addressing the management of water resources from a comprehensive manner. In this regard, the paper also set the objective to explore the gaps in the global agreements and to propose a range of generalized approaches for addressing loss and damage from water-related disasters.

The paper answers a number of questions in pursuance for achieving the principle and complementary research objective. The research questions are:

- What are loss and damage? Why loss and damage are considered as a new school of thought other than adaptation and mitigation?
- Is it factual that the water resources is mostly exposed the sector to loss and damage from natural disasters?
- How the global policy regime is addressing the fact?
- What is the range of approaches for addressing the loss and damage in the water sector?
- What are the gaps and what need to be addressed?

## Methodology

Two principle databases were utilized for the assessment of a global footprint of loss and damage. Global disaster dataset is collected from the EM-DAT's International Disaster Database (Guha-Sapir, Below et al. 2009). However, the damage statistics available from the disaster database is unadjusted and need to be adjusted to remove the bias of global population increase, economic growth and infrastructural growth over the period. In this regards, the unadjusted damage value is normalized with respect to population, inflation (as a % of GDP deflator) and personal wealth (per capita GDP is considered as a proxy) over the time period (1990-2013). However, the comparability between the unadjusted and normalised damage at the global scale couldn't be achieved because of the unavailability of the countrywide population and economic data. In the global scale, a total of 193 countries those who are the country party in the UNFCCC process are considered for unadjusted damage calculation. On the other hand, for normalized damage calculation, a total of 122 country parties are considered for normalized economic damage calculation.

The global economic damage estimates are standardized using the conventional approach to normalizing natural disaster damage by Roger Pielke Jr. and co-authors (Pielke, Landsea et al. 1999, Pielke, Rubiera et al. 2003, Jr., Gratz et al. 2008, Roger A. Pielke, Gratz et al. 2008, Vranes and Jr. 2009) using the following formula.

$$\text{Normalised Damage}_t = \frac{\text{GDP Deflator}_s}{\text{GDP Deflator}_t} \times \frac{\text{Population}_s}{\text{Population}_t} \times \frac{\text{Wealth per capita}_s}{\text{Wealth per capita}_t}$$

where  $s$  is the (chosen) year one wishes to normalize to,  $t$  is the year in which damage occurred, the Gross Domestic Product (GDP) deflator adjusts for inflation (i.e., change in producer prices), while the remaining two correction factors adjust for *changes in* population and wealth per capita.

Global population, inflation adjusted GDP estimate and GDP per capita as a proxy of wealth per capita data are collected from the World Bank's open data portal (The World Bank 2015). Details of the statistical tests and hypothesis are described in the relevant sections of the data analysis and discussion.

The global loss and damage debate is explored through secondary literature review. All the relevant negotiation documents available through the UNFCCC portal is reviewed to track the progress in the negotiation process related to adaptation and mitigation. Evolution of the concept of loss and damage is carefully explored to check the validity of the hypothesis that current progress in the adaptation and mitigation processes are not sufficient in addressing the loss and damage. Loss and damage doesn't have any unanimously agreed definition, thus the paper has also attempted in clarifying 'loss' and 'damage, in general, terms as well as from the perspective of the UNFCCC's negotiation window, i.e., beyond adaptation and mitigation. Finally, the possible range of loss and damage in the water sector resulting from climate change norms and stressors is summarised and a comparative analysis is conducted for identifying the commonalities and differences in loss and damage with the conventional adaptation and mitigation approaches.

## Symbolic pathways to climate change induced loss and damage

Warming of the surface air is the first order impact of climate change. Consequently, the second order impact resulting from the changes in the air temperature is observed in the changes in water level in the sea due to thermal expansion of seawater and melting of permafrost and glaciers. Second order impact is also detected in the anomaly of the precipitation pattern, both in terms of more and less rainfall as variation over the temporal scale. Another second order impact of warming is the increased incidences of storms formed in the land (e.g., tornado and nor westers) and water (e.g., cyclones and typhoons). The third order impacts become evident in the water, land, social and economic sectors like health, agriculture, industry, etc.. For example, if the sea level rises in the coastal region, valuable land resources may be engulfed by seawater. In turn, the salinity of the land may be increased affecting the freshwater resources available in underground aquifers and surface water reservoirs, rivers and lakes. Similarly, changes in the evaporation from land, water, and vegetative sources may enhance the occurrences of drought, i.e., the scarcity of available water. On the other hand, if the rate of evaporation is increased and the formation of convective clouds enhanced then there may be more water during the rainy season that is an indication of flood like situation. Furthermore, complexity arises when the riverine flood situation couples with the rising sea or high water level in the estuary due to the formation of a sea storm. Loss and damage are mostly evident as the third order impact to the social and economic sectors. Rapid onset events, like a flash flood, storm surges, and inland storms usually cause direct loss of life and primary productions from the agricultural sectors, like crops, fisheries, etc. Rapid onset events, cause damage to infrastructures like road and railway networks, buildings, and electric supply, water supply, and sanitation facilities. Similarly, the slow onset events like flood, drought, and salinity intrusion, cause loss and damage to similar social and economic components. However, loss and damage from the slow onset events are far more creeping than that of the rapid onset events in the long term. A schematic causal relation diagram is drawn as a simplification effort to portray the complexity paradigm of loss and damage (see figure 1).

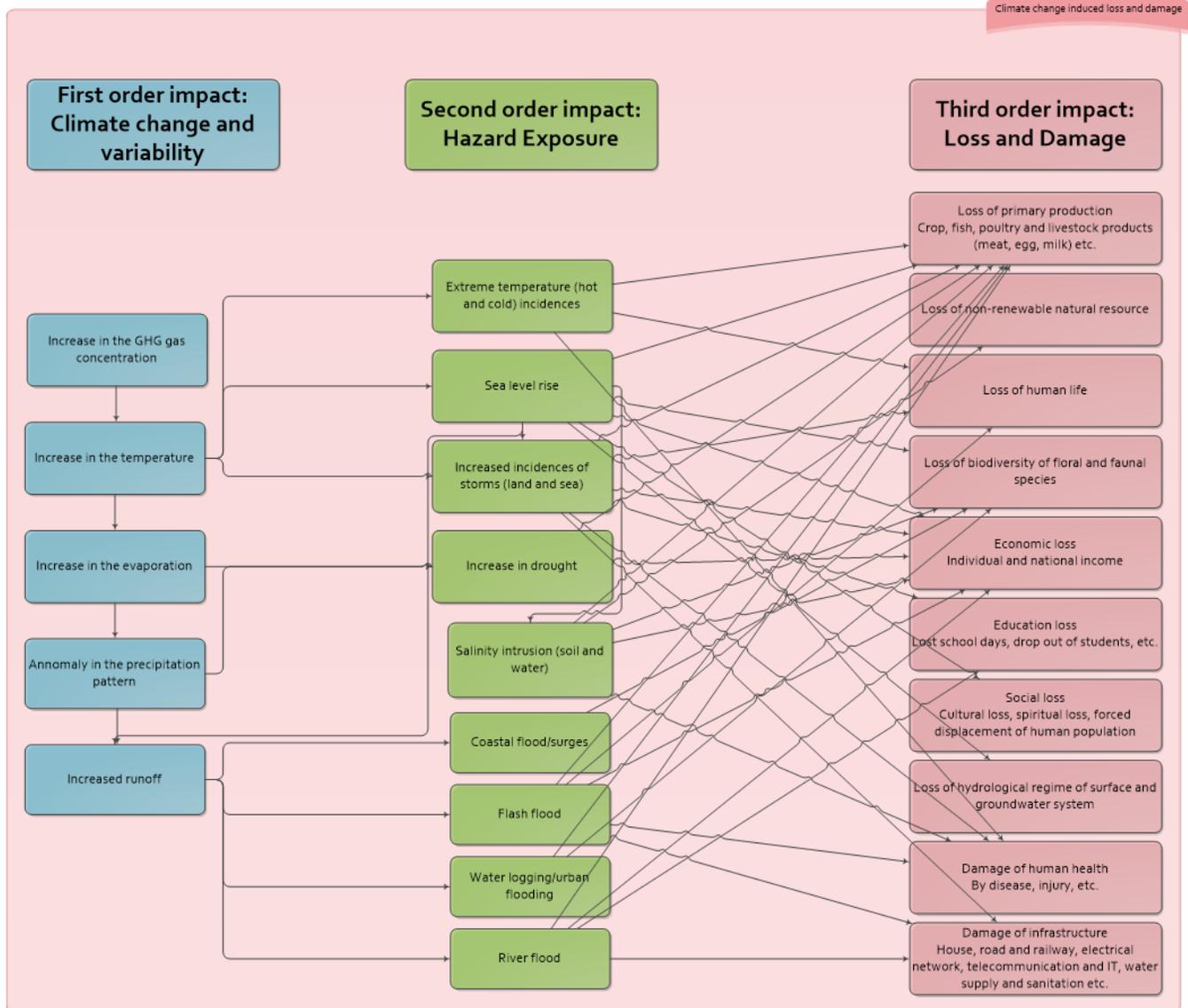


Figure 1: Climate change impact and the plethora of loss and damage

## Analysis and discussion

Climate change induced loss and damage is not a new issue. Under this context, the term 'loss and damage' are synonymous to 'impact' of climate change, mostly covering the tangible and economic dimensions. However, the context of the work programme on loss and damage in the UNFCCC process is relatively new and welcoming debates from various grounds. The ongoing debate on loss and damage has taken a new height when the key terms 'loss' and 'damage' is representing much more complex and broader issues than the original meaning or classical definition. In the UNFCCC process, some of the country parties define loss and damage as an initiatives 'beyond adaptation and mitigation'. On the contrary, some others consider loss and damage as a financial instrument focusing on liability and compensation, and so on. However, the principle caveat is the universally agreed definition of loss and damage is yet to be adopted in the UNFCCC process. The hand book for damage and loss assessment (DaLa) prepared by the ECLAC provided the classic definition 'loss' and 'damage' (Economic Commission

for Latin America and the Caribbean 2003, United Nations 2012). It defines “*damage as the monetary value of partially destroyed assets, assuming that assets will be replaced in the same condition-in quantity and quality-as before the disaster and losses as changes in the flow of goods and services that will not be forthcoming until the destroyed assets are rebuilt, over the time span that elapses from the occurrence of the disaster to the end of the recovery period*”. However, this classical definition doesn’t capture the intended robustness of the UNFCCC’s loss and damage work programme. Under this circumstance, Warner et al. provided a working definition of loss and damage from the perspective of risk continuum and limit to adaptation and coping (Warner, Geest et al. 2013). Their definition stated, “*Loss and damage refer to negative effects of climate variability and climate change that people have not been able to cope with or adapt to*”. This definition underlines the novelty of loss and damage work programme as ‘beyond’ adaptation and mitigation based approaches. The classical definition represents loss and damage as a proxy for ‘impact assessment’. On the other hand, the later and recent working definition recast the concept of loss and damage to the lens of ‘management of impact’. Understanding the complexity and dubious nature of the loss and damage continuum, the UNFCCC work programme on loss and damage primarily set three main components to deal with: (i) the assessment of loss and damage, (ii) identifying the range of approaches for addressing loss and damage, and (iii) identifying the role of the Convention (UNFCCC) to facilitate the implementation ((United Nations 2011, United Nations 2011, United Nations 2011, United Nations 2011, United Nations 2011, Warner, Kreft et al. 2011). Figure 2 portrays an overall conceptualization of the loss and damage work programme (see figure 2).

Mainstreaming climate change induced loss and damage in the UNFCCC negotiation process were not easy. Back in 1992, on the eve of the formation of UNFCCC, Vanuatu on behalf of the Alliance of Small Island States, proposed for activating an insurance pool as a risk transfer mechanism to address loss and damage associated with sea level rise. That proposal was not accepted for inclusion and then it took long eighteen years to reach a common consensus at COP 17 in Durban on different components of loss and damage work programme (United Nations 2011). The country parties have decided to establish an international mechanism for loss and damage at COP 18 in Doha on 2013, to improve understanding, strengthen coordination and enhance action and support (United Nations 2012). Finally, at the nineteenth session of COP in Warsaw, institutional arrangements to address loss and damage were created with the establishment of the Warsaw International Mechanism for Loss and Damage (WIM)(Roberts, Geest et al. 2014). However, the progress in the loss and damage negotiation process still lack the specificity in managing the finance for loss and damage, modalities for institutional setup under the WIM, role and differentiated responsibilities of different country parties, linkage with mitigation, etc. It is also to be noted from the perspective of this paper that effective management of water resources has never received special attention in the UNFCCC’s overall process or explicitly under the loss and damage work programme. Although it is imperative that most of the climate change induced loss and damage propagate through water and appropriate management water resources often tend to be the stand-alone practicable solution for risk reduction, but it is never been acknowledged in the global political domain of climate change and loss and damage debate.

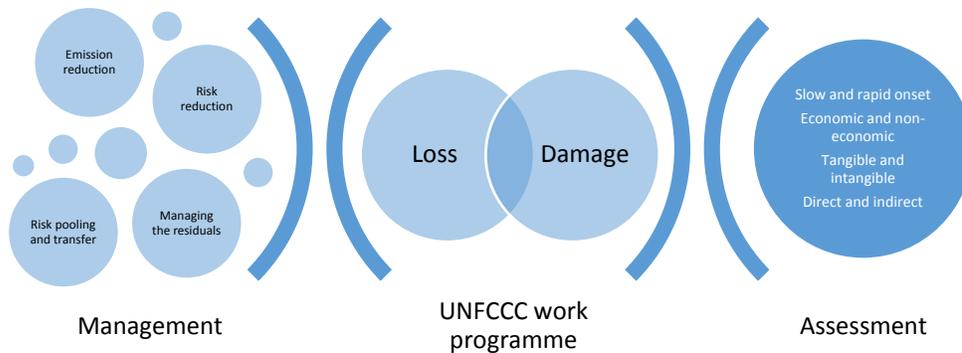


Figure 2: Range of approaches for assessing and addressing loss and damage

### Assessment of damage

It is virtually certain that the frequency of disasters, irrespective of the disaster sub-group, is on the rise. It is alarming to note that each year the globe is experiencing around ten more disasters. The trend statistics is statistically significant at 99% confidence interval. Till the end of last century, there was a prominent increase in the trend line (see figure 3). But the cumulative annual frequency dropped in the following decade. It triggers a doubtful query whether or not the rising trend is affected by the bias of excessive weight of frequency in the previous decade or not. To answer this query, an independent sample t-test is conducted where the hypothesis of equality of variance is checked through the Levine's test, and the hypothesis assuming the equality of means is validated by the conventional t-test. Year 1997 is considered as the cutoff point for diving the time series in two groups: 'before 1997 (<1997)', during and after 1997 (=>1997)'. It is revealed from the t-test that the mean annual frequency of disasters has increased from 217 incidences to 418 incidences. The change in the mean and the variance is also statistically significant at 99% certainty level. However, it is to be noted that not all these disasters are driven by climate change, or the water related hazards drive the disaster incidences. Some of the disasters are directly driven by human action or not directly influenced by the climate change and variability. Hazards categorized under the biological and geological sub-group can be excluded for assessing the impact of climate change or measuring the loss and damage from water-related disasters.

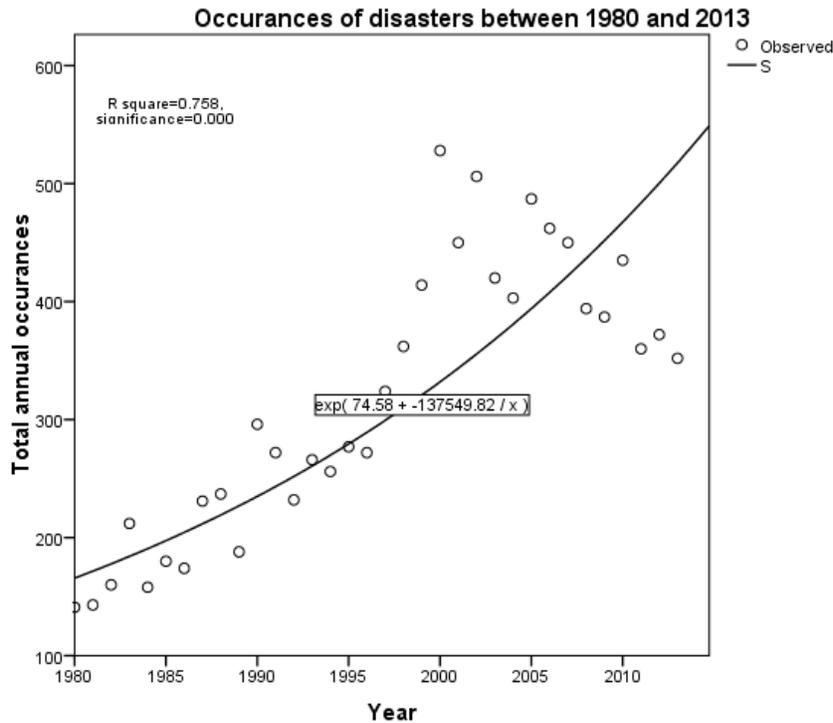


Figure 3: Historical trend in the frequency of natural disasters

An exploratory analysis of the disaster subgroup reveals that more than three out of every four disasters are either hydrological, meteorological or climatological disasters (figure 5). All the broad type and sub-type of disasters under those three sub-groups can be clustered as water-related disasters, as most of these disasters propagate through hydrosphere, or those are driven by the components of the hydrological cycle. Among the water-related disasters, there may be some confusions in considering the occurrences of wildfire as a water-related disaster. However, wildfire mostly occurs as a consequence of excessive warming and prevalence of dryness in the forest areas and dryness can be considered as a proxy of water scarcity situations or indications of excessive loss of water from the ground and vegetative surface.

Among the all kinds of water related disasters, hydrological disasters are more frequent (48% of total occurrences in all kinds of disaster) followed by the meteorological and climatological disasters (figure 5). However, this findings doesn't undermine the potential severity of non-climatic disasters, as the relative cumulative frequency of biological, geophysical and climatological disasters is quite identical (around 10%). It is also imperative that the relative frequency estimates are not the proxy for the respective severity, i.e., a low frequent disaster event may have a high propensity for loss and damage.

Annual trend in the frequency of water related disastfers between 1980 and 2013

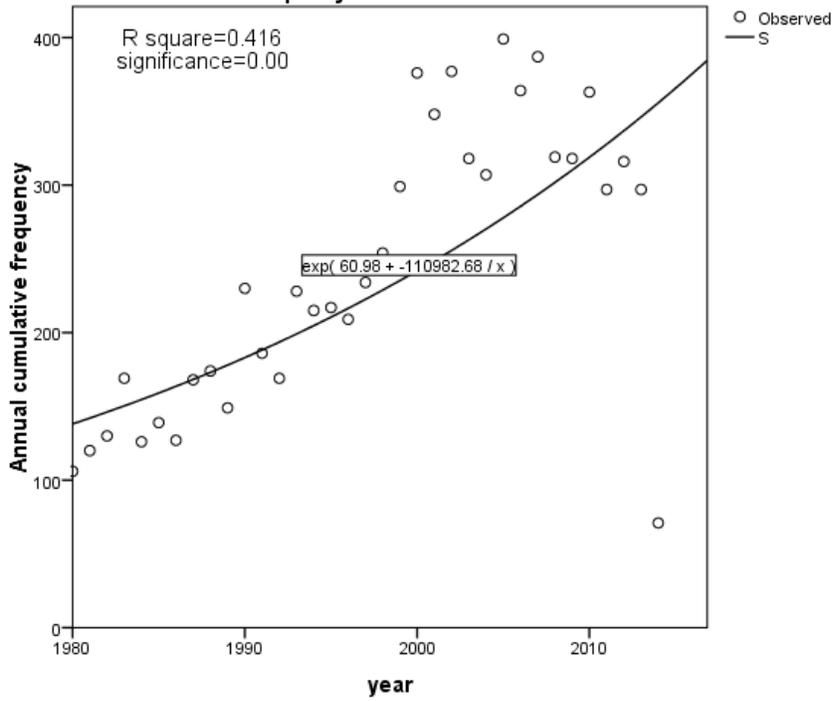


Figure 4: Historical trend in the frequency of water related disasters

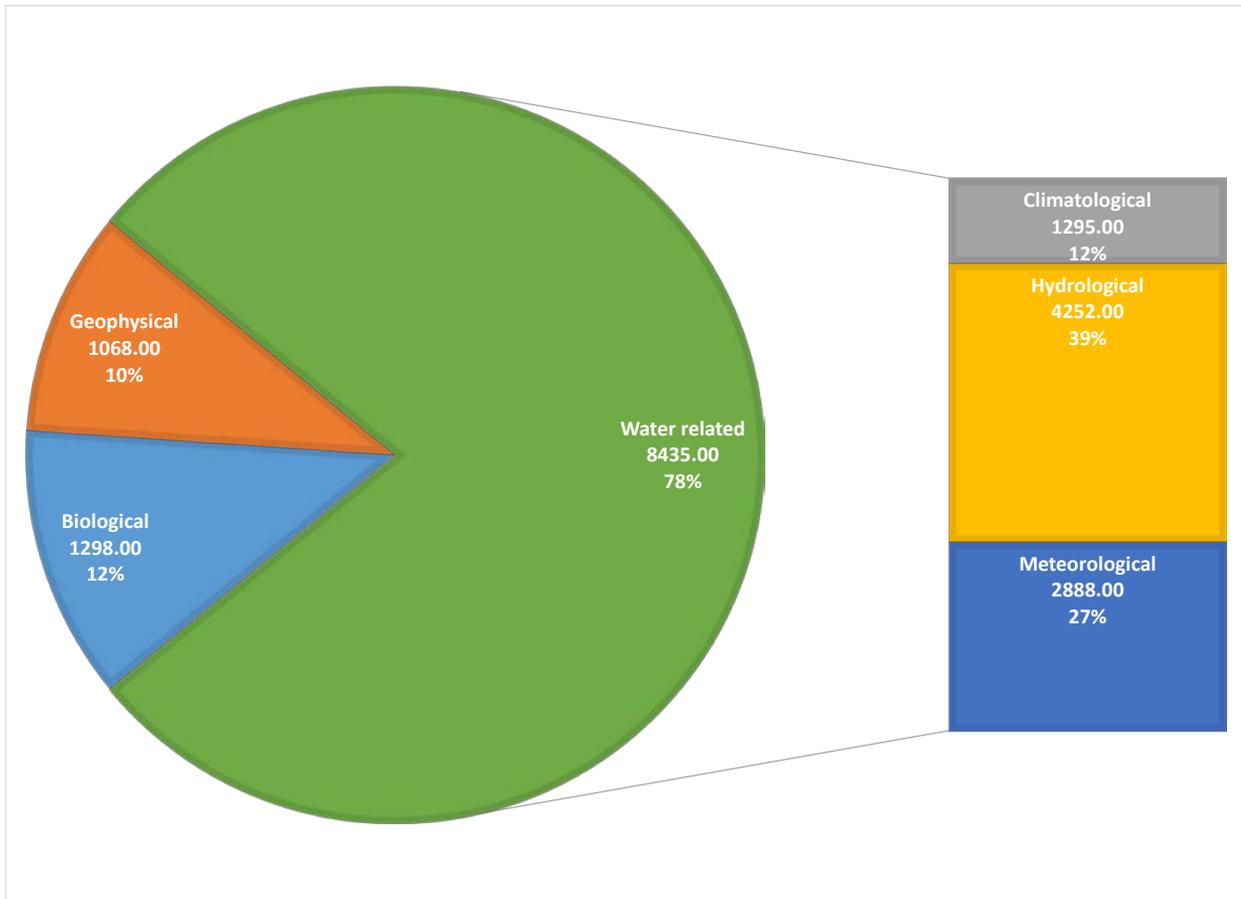


Figure 5: Proportion of different kinds of disasters in terms of cumulative frequency of occurrences

Among the hydrological disasters, the flood is the most frequent. Each year the world experiences around 70 general flood events. Tropical cyclones and local storms are the most occurring, at the rate of 45 events/year and 21 events/year respectively. Similarly, drought followed by the cold wave and forest fire incidences are recorded as the most frequent among climatological disasters that occur in the annual rate of 15, 9 and seven respectively.

It is alarming to note that almost all the different kinds of flood incidences including the general flood, flash flood and coastal flood inundation resulting from the storm incidences have been increasing over the period that are also statistically significant. Cyclone and the local storm events have been on the rise as well. However, the trend is statistically significant only for the local storm events. Although the frequency of extreme winter conditions is not prominent, however, the increasing trend is virtually certain. Similarly, the rising trend of the cold wave is also statistically significant.

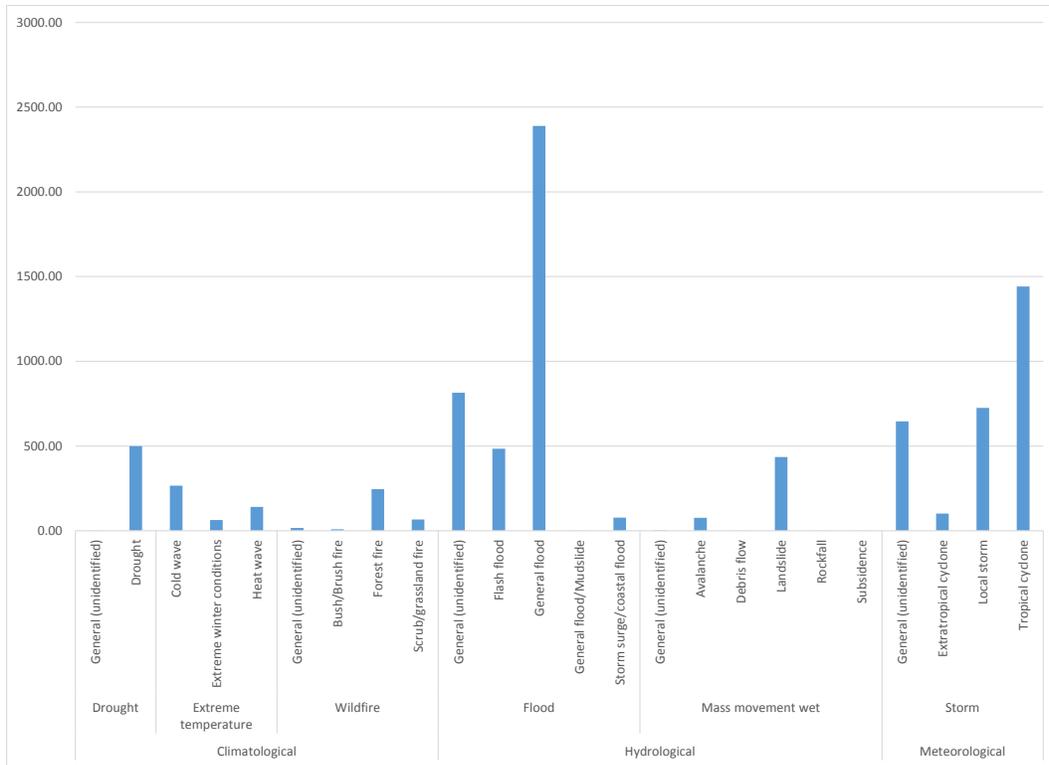


Figure 6: Cumulative frequency of water related disasters

Table 1: Curve estimation results from regression analysis of climatological, hydrological and meteorological disasters

Disaster category	Disaster sub-category	Disasters	best-fit curve estimation	Model Summary					Parameter Estimates	
				R Square	F	df1	df2	Sig.	Constant	b1
Climatological	Drought	Drought	S	0.00	0.16	1.00	33.00	0.69	10.74	-16433.99
	Extreme temperature	Cold wave	S	0.38	19.26	1.00	32.00	0.00	120.34	-237170.00
		Extreme winter conditions	S	0.51	11.65	1.00	11.00	0.01	115.32	-228545.04
		Heat wave	S	0.13	3.78	1.00	26.00	0.06	59.91	-117058.68
	Wildfire	General (unidentified)	S	0.01	0.05	1.00	5.00	0.84	40.52	-80135.95
		Bush/Brush fire	S	0.15	0.73	1.00	4.00	0.44	-129.33	260756.39
		Forest fire	S	0.01	0.23	1.00	30.00	0.63	16.46	-29404.30
		Scrub/grassland fire	S	0.06	1.72	1.00	26.00	0.20	-31.11	63381.68
Hydrological	Flood	General (unidentified)	S	0.39	18.22	1.00	28.00	0.00	-135.50	276239.09
		Flash flood	S	0.43	23.84	1.00	31.00	0.00	141.59	-278384.95
		General flood	S	0.69	73.19	1.00	33.00	0.00	209.80	-411568.37
		Storm surge/coastal flood	S	0.36	11.46	1.00	20.00	0.00	101.33	-200226.91
	Mass movement wet	Avalanche	S	0.01	0.22	1.00	26.00	0.64	11.23	-20714.27
		Landslide	S	0.13	5.08	1.00	33.00	0.03	47.43	-90025.24
Meteorological	Storm	General (unidentified)	S	0.00	0.12	1.00	27.00	0.73	16.32	-26806.42
		Extratropical cyclone	S	0.04	0.44	1.00	10.00	0.52	-56.78	117781.07
		Local storm	S	0.48	29.93	1.00	33.00	0.00	81.68	-157343.94
		Tropical cyclone	S	0.06	2.27	1.00	33.00	0.14	26.81	-46282.24

The independent variable is year.

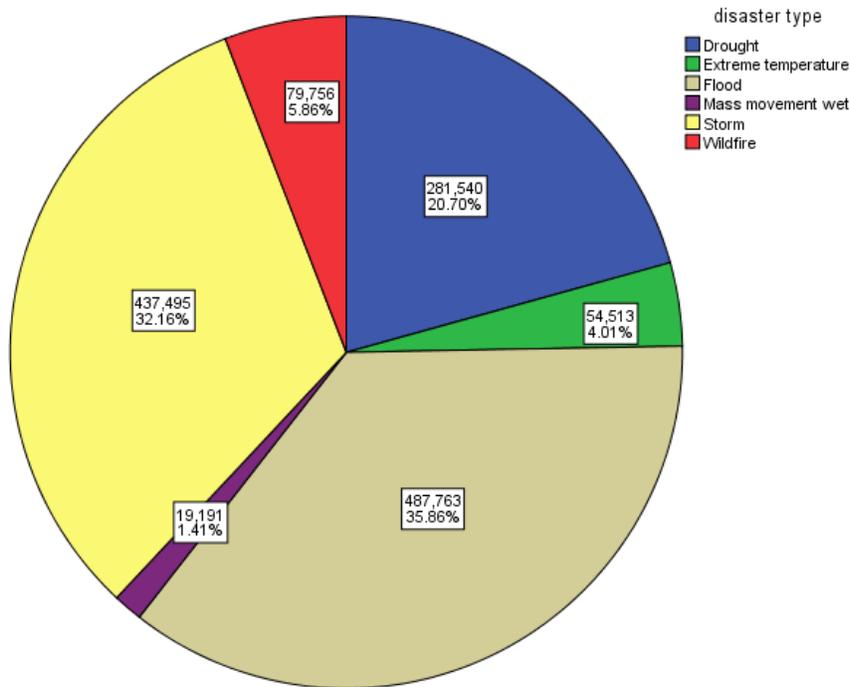


Figure 7: Cumulative damage worth of water related disasters

Similar to the relative frequency estimates, the cumulative damage from flood incidences is the most prominent (figure 7). Damage figure is normalized for ensuring the comparability across the scale. Average annual normalized flood damage worth USD 14.75 billion (. Damage from storm incidences is also notable which incur average annual normalized damage of USD 13.2 billion. Drought incidences are not that frequent as flood and storm. However, the average annual normalized damage worth USD 8.5 billion. Although the hydrological disasters are the most frequent one and climatological disasters are the least. However, the contrasting scenario prevails when the severity of the incidences are taken into account. On an average, each of the climatological incidences cause damage of USD 228 million, followed by the meteorological incidences causing damage of USD 140 Million and hydrological incidences incurring damage worth USD 82 million. Combining all the disaster incidences, each year the cumulative damage stands at USD 40 billion. It is also revealed that irrespective of the disaster subgroup the damage worth has been increasing over the period that is also statistically significant in the range of 95 to 99 percent confidence interval.

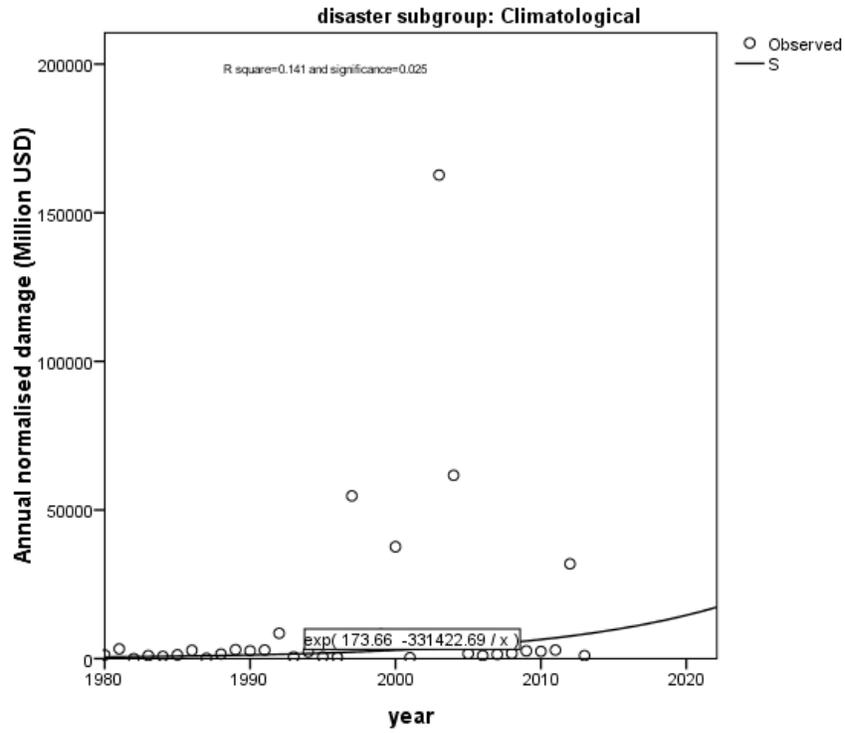


Figure 8: Historical trend in the climatological disasters

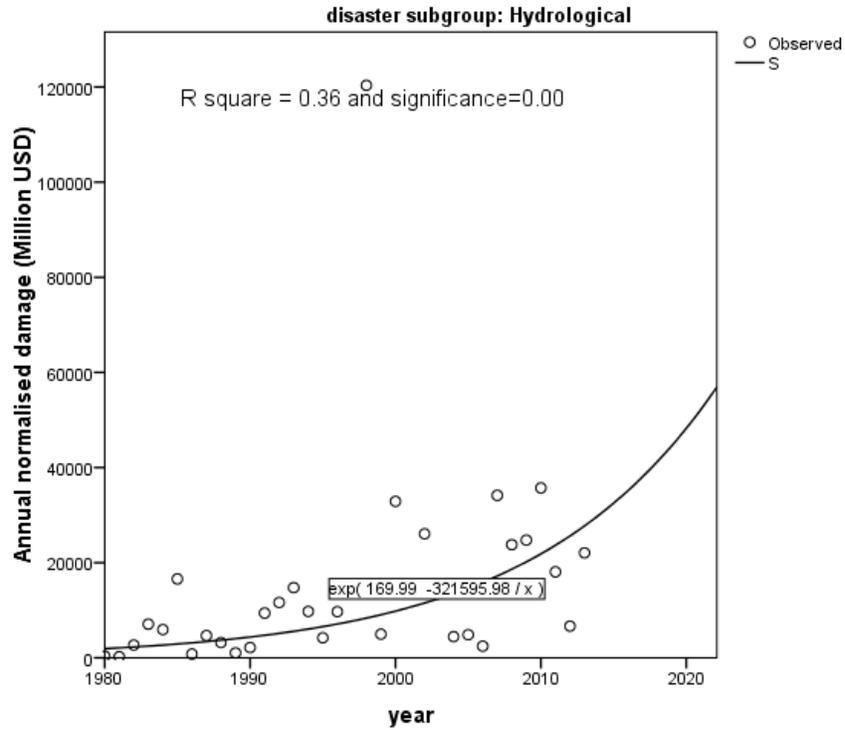


Figure 9: Historical trend in the hydrological disasters

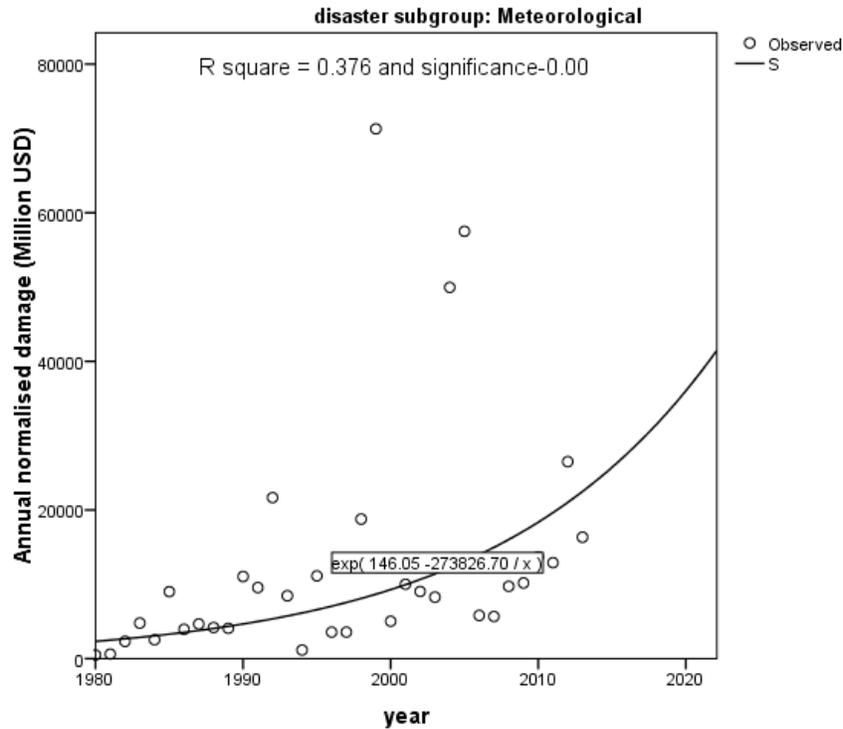


Figure 10: Historical trend in the meteorological disasters

Similar to the frequency of historical damage worth for all the climatological, hydrological and meteorological disasters have shown prominent rise (figure 8,9 and 10). Similar to the result of the independent t-test, it is also revealed that the change in the mean and variance of mean annual damage statistics for the period 1980-1996 and 1997-2013 is statistically significant (at 95% certainty level). It is notable that the mean annual damage worth for the climatological disasters have increased more than ten times, from USD 1.93 to 22.5 billion in the later period. Similar statistics regarding the hydrological and meteorological disasters have also increased from USD 6.1 to 23.6 billion and USD 6.0 to 19.6 billion respectively.

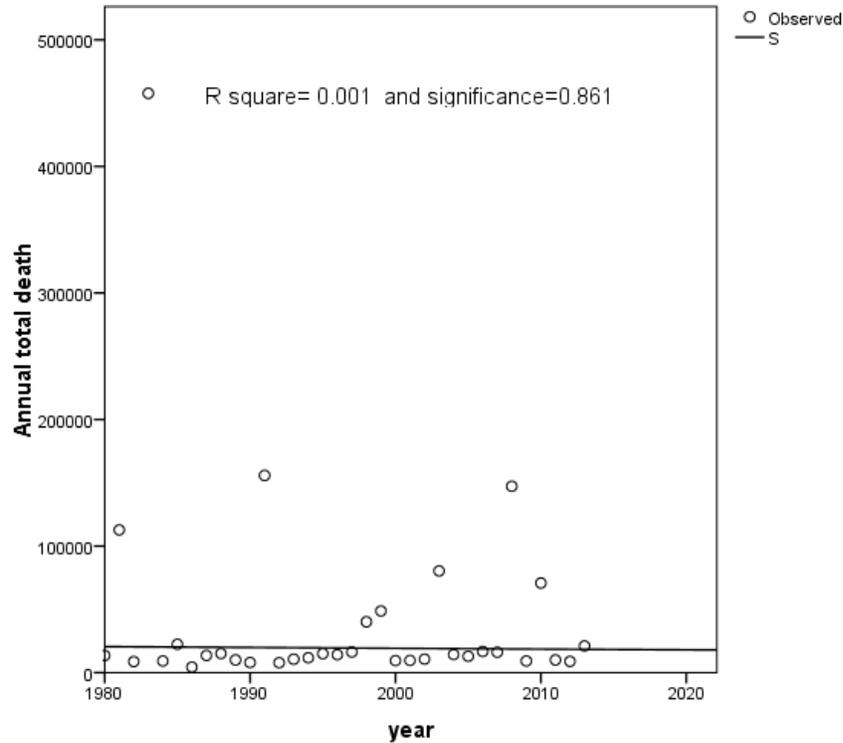


Figure 11: Historical trend in the cumulative death toll by natural disasters

### Loss assessment

Annual loss is assessed in terms of human death toll as well as number of affected people who have lost their home, lost health integrity due to injury or needed external assistance to cope with the loss from disasters. Unlike the frequency and damage estimates, the average annual fatality of human has been decreased over the analysis period (not statistically significant). Although the statistical evidence is not statistically significant, the mean annual death toll have decreased from 52,390 to 31,925 death incidences per year before and after 1997 (figure 11). Conversely, the average annual number of the total affected population has shown a statistically significant rise over the analysis period. The number of the affected population have increased from 147 million per year to 207 million per year (figure 12).

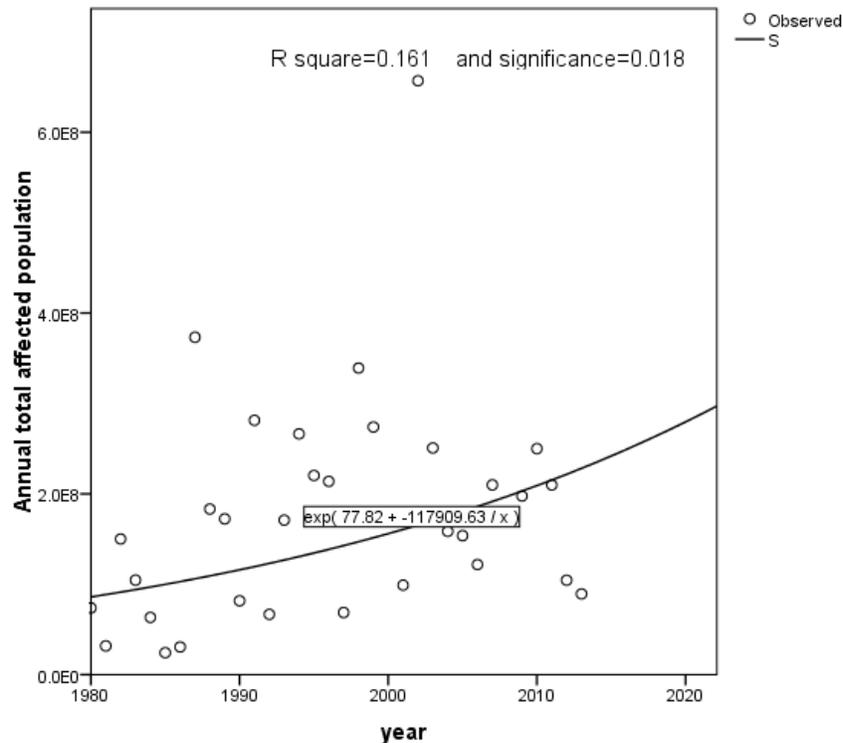


Figure 12: Historical trend in the frequency of affected population by water related disasters

## Range of approaches for addressing loss and damage

(Verheyen 2012) provided a useful insight into different types of loss and damage that is relevant to the management of loss and damage. The classification referred to three types of loss and damage: avoided, unavoided and unavoidable. Avoided loss and damage is manageable by mitigation and adaptation, whereas unavoided loss and damage arises due to inadequate mitigation and adaptation efforts, and lastly, some loss and damage that is unavoidable no matter how ambitious mitigation and adaptation efforts are. Similarly, Warner et al. (2013) provided insight into the main reasons for occurring loss and damage, which are: loss and damage occurs when existing efforts for coping and adaptation are inadequate, adjusting to the climatic stressors have costs that are not regained, adopted measures have residual long term negative impacts and also when no measures are adopted (Warner, Geest et al. 2013). The paradigm of 'risk' provides further insight into the assessment and management of loss and damage from an ex-ante (futuristic) perspective. Risk comprises of three principle components: hazard, exposure and vulnerability (IPCC, 2007). Further, the vulnerability can further be sub-divided into two components: sensitivity and adaptive capacity. The classical formulation of risk for serving the assessment purposes are as follows:

$$\text{Risk } (R) = \text{Hazard } (h) \times \text{Exposure } (e) \times \text{Vulnerability } (v)$$

$$\text{Vulnerability } (v) = \frac{\text{Sensitivity } (s)}{\text{Adaptive Capacity } (a)}$$

$$\text{Therefore, Risk} = \frac{\text{Hazard} \times \text{Exposure} \times \text{Sensitivity}}{\text{Adaptive capacity}}$$

The above formulation implies that the risk of loss and damage can be addressed either by reducing the hazard, exposure and sensitivity dimensions or also by enhancing the adaptive capacity, individually or exclusively by suitable combination of all. However, there are certain types of risk that can't be avoided or managed. Those are generally termed as 'residual risk'. The classical formulation of risk does not cover the issues regarding the management of residual risks.

Considering all the principles stated above, there are five possible range of approaches for addressing the loss and damage: risk reduction, risk retention, and risk pooling or transfer, hazard reduction or mitigation, management of residual risks. In the following sections, each of the stated approaches are discussed covering the principles, respective applicability, examples pertinent to water resources management and some indications about the feasibility in terms of design robustness, cost implications, social acceptance and environmental friendliness of the interventions.

Approach	Risk reduction
Relevance with the loss and damage principle	<p>These approaches are intended to manage 'avoided' and 'unavoided' loss and damage. Risk reduction approaches can be subdivided into two categories, structural and non-structural. Structural risk reduction approaches relevant to water management includes retrofitting the height of the flood embankment and drainage infrastructures, etc. Non-structural risk reduction approaches include early warning system, community based disaster management initiatives, and so on. Structural approaches mostly reduces risk by altering the exposure dimensions, e.g., reduce the population exposure living in the flood plain by constructing new flood defence or raising the plinth/base of the key infrastructure above the flood level. Non-structural options mainly address the vulnerability issues, i.e., either by reducing the sensitivity of the exposed element or by enhancing the adaptive capacity of the same.</p>
Specific example	<p>Managing excessive water (flood, storm surge, urban drainage, water logging):</p> <ul style="list-style-type: none"> <li>• Retrofitting of flood defence embankment for more frequent and high intensity flood event</li> <li>• Rehabilitation of drainage channels and control infrastructure to withstand higher level of storm water discharge</li> <li>• Retrofitting of the coastal defence structures to withstand higher frequency and magnitude of storm surge events</li> <li>• Tidal basin management approaches for utilising the sediments to enhance the delta development process and facilitating the natural navigation process</li> <li>• Flood tolerant crop variety development with shorter production period, longer stem (above flood level), adjustment of sowing and harvesting time, etc.</li> <li>• Raising the plinth/base of the housing and commercial facilities, altering the height of the road and railway infrastructure, provision of emergency water supply and sanitation facilities, emergency shelter for human and animals, etc.</li> <li>• Flood early warning system with improved lead time facilities</li> <li>• Preparedness training to facilitate community based flood management options</li> <li>• Incorporating climate change concerns and water management principles in the academic curricula</li> </ul> <p>Water scarcity management (drought)</p> <ul style="list-style-type: none"> <li>• Rainwater harvesting based options for managing agricultural water demand.</li> <li>• Drought tolerant variety development, with low consumptive water demand, more tolerance to heat, cold and fog exposure, etc.</li> </ul>

	<ul style="list-style-type: none"> <li>• Surface water conservation as well as limiting the extraction and use of groundwater based options.</li> <li>• Improving the efficiency of agricultural water supply (e.g., irrigation) through management response, e.g., crop per drop approach, alternative wetting and drying technique, etc. may be adopted</li> <li>• Renewable energy drove option for desalinization of sea water or surface water affected by excessive soil salinity in the coastal region</li> </ul>			
Feasibility	High (+++)	High (+++)	Moderate (++/--)	High (---)
	Design robustness	Financial investment	Social acceptance	Environmental friendliness

Approach	Rick retention
Relevance with the loss and damage principle	Risk retention measures are aimed at enhancing the capacity of the exposed population to absorb the shocks of loss and damage. Unlike the risk reduction approach, these interventions do not directly address hazard specific loss and damage. Rather, the principle focus is given for improving the adaptive capacity through emergency support, launching social safety net programmes and also by introducing microfinance tools and instruments. Under the lens of loss and damage, this particular approach works well when the risk reduction approaches fails due to the unprecedented scale of natural hazards.
Specific example	<p>Emergency support</p> <ul style="list-style-type: none"> <li>• Creation of emergency food bank to combat post disaster situations</li> <li>• Providing food, water and sanitation facilities during and after the disaster event</li> <li>• Provision of emergency support fund as a part of the national development budget, e.g., Government of the Peoples Republic of Bangladesh transfers 1.5% of the development budget to the emergency fund for disaster management</li> <li>• Involvement of the Non-Governmental Organisations during the post disaster emergency support and rehabilitation</li> </ul> <p>Social safety net programmes</p> <ul style="list-style-type: none"> <li>• Aims at reducing the poverty and enhance the standard of living by providing or subsidizing the cost of the basic goods and services, i.e., food, cloth, housing, public health service and education to the particularly vulnerable community. Social safety net programmes are different from the emergency support programmes, as SSPs are not intended to provide free service or aid. In most of the cases, SSPs create the livelihood opportunities for particularly vulnerable communities and provide some subsidies for delivering basic goods and services for living. Food for works programme in South Asia (India and Bangladesh) and Africa (Kenya, Ethiopia) run by the World Food Programme is an example of such programme.</li> <li>• Creation of a disaster management or emergency fund as an integral component of the SSP programme</li> </ul> <p>Microfinance tools</p> <ul style="list-style-type: none"> <li>• Micro-credit programmes are intended to provide financial support to those who are particularly vulnerable and do not have access to the mainstream financial intermediaries (e.g., bank). Micro credit help communities or individuals to get out of the loss and damage from natural disasters. Sometimes, the capacity to</li> </ul>

	<p>cope or adapt get eroded due to repeated incidences of natural disasters and a small amount of financial support may be of great help. Under this circumstance, micro-credit facilities help regaining the capacity to rehabilitate or rebuild the capacity to combat next lag of disaster occurrences.</p> <ul style="list-style-type: none"> <li>• Creation of community based emergency fund from the residue of the loan repayment options enhances the capacity</li> </ul>			
Feasibility	High (+++)	Moderate (++)	High (+++)	High (+++)
	Design robustness	Financial investment	Social acceptance	Environmental friendliness

Approach	Rick pooling and transfer			
Relevance with the loss and damage principle	<ul style="list-style-type: none"> <li>• Risk pooling options are intended to shifts economic risks from an individual or organization to an insurer (UNFCCC, 2012a). This approach works well for managing economic loss and damage that cannot be prevented through risk reduction or retention based approaches. Microfinance instruments like micro insurance, index based insurance for agriculture are typical risk transfer options.</li> </ul>			
Specific example	<ul style="list-style-type: none"> <li>• NGOs are operating the micro-credit operations usually include a small amount of money in the loan repayment for providing the insurance cover to the loaned investment. This option can further explore for proving life insurance backup to the vulnerable family.</li> <li>• Insurance protection against the loss of agricultural production is an emerging field, and index-based insurance options are the mostly used tool by far. Under this approach, loss of agricultural production from flood and drought incidences are compensated under the insurance mechanism.</li> </ul>			
Feasibility	High (+)	Moderate (++)	Low (+)	Nil (0)
	Design robustness	Financial investment	Social acceptance	Environmental friendliness

Approach	Reducing hazard			
Relevance with the loss and damage principle	<ul style="list-style-type: none"> <li>• Hazard reduction is only possible through long term ambitions and actions for reducing the rate of warming through greenhouse gas emission reduction. Under the lens of loss and damage, the mitigation options are found useful in avoiding loss and damage from natural hazards. Mitigation is not usually considered in the range of risk reduction, retention and transfer based approaches. However, mitigation based approaches can be act as complimentary to approaches related to adaptation and addressing loss and damage.</li> </ul>			
Specific example	<ul style="list-style-type: none"> <li>• Irrigated agricultural operation generates significant amount of greenhouse gases from inundated lands. Thereby avoid using standing water on the agricultural field not only enhances the water use efficiency but also reduces the GHG emission significantly. Alternative wetting and drying technique for irrigated rice agriculture is such an approach rendering the benefit of mitigation and complimentary benefit of adaptation through water conservation.</li> <li>• Generation of hydro-electricity is one of the clean energy sources. However, damming the rivers for hydro-electricity generation possess significant negative impact on the environment and society. Exploring the micro scale hydro-electricity generation from the flashy river system might not possess that level of</li> </ul>			

	severity. In one side, this micro scale dams across the flashy river system will be able to serve the flood control function as well as reduce the dependency on the non-renewable energy based options.			
Feasibility	High (+++)	Moderate (++)	Moderate (++)	High (+++)
	Design robustness	Financial investment	Social acceptance	Environmental friendliness

Approach	Managing residual loss and damage			
Relevance with the loss and damage principle	<ul style="list-style-type: none"> <li>It is imperative that almost all kinds of structural adaptation options related to water resources management, even supported by a robust environmental management framework, may have significant residual environmental and social impacts. Residual loss and damage may be evident because of the unprecedented nature of the climate change induced hydro-meteorological hazards which often overshadows the perceived sense of security and reduction of vulnerability. Managing the residual impact is one of the novelties of the UNFCCC work programme on loss and damage. Practising the ecosystem based approaches usually have a much less residual impact than traditional structural adaptation options.</li> </ul>			
Specific example	<ul style="list-style-type: none"> <li>Using coastal mangrove forestation as a barrier to storm surge serves the dual benefit of mitigation and adaptation, by acting as a sink for greenhouse gas and by reducing the excessive energy of the storm surges. On the other hand, traditional coastal defence structures are very expensive to implement and manage as well as notable environmental and social impact.</li> <li>Raising the height of the land in the coastal region may be a good adaptation option against sea level rise. Natural sediment management options following the tidal river management approach is such an approach doesn't have any significant environmental and social implications. In this process, sediment carrying river water is entered into a preselected circular river basin. The river water releases the energy and the sediment is deposited in the river basin.</li> </ul>			
Feasibility	High (+++)	Moderate (++)	Moderate (++)	High (+++)
	Design robustness	Financial investment	Social acceptance	Environmental friendliness

In a nutshell, a range of approaches to address loss and damage as all about dealing the unprecedented nature of more intense and frequent natural disasters. Therefore, one single approach, i.e., the risk reduction, risk transfer, etc., is not sufficient to address the wide horizon of loss and damage. Therefore, all the approaches are not exclusive, rather complimentary to the traditional approaches for adaptation and mitigation.

### Conclusion and recommendations

Analysis results showed that the global frequency of water-related natural disasters is doubled between the period 1980-1997 and 1998-2013. It is also virtually certain and statistically significant that global worth of mean annual damage accounts more than USD 30 Billion. It is also revealed that the range of approaches addressing loss and damage differs from adaptation from two broad perspectives: when the adaptation/mitigation has limits or those procedures are not possible to undertake, and when the

conventional approaches has some costs in the long terms that can't be regained (residual impact). It is expected that outcomes from the paper contribute specificity to the loss and damage debate by providing farm evidence of the global footprint of loss and damage. However, further analysis is due for addressing non-economic and intangible loss and damage assessment and a relevant mechanism to address those. A few recommendations are specified below for further research which are as follows:

- Addressing the risk of loss and damage need the assessment of loss and damage beforehand. The assessment of loss and damage has two paradigms: the ex-ante assessment (futuristic) and the ex-post (historical) assessment. The ex-ante assessment are is mostly used for probabilistic risk assessment to address climate change. Therefore, the assessment of a global footprint of loss and damage in this study is not an attempt to assess the risk of loss and damage. Rather, it was intended to provide some evidence of climate change induced loss and damage related to water resources.
- 'Loss and damage' as a concept for managing the negative impact of climate change still lacks clarity. Commonalities and differences in the traditional adaptation and mitigation based approaches need particular attention to bringing united decisions in the UNFCCC process.
- Normalization of loss and damage often creates controversies among different approaches and economic principles. Here, the inflation adjusted GDP data collected from the World Bank portal is used. However, the GDP based indicators are not the best indicator for normalization. A future attempt will be taken to try some other exclusive or composite economic indicators combining the purchasing power parity, GDP, currency value can be used for normalization.

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