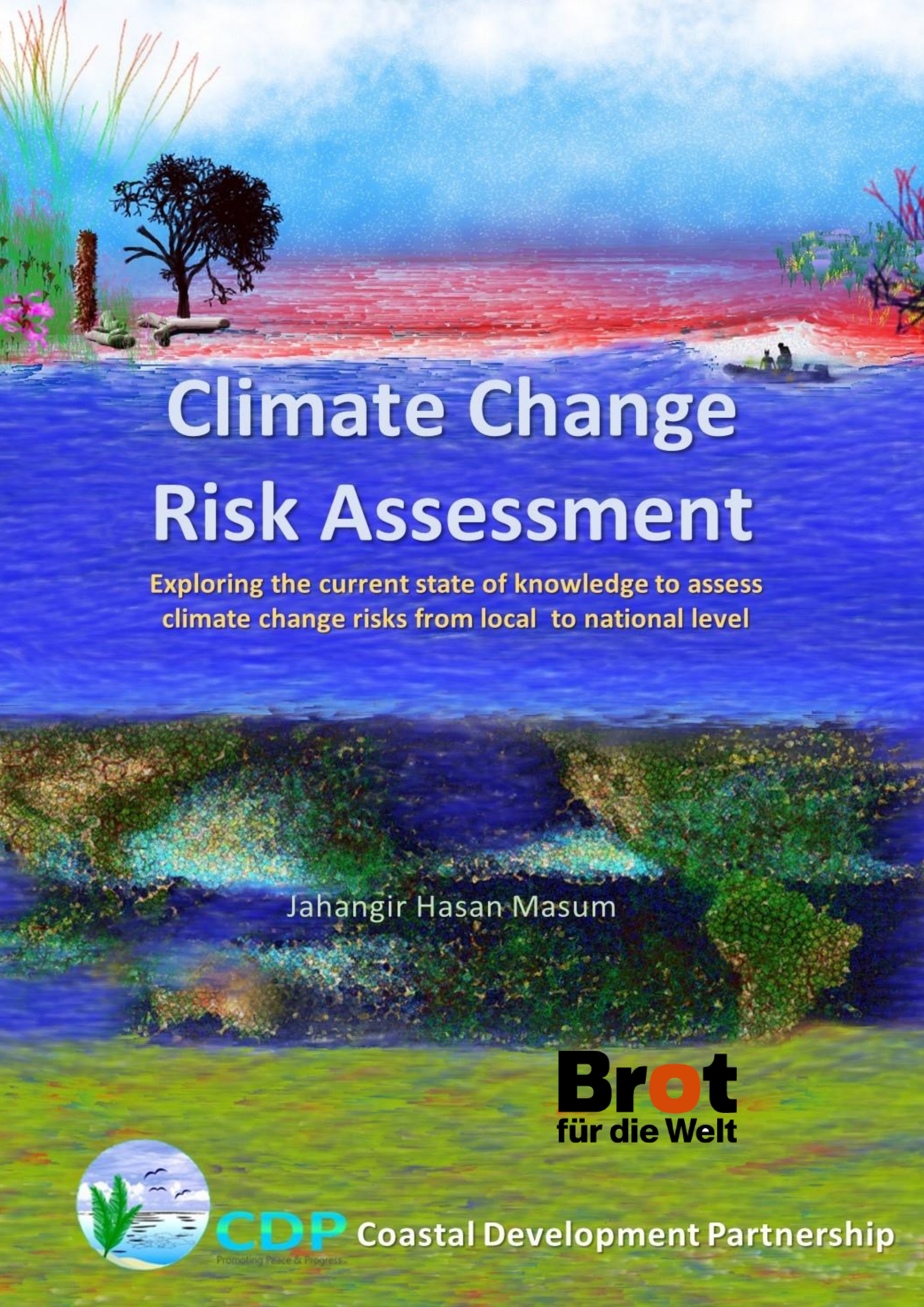

Climate Change Risk Assessment

Exploring the current state of knowledge to assess climate change risks from local to national level

Jahangir Hasan Masum

Brot für die Welt

CDP Promoting Peace & Progress

Coastal Development Partnership

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Citation: Masum, J. H., 2019: Climate Change Risk Assessment: Exploring the current state of knowledge to assess climate change risks from local to national level, Coastal Development Partnership (CDP), Bangladesh, ISBN: 978-984-34-7046-1

Declaration: This publication has been developed for the CDP SPACE project, which is funded by the Bread for the World, Germany. The findings, interpretations, and conclusions expressed in this publication are those of the author and do not necessarily reflect the views and policies of the Coastal Development Partnership (CDP) and the Bread for the World, Germany. CDP and Bread for the World do not guarantee the accuracy of the data included in this publication and accept no responsibility for any consequence of their use.

Published By:

DiPubs,
Madina Tower, Flat # 10C
181/A South Pirerbag, Mirpur,
Dhaka-1216, Bangladesh.

ISBN: 978-984-34-7046-1

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Executive Summary

Climate change induced risk results from the interaction of three components; vulnerability, exposure and hazard. The changes in the climate variables (temperature, wind and precipitation) over a longer period of time influence the characteristics of the climate risk components. The magnitude of climate risks is expected to increase human casualties and economic losses in the future. Considering the slow pace of mitigation and adaptation up to now, it is almost certain that in many climate vulnerable countries, negative impacts of climate change will exceed adaptive capacities.

Although climate change publications have experienced rapid growth in recent years, comprehensive literature review on climate risk assessment has not received attention from the research community. The accurate assessment of risk and its driving factors is essential for deciding on efficient management of climate risks. Although over recent years, climate risk has emerged as the central concept in the science-policy dialogue, this concept has rarely been applied to deliver climate risk assessment results at local or national level. Making sense of climate change risks and responses at the local level including loss and damage requires an integrated climate risk management (risk analysis, risk reduction and risk transfer strategies) approach that includes both climate variability and social vulnerability. Climate risk assessment offer a systematic approach to capture the character and scale of different risks (estimation of the magnitude & frequency of natural hazards, the exposed assets & people, and vulnerability of assets and people under certain natural hazards), to make informed decisions. Climate risk scenarios are not predictions about how the future will turn out, rather, believable possibilities that may appear.

Climate risk assessment practices are having difficulties in defining and agreeing on principles. Climate change risk and vulnerability have been defined in different ways by different disciplines or organizations with different needs. Besides, climate risk & vulnerability assessment approaches are still guided by scientific and technical factors, and often neglects the socio-cultural and political economy factors. Too much attention on the techno-scientific expertise often not only create a disconnection between national priority and local priority, but also may overshadow community concerns or mislead community perceptions. The downscaling of global and national data models to the local level can result in 'coarse assessments' of climate risk. Although national level risk assessment provides basic inputs for helping decision-makers to make better and informed decisions, it may not necessarily provide answers to questions concerning the level of risks, trade-offs in risk control, costs and benefits at local level. On the contrary, local risk assessments provide specific information which is often not up-scalable or reproducible in national context.

Protecting vulnerable communities is the key to climate justice. All people have a right not to suffer from climate impacts that undermine their basic needs. By fully engaging multiple stakeholders in dialogue and building networks for sharing knowledge and innovations, risks can be managed more appropriately. More efforts need to be dedicated to bottom-up risk assessment rather than conventional top-down meteorological approaches. The IPCC framework that suggest, climate risk (CR) = hazard (H) x exposure (E) x vulnerability (V), should be used as the foundational risk equation for climate risk assessment.

Introduction

A literature review is an evaluative report of studies found in the literature related to a selected area (Boote & Beile, 2005). In general, it is assumed that the results in the published literature are established facts or statements. Research community considers literature review as an essential component of knowledge development process. One study (Wang et. al.,2014) based on 3,004 papers on climate change vulnerability, published in 658 academic journals from 1991 to 2012, has identified that the vulnerability researches on climate change have experienced a rapid growth since 2006. Although climate change publications have experienced rapid growth in recent years, there are a few efforts from scholars to do literature review. The need for reviewing literature on climate risk assessment has emerged from the shortfall of comprehensive literature review that can enhance conceptual understandings of the practitioners who works with climate risk assessment at the local or sub-national level.

As web is now a vast source of information, it was logically assumed to have some documents on climate risk assessment. Nevertheless, no results were found in keyword analysis by google search for keywords such as "climate risk assessment review"; "climate risks literature review"; "literature review on climate risks"; "literature review on climate change induced risks"; "literature review on climate change induced risk assessment" till October 13, 2018. The keywords analysis has used “quotes” to identify documents that has all the key words”, not any word within the keyword. The keyword analysis by google search has shown that documents related to climate exposure assessment, climate risk assessment methodology is very low in number and increasing quite slowly. Although documents related to climate change vulnerability assessment is quite stagnant at the present time, climate change risk assessment and natural hazard assessment related documents are increasing quite rapidly in the web.

Google Keyword Search	**Document in pdf format**		**Document in any format**		**Scholarly Articles**	
	11/10/2018	13/10/2018	11/10/2018	13/10/2018	11/10/2018	13/10/2018
"climate risk assessment review"	0	0	0	0	0	0
"climate change assessment"	97,400	103,000	173,000	176,000	28,200	29,700
“climate risk assessment”	73500	75,800	147,000	151,000	12900	12,900
“climate change risk assessment”	75300	71,300	107,000	114,000	25300	26,400
"climate change risks assessment"	960	1,020	1,220	1,230	12	12
"Natural hazard assessment"	44,400	46,700	63,600	66,400	14,000	14,300
“climate change hazard assessment”	620	578	755	951	11	14
"climate change vulnerability assessment"	51,400	51,200	80,700	80,700	16,900	16,400
"climate change exposure assessment"	23	24	655	607	2	8
"Climate Risk assessment methodology"	39	41	65	106	6	6
"Climate Change Risk assessment methodology"	75	45	55	115	8	8
Keyword analysis by google search was done on October 11, 2018 and October 13, 2018 “quotes are used to identify documents that has all the key words”						

CDP literature review on climate risk assessment combines both summary (recap of the important information) and synthesis (re-organization of the information) from the published body of knowledge. This literature review focuses on learning about how other researchers have investigated, defined and measured key concepts linked with climate risks, vulnerability and hazards at the sub-national or local level. The purpose of the review is to provide an improved understanding of key concepts linked with climate risk assessment so that stakeholder at the local or sub-national level can enhance their capacity.

Understanding Climate Risk Concepts

Climate is the combined effect of the physical variables such as rainfall or precipitation, temperature and wind in the long-term. Any temporal and spatial changes in the climate variables (temperature, wind and precipitation) over a longer period of time causes changes in the climate system. Rainfall is the amount of precipitation in liquid form falling over a specific area. Temperature refers to the degree of hotness and coldness of the atmosphere. Rising temperature causes changes in precipitation and humidity (the moisture content of the atmosphere) through the hydrological cycle.

Conventionally, risk is considered as a potential harmful event that has not yet occurred but may affect individuals, households or communities within a specific area, if it occurs in the future. This envisage that risk is a virtual threat that evolve in time and space. According to the UN definition, risk is the probability of harmful consequences or expected losses (deaths, injuries, property, livelihoods, economic activity disruption or environmental damage) resulting from interactions between natural or human-induced hazards and vulnerable conditions (UNISDR 2009).

The risk concept has been increasingly adapted and introduced as a systematic approach for dealing with natural hazards since 1980 (Brundl and Margreth 2015). Research has been playing a key role for conceptual development of climate risks. Studies have recognized the need for conceptual development of climate risk, exposure and vulnerability issues at the sub-national or local level (Hewitson et. al., 2014, Cardona et. al., 2012), because climate risk related concepts have been interpreted in different ways across different disciplines (Jurgilevich et al., 2017). As the concept of risk is strongly shaped by human perception and cultures, the inconsistencies in risk terminology and concepts may produce different interpretations. Different interpretations of climate risk may affect individual or collective decision-making process to address risk. Risk experts tend to focus on the standard concept of risk as the possibility of damage, while the general public tends to expand the concept of risk to include other “non-damage” attributes.

Climate risk is the probability that an extreme natural hazard may cause adverse impacts on vulnerable elements exposed to it, including loss of lives, properties or other economic assets (Balica, 2012; Esnard et al., 2011). The Intergovernmental Panel on Climate Change (IPCC) assessment reports have been providing concepts and definitions about climate change components since 1992. Previous studies on climate change impacts had focused on assessing vulnerability using the IPCC third and fourth assessment reports as a conceptual starting point. Nevertheless, IPCC third and fourth assessment reports had not considered hazard as a separate element in the vulnerability framework, rather presumed the inclusion of exposure as a manifestation of the hazard. The IPCC Fifth Assessment Report has introduced the concept of climate risk. Although over recent years, climate risk has emerged as the central concept in the science-policy dialogue (IPCC 2014), this concept has rarely been applied to deliver climate risk assessment results at local or national level (Muccione et al., 2016). In addition, there exists ambiguity for using the climate risk concept to guide the assessment of climate change impacts for climate risk reduction planning at different scales such as village level, sub-national level or national level. Understanding the relationship between vulnerability, adaptive capacity (a system or person’s ability to adapt to changes) and resilience (a system or person´s ability to resist negative outcome from a risk or hazard) is very important to both identify and understand the susceptibility of elements at climate risk (Fuchs et al., 2012; Cutter et al. 2008).

In the literature, natural hazards are described as extreme natural events in the light of IPCC's forecasts (McGuire et al., 2002; Smith and Petley, 2009). Magnitude and frequency, as well as temporal and spatial scale, are key geomorphic concepts strongly correlated to natural hazards (Irasema, 2002). The vulnerability as a concept is directly linked with the physical, social, economic and political components that influence a system when it is threatened by a specific event, as well as its ability to mitigate and recover if such event really occurs (Almeida et al., 2016). Vulnerability interacts with single or multiple natural hazards to generate climate risk. The vulnerability to climate change is a measure of possible future harm (Hinkel 2011). All social groups within a community are not equally vulnerable (CARE, 2009; Kuhlicke et al., 2011). Some population groups are generally considered more vulnerable than other groups (such as elderly or person with disability).

The Reality of Climate Induced Risks

Many studies have concluded that climate change imposes risks to livelihoods, communities, cultures, human health and natural environment (Fatorić & Seekamp, 2017; Kumssa & Jones 2011; Watts et al., 2015). Climate change could make many areas of the world uninhabitable for most of the year without extensive air conditioning (Sherwood & Huber 2010). Climate change is increasingly recognized as a threat to cultural heritage (Fatorić & Seekamp, 2017). Without increased adaptation, it is estimated that an additional 100 million people will fall into poverty due to floods and droughts (Hallegatte et al., 2015). Human casualties and economic losses due to natural disasters have been increasing over the last five decades (Dewan, 2013). Disaster victims in developing countries accounted for 70% of the world's total damages from natural disasters (Guha-Sapir et al., 2015). Reported disastrous events have significantly increased worldwide from 294 in 1950–1959 to 4210 in 2003–2013 (Maria et.al, 2016). Based on this data, it can be inferred that reported disastrous events were around 29 per year in 1950–1959 while in 2003–2013, such events were around 383 per year. Within the last 54 years (1959-2013), reported disastrous events have increased worldwide at the rate of around 73 events per year.

Several consequences of global warming are already visible, such as increasing trend of global mean surface temperature (Morice et al., 2012) & sea-surface temperature, ocean heat content (Hobbs & Willis 2013); melting of sea ice (Wadhams et al., 2011) & glaciers (Gardner et al., 2013), and loss of ice sheets from the Greenland and Antarctica (Clark et al., 2015). Climate model projections have predicted an increase in global mean surface temperature in the time period 2081-2100 of 0.3^{o}C to 4.8^{o}C, relative to 1986-2005 (IPCC 2013). Since 1951, more than half of the increased global mean temperature was caused by human influence on climate (Knutson et. al., 2017).

Flooding is the most frequent and damaging of all-natural hazards. Flood can be induced when precipitation is above the normal level and drought occur when it is below the normal level. During the period 1980–2015, more than 225,000 people have lost their lives due to flooding and the direct economic losses were around US$1.6 trillion (Munich Re, 2016). Exposure to floods can cause death directly via drowning, physical trauma, or secondary effects such as the failure of water and sanitation services, the spread of waterborne diseases and decreased nutrition (Abhas et. al., 2012). The global population exposed to river and coastal flooding had doubled, increasing from around 520 million people in 1970 to almost 1 billion in 2010 (Jongman et al., 2012). People in low-income countries are much more vulnerable to negative flood impacts than those living in high-income countries (Jongman et al., 2015).

Climate change is expected to increase the frequency of flooding related to extreme rainfall in the future because global warming will increase the frequency and intensity of extreme rainfall or precipitation events (Alfieri et al. 2015; Rojas et al. 2013; Hirabayashi et al., 2013; Bruwier et. al., 2015; IPCC, 2013). Damages from river flooding could be 20 times greater by the end of this century (Winsemius et al., 2015). Since the 1970s, tropical cyclone intensities have increased far more rapidly in all major ocean basins where tropical cyclones occur (Trenberth et al., 2007). Climate change is expected to strengthen the intensity of the most powerful tropical cyclones (Knutson et al., 2010, Grossmann & Morgan 2011, Walsh et al., 2016).

Changes in rainfall pattern due to climate change is expected to affect water availability, water demand, water quality and water level of basins (Heng et al., 2013). Landslides caused by heavy rainfall may become more frequent if climate change causes increased rainfall (Lee et al., 2016). Extreme rainfall may expose people to water borne infectious diseases because increased rainfall brings water borne infectious diseases from one place to another through runoff in an area. Inadequate rainfall or precipitation means that there is insufficient water for the ground water and surface water to recharge which consequently has negative effect on the provision of water supply. Inadequate rainfall causes the drought. The frequency and intensity of droughts are likely to increase with global warming (Stocker et al., 2014; Field et al., 2012).

Over 90% of the excess heat absorbed by the climate system ends up in the ocean and raises ocean temperatures (Rhein et al. 2013). The increased ocean temperature causes sea-level rise by accelerating the retreat of glaciers, sea ice and ice sheets (Slangen et al., 2016). The ice sheets on Greenland and Antarctica are by far the largest potential source of future sea-level changes, storing approximately 65 meters sea-level equivalent and are expected to dominate the sea-level budget on the long term (Clark et al. 2015). Global sea-level has risen by more than 20 cm since 1980 (Hardy and Nuse, 2016). Over the period 1901–2010, the global mean sea level has already increased by 17-21 cm, a rise that is expected to continue well beyond 2100, even under strong mitigation scenarios (Church et al. 2013). By 2100, the global mean sea level is projected to be 25–123 cm higher (Hinkel et al., 2014) or 26–82 cm higher than the 1985-2005 (IPCC 2013). While sea levels are rising globally, both exposure and vulnerability to sea-level rise will be hyperlocal due to geographical differences in physical risk factors and their interactions with local population factors (Hauer et al., 2016). An increase in mean sea level can increase the impacts of storm surges and the risk of flooding events in coastal zones. Low elevation in coastal zones makes human settlement exposed to flooding and storm surges (Syvitski 2008). Higher rates of coastal erosion are expected under future sea level rise scenarios. Sea level rise may also cause greater intrusion of saltwater towards inland during storm events. Exposure to salinity intrusion may cause change in fish composition and shifting of fishing zone in the coastal areas.

Climate change is expected to influence the river dynamics through changes in the river flow and sediment transport. Around the globe, climate change is likely to increase river salinity in some regions (Miguel et al., 2013). Exposure to salinity has negative impact on household food security (Parvin & Ahsan 2013). Exposure to saline drinking water is linked with hypertension and pre-eclampsia, skin diseases, acute respiratory infection and diarrheal diseases and transmission of mosquito-borne diseases (Talukder et al., 2015). WHO identified hypertension or high blood pressure as a silent killer and global public health crisis, accounting for 9 million deaths per year (WHO 2013).

Climatic changes have a direct impact on vegetation and crop production (Wilcox & Makowski 2014; Ladányi et al., 2016). Soil salinity have a negative effect on production of agricultural crops. The rising temperatures and sea level rise have a significant effect on soil salinity, mainly in coastal or delta regions (Haider & Hossain 2013; Brammer, 2014). Soil salinity is negatively associated with household food security in rural deltaic environments (Sylvia et. al., 2015) and indirectly reduce households' overall well-being (Brainerd and Menon 2014). A household is categorized to be food insecure if more than 75 % of its total expenditure is on food items (Smith and Subandoro 2007). Tidal penetration can increase the extent of perennially and seasonally saline soils and diminish soil organic content. In global context, the percentage of land with highly degraded soils had increased from 15% of total land area in 1991 to 25% by 2011 and most of this soil degradation is associated with water-induced soil erosion (UNCCD, 2013). Soil erosion results in the productivity loss of soil by decreasing soil depth. Soil erosion challenges tend to be greatest in the more heavily populated, underdeveloped, and ecologically fragile areas, where the adaptive capacity is weakest (Leh et al., 2013; Erkossa et al., 2015).

Exposure to droughts and floods threaten agriculture dependent livelihood of rural people by lowering crop yields and livestock productivity (Ranganathan et al., 2010). Rainfall variability, shifts and trends largely impact the economic, social and biophysical conditions of a country (Gallant et al, 2007). Economically low-income countries are more vulnerable to natural disasters (Toya & Skidmore 2007). Exposure to natural hazards may cause severe impact on human, physical and financial capital as well as a reduction in economic activity (such as income and investment, consumption, production and employment) in the real economy.

Hotter years are associated with lower economic growth rates in poor countries (Dell et al., 2009). Exposure to hot years can reduce the level of industrial output in poor countries by 2% per degree Celsius and agricultural yield by 2.4% per degree Celsius (Dell et al., 2012). The hotter-than-average years lead to lower-than-average productivity in already hot countries, and the reverse effect in colder countries, where hot years are associated with increased productivity (Park and Heal 2013). Study has also found that a 2.4 percent decline in exports per degree Celsius for hotter-than-average years in poor countries (Jones and Olken 2010). A day with maximum temperatures above 30°C reduces daily labor supply by 14% in the agriculture or construction sectors (Graff Zivin and Neidell 2014).

Exposure to temperature stress can reduce human productivity because people can easily be disturbed and distracted when temperatures goes above 22°C or below 18°C (Geoffrey and Parky, 2016). Hot days are associated with lower human productivity. When humidity-inclusive temperatures reach 35°C, extended periods of outdoor activity become impossible for even the most physically fit adults because human bodies can no longer dissipate heat (hyperthermia). Above 25°C, the average human productivity loss is 2% per degree Celsius (Seppanen et al., 2006). Manufacturing worker efficiency at the plant level declines substantially on hotter days (Adhvaryu et al., 2014). Above 22°C, each additional degree Celsius (^{0}C) is associated with a 1.8 percent reduction in labor productivity of Indian call centre workers (Niemela et al., 2002). Exposure to temperature stress during pregnancy causes low birth weight (Graff Zivin and Shrader 2016) and may hamper the education because students will not be able to concentrate during the unusually hotter days (Graff Zivin et al., 2015). Poor households are more exposed to temperature stress and heat waves because poverty-stricken households tend to reside in hotter environments within countries (Acemoglu and Dell 2010).

Heat waves were responsible for four of the ten deadliest natural disasters in 2015 (UNISDR et al. 2015). The increase in global surface temperature due to climate change is expected to increase the frequency and intensity of heat waves in the future (Kirtman et al. 2013; Patz et.al, 2005). Exposure to heat waves or cold waves poses a serious health risk and causes high numbers of illnesses and deaths among the older individuals (older than 65 years) and children (Huynen et al, 2001; Smith et al. 2014; Xu et.al, 2014; Graff Zivin & Shrader 2016). The level of heat stress experienced by a person is a function of temperature, relative humidity, wind speed, solar radiation, clothing, and many other factors (Nguyen & Dockery, 2016). At a given temperature, high humidity increases the level of heat stress on a person. A day with temperatures exceeding 90°F (32°C) can increase local monthly mortality rates by more than 1 percent (Deschenes & Greenstone 2011). People with respiratory or cardiovascular diseases, diabetes, chronic mental disorders or other pre-existing medical conditions are at greatest risk of being negatively affected by heat waves (Kovats and Hajat 2008). Increases in mortality during the most devastating heat waves are linked with high night-time temperatures and exposure to hot weather for longer duration (Laaidi et al. 2012; Tan et al. 2007). Heat waves with hot conditions lasting through the night have a greater impact on human health than those with cooler nights (McGregor et al. 2015). The resulting health damage may persist after the heat wave that created the ozone has ended (Graff Zivin & Neidell 2014).

Global warming is causing more water evaporation, increasing cloud formation and the potential for lightning storms at the local level. Individuals involved in outdoor sports and recreational activities, including spectators, are at high risk of lightning injury (Cherington 2001). The lightning fatality rates are concentrated in rural areas and have a direct relation with manual labor–intensive agriculture (Gomes and Ab Kadir 2011). Lightning hazards in urban areas differ from rural areas (Pinto et.al., 2013). The urban characteristics (e.g., roughness, aerosols, and urban heat islands) can enhance the thunderstorms in urban areas and consequently induce more lightning (Kar & Liou 2014).

Importance of Climate Risk Assessment

The accurate assessment of risk and its driving factors is essential as a basis for deciding on efficient management of climate risks. Climate risk assessment helps to identify hotspots (areas and people that have been, or potentially will be, most affected by the adverse impacts of climate change) for making evidence-based decisions to reduce climate change induced risks of the targeted household, community, regions or sectors. Climate risk assessment at various spatial and temporal scales are essential to understand the climate risk situation, development of climate-related policies & strategies, adaptation planning and resource mobilization (Huggel et al., 2015; Lee et. al., 2015).

Responding to climate change risks require a knowledge-based approach because present planning decisions are sensitive to the uncertainty surrounding future risks associated with climate change (McDermott & Surminski 2018). Climate risk scenarios serve as a decision support tool for responding to climate risks that may occur. Participatory climate risk scenarios are essential for developing adaptation strategies (Lempert & Groves 2010). As the risk from natural hazards cannot be eliminated, climate risk assessment also supports hazard mitigation by minimizing the exposure of the hazard to humans. Vulnerability assessment as one of the key components of climate risk assessment help planners to prepare disaster plans and improve effectiveness of disaster management (Cutter & Finch 2008; Gao et. al., 2014; Zhou et. al., 2014).

The identification of vulnerability factors to natural disasters is essential to effectively develop and implement adaptation & mitigation strategies (Emrich & Cutter 2011; Zhou et. al., 2014). If vulnerability and risk assessments incorporate both physical and socio-economic information, then climate change risks in a particular area or a sector will be shown more accurately (Preston et al 2011).

Policy-makers need decision support tools to summarize the sub-national level climate risks in a simple and effective way (Hanger et al. 2013) because climate change have spatial & temporal variations that affect the various regions differently (Lobell, et al. 2011). The findings of the sub-national-level climate risk assessment have greater practical usefulness to any country because of its ability to capture context-specific concerns (Noy & Yonson 2018). Besides, local planners' value scientific knowledge, either for themselves or for their organization (van Stigt et al., 2015). However, local planners often do not have the capacity to effectively recognize or use relevant information (Bruno and Dessai, 2016; Lemos et al., 2012, 2014; Kirchhoff et al., 2015; Haigh et al., 2015; Mase and Prokopy, 2014; Prokopy et al., 2013; Troccoli et al., 2010).

Experts consider that reframing climate change assessments towards risk may help policy-makers to prioritize, communicate and address the climate change challenge more effectively (Weaver, et.al., 2017). Besides, changes in the IPCC focus from top-down, science-first vulnerability assessments to risk assessments can help to consider climate change as one risk along with many other challenges (Meadow, et.al., 2015). The European Council has highlighted the role of climate risk assessment within the adaptation policy (EC 2013). The level of tolerable climate risk depends primarily on the legal provisions in force, policies adopted for the environment and cultural goods, as well as on the approval of the local communities according to their unique cultural traditions and ethical values (Bogdan et. al.,2018).

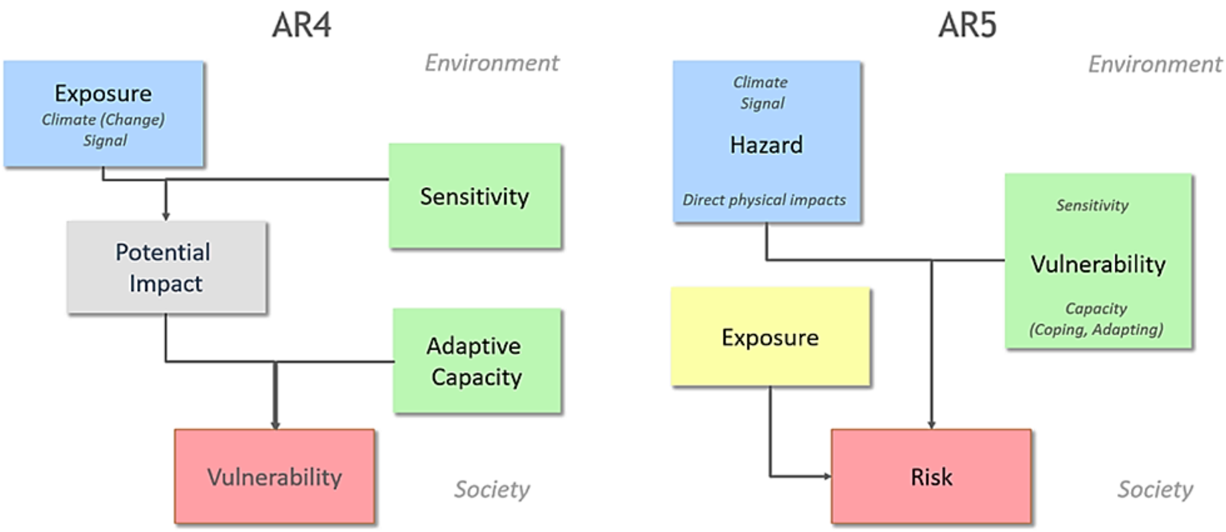
Translating' risk assessments into policy action is one of the biggest challenges for evidence-based decision-making (Krebs 2011). Applying global data models to the local level (i.e. 'downscaling') can result in 'coarse assessments' of risk and may not consider the unique climatic features of local areas (McDermott & Surminski 2018). The framing of uncertainty is an important barrier to translating risk assessment into decisions at the local level. Uncertainty most commonly refers to a state in which future possibilities and chances are unknown; risk refers to decision-making in situations of uncertainty. The inherent uncertainty that comes with climate risk assessments creates a dilemma for local decision makers who need to incorporate climate change into their plans (McDermott & Surminski 2018).

Although scientists can play key role in translating research to make it more accessible for the planner, due to lack of knowledge among scientists about the planning process and political context presents a significant barrier to their engagement (Marshall et al., 2017; Poff et al., 2016; van Stigt et al., 2015). When scientists and information users collaborate in co-production of climate information, the findings are more usable for solving problems and supporting management decisions (McKinley et al., 2012; Lemos et al. 2012). Climate risk assessment can improve the communication of risk information among the people, experts and decision-makers (Slovic, 1987). Climate information includes climate change projections, inter-annual and seasonal climate forecasts (Lemos et al. 2012).

Identification of the Climate Risk Components

Climate change risk results from the interaction of three components; vulnerability, exposure and natural hazard (IPCC, 2014). The changes in the climate variables (temperature, wind and precipitation) over a longer period of time influence the characteristics of the climate risk components. Any small changes in the climate variables could have significant implications for the frequency and magnitude of extreme natural hazards (Coumou & Rahmstorf, 2012).

Hazard is the probability of occurrence of a physical event that have potential to cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems environmental resources (IPCC, 2014). However, hazard does not necessarily result in damage or loss of life. Depending on the characteristics of the system, the effect of a natural hazard will vary (Cutter et. al., 2008). Hazards can be characterized as 'non-adaptable' because one cannot directly influence the occurrence of hazard with adaptation in the short or medium term (Cardona et. al., 2012). Natural hazards become disasters when they intersect with the human environment. Disaster is the occurrence of an extreme hazard event that violently impacts vulnerable communities. In most cases, a climatic hazard event may create or influence another hazard.



Vulnerability refers to the susceptibility of people, society or economy to death, injury or damage by single hazard or multiple natural hazards (Toufique & Islam, 2014; Birkmann et al., 2013). Vulnerability can be categorized into three dimensions (Birkmann et al., 2013), such as physical vulnerability (ecosystem characteristics, physical assets, & infrastructure); social vulnerability (human welfare, social integration, health) and economic vulnerability (productive capacity, economic resources, unemployment and low-income conditions).

According to the IPCC Fifth Assessment Report, vulnerability results from the interaction of two components; sensitivity and capacity (coping/adaptive). Sensitivity is defined as the degree to which a system will be affected, either adversely or beneficially, due to changes in the climate variability. Capacity is generally defined as the ability of a system, individual or society to adjust to change, moderate the effects, and cope with a disturbance (Burton et al., 2002; Brooks et al., 2005). In climate change context, adaptive capacity is the ability of a system to adjust to climate change variability and extreme weather to reduce potential damage (Allison et al., 2009) or to cope with the consequences (IPCC 2014).

Vulnerability is typically linked to prevention, preparedness and mitigation, while resilience is linked to response, rehabilitation, reconstruction and recovery, as well as mitigation to address future risks (Noy and Yonson 2018). High degrees of vulnerability indicate low resilience. Resilience is a measure of the system's capacity to absorb disturbance, reduce or avoid losses, minimize welfare losses and reorganize into a fully functioning system that existed before the disturbance (Adger et al., 2005; Blanco-Londoño, et. al., 2017; Folke, 2006; Klein et al., 2003; Hallegatte 2014; Manyena, 2006).

In the context of disaster risk, resilience refers to "the to resist, absorb, accommodate to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures, and functions through risk management" (UN 2016). Resilience at the micro-level is influenced by the distribution of the losses incurred across the affected households, the household's ability to smooth their consumption, and their access to risk sharing schemes (Hallegatte 2014).

According to the IPCC (IPCC, 2014; 2012), exposure refers to the presence of people, livelihoods, biodiversity, ecosystem services, environmental resources, infrastructure, and assets in a geographical location that are susceptible to potential future harm, loss or damage by natural hazards. Two exposure types are found in literature; 'exposure as a manifestation of a hazard' and 'exposure as a geographical location'. Exposure as 'a manifestation of a hazard' represents hazards characteristics (inundation, precipitation, heat levels, sea-level rise (SLR)), whereas the exposure as 'a geographical location' represents the degree to which a place is exposed to natural hazards (Zhou et al., 2015). Exposure as a manifestation of a hazard was in line with the earlier IPCC frameworks. Exposure as a geographical location of an object at risk goes in line with the latest IPCC frameworks (Cardona et al. 2012).

The impacts of climate change that cannot be avoided through adaptation or mitigation is often defined as loss & damage (Warner & Geest, 2013). Loss and damage are directly linked with the intensity & frequency of hazards. Loss & damage related information can be collected using appropriate indicators such damages to infrastructure (economic loss) or loss of life (non-economic). Damage can be defined as the amount of money needed to restore the area back to its original condition before the disaster (Kang, et al., 2005). Wealth enables the people to absorb and recover from losses quickly (Cutter et. al., 2003). Loss and damage require both curative measures (e.g. displacement) to address unavoidable impacts and transformative measures (e.g. voluntary resettlement or alternative livelihoods development) to address intolerable risks (Mechler and Schinko, 2016). In loss and damage context, it is useful to distinguish between measures aimed at preventing loss and damage from occurring and measures aimed at responding to unavoidable loss and damage.

Understanding the Climate Risk Assessment Approaches

Climate change risk is a product of hazard, exposure and vulnerability (IPCC, 2012). While hazards are related to the physical aspect of risks (natural events with negative impacts), exposure and vulnerability encompass socio-economic characteristics (Vousdoukas et al. 2018). Climate risk levels are dynamic, because it is influenced by physical as well as social processes that change over time. Climate risk assessment can be considered as an effective guiding tool for promoting climate risk management culture. Portfolios of risk management measures, including risk reduction and risk transfer, can be tailored to specific current and future risks (Hochrainer-Stigler and Pflug 2012). Contemporary approaches in climate risk assessment and vulnerability assessment are mostly driven by a divide between natural and social sciences (Menoni et al., 2012, Birkmann et al., 2013; Fekete 2012; Siagian et al. 2014). Nevertheless, some studies have tried to bridge this gap (Kuhlicke 2013).

Many studies have recognized the importance of addressing multiple hazards collectively because the impacts of one hazardous event are often exacerbated by interaction with other hazards (Liu et al. 2014; Marzocchi et al., 2009). For example, storm surges are associated with tropical cyclone. Lightning occurs with all thunderstorms and severe thunderstorms spawn tornados. Thus, it is necessary to identify not only the potential primary hazard but also the triggering effect of the primary hazard over other secondary hazards. In geographic context, some areas such as coastal zone, are often highly vulnerable to multiple hazards such as floods, droughts, hurricanes, storm surges, sea-level rise and salinity intrusion (Dasgupta et al. 2011; Torresan et al., 2012; Szabo et al. 2015a). Around 790 million people in the world are relatively highly exposed to at least two hazards, and 105 million people to three or more hazards (Dilley et al., 2005). On the other hand, government authorities are usually assigned to address single hazard risk (Komendantova et al. 2014), for example water boards are often only responsible for floods, not other hazards. In the single-type natural hazard-based risk assessment approach, which is generally followed by the disaster risk reduction (DRR) approach, individual hazard is treated separately, without considering how different hazards may interact with each other (Kreibich et al. 2014). The multi-hazards concept is related to the analysis of different relevant hazards, triggering and cascade effects threatening the same exposed elements with or without temporal concurrence (Komendantova et al., 2014).

The IPCC has recommended for adopting a multi-hazards approach to provide more effective adaptation and reduction measures, in the present and in particular in the future (IPCC, 2012). Multi-hazards refer to all possible and relevant hazards, and their interactions, in a given spatial (area that the hazard impacts) scale and/or temporal scale (duration over which the hazard acts). Hazard interactions refer to the effect(s) of one hazard on another.

Many risk studies have adopted a process oriented cascading approach to understand the chain of causality that emerges when hazards, risk and accumulated vulnerabilities connect across multiple scales to produce a disaster (Gianluca & Alexander, 2016). The adoption of a multi-risks approach for the assessment of climate change impacts at different spatial scales is more appropriate (Dilley et al., 2005; IPCC, 2012). There is a difference between multi-hazards assessment and multi-risks assessment. Multi-hazards assessment provides an analysis of different hazards and aggregate them into a multi-hazards index, while multi-risks assessments encompasses both multi-hazard and multi-vulnerability concepts, by integrating possible interactions between hazards and vulnerability (Giardino et. al., 2018; Gallina et al., 2014, 2016; Forzieri et al. 2016; Valentina et al., 2016).

Top-Down Approaches		Bottom-Up Approaches	
Name	***Approach***	***Name***	***Approach***
Scanning the Conservation Horizon: A Guide to climate change vulnerability assessment (Glick, et al., 2011)	Assesses ecological impacts of climate change	CRiSTAL (Community-based Risk Screening Tool – Adaptation and Livelihoods)	Planning tool to integrate risk reduction and climate change adaptation into livelihoods projects
Review of climate change adaptation methods and tools (Schipper, et al., 2010)	Examines approaches that have been developed and applied around the world.	CARE Climate Vulnerability and Capacity Analysis Handbook (CARE, 2009)	Provide participatory methodology to assess climate change vulnerability at the community level.
Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments (Snover, et al., 2007)	Presents a general framework for sectorial top-down vulnerability assessments	Framework for Community-based Climate Vulnerability and Capacity Assessment in Mountain Areas (ICIMOD, 2011)	Provide an analytical framework and a participatory methodology for assessing climate change vulnerability in mountain communities
Impacts, Vulnerabilities and Adaptation in Developing Countries (UNFCCC, 2007)	Provides a general framework for carrying out vulnerability assessments at the national level	Participatory Capacity and Vulnerability Analysis (Oxfam, 2002)	A useful resource for carrying out participatory vulnerability assessments in rural and urban communities
Handbook on Vulnerability and Adaptation Assessment (UNFCCC, 2008)	Gives detailed instructions on developing socio-economic and climate change scenarios, and on carrying out top-down vulnerability assessments	CEDRA – Climate change & Environmental Degradation Risk and adaptation Assessment (Tearfund, 2012)	Combines assessments of risks from both climate change and environmental degradation

The approach to conduct a climate risk assessment primarily depends on the scale of assessment. Spatial units (such as village, city, region) for assessment is appropriate for formulating and implementing policies (Allison et al. 2009). Climate risk assessment approach can be viewed in two ways: (1) top-down and bottom-up, and (2) prescriptive and diagnostic. Top-down approaches start with an analysis of climate change impacts, while bottom-up approaches start with an analysis of the people affected by climate change (van Aalst, et al., 2008). Prescriptive and diagnostic approaches describe whether the assessment looks forward or backwards in time (Jones and Preston 2011).

Vulnerability is a dynamic process as it changes over time, but due to assessment purpose, it is often viewed as a static process (Cutter et. al., 2008; Westerhoff and Smit 2009). In practice, most of the climate vulnerability assessments follow a top-down approach and mainly focuses on the biophysical impacts of climate change, distribution of natural hazards, human occupancy, maladaptation and the degree of loss associated with a specific hazard (Cutter, 1996; Cooper & Pilkey, 2012; Muler & Bonetti, 2014; Wolf, et al., 2013). Previously, many vulnerability assessment approaches have not emphasized on the social dimension of vulnerability because it is difficult to quantify social vulnerability (Cutter et al. 2003; Flanagan et. al., 2011). The social vulnerability is usually perceived as a socially-constructed processes and structures that influence social systems to make individuals or communities vulnerable (Kunte et al., 2014, Mahapatra et al., 2015). Most of the bottom-up vulnerability assessment approaches usually focus on the assessment of current vulnerability, mainly provide information about the vulnerability of different social groups and generally do not rely on model-generated climate data. Bottom-up approaches involve collecting information from a specific location using participatory methods and tools which usually do not require extensive training (Hinkel, et al., 2010; Wolf, et al., 2013). Several vulnerability assessments have adopted a socio-ecological systems approach to address the cross-scalar and multi-actor dynamics of the vulnerability (Hallie & Amy 2006; Adger 2006; McLaughlin & Dietz 2008). IPCC suggests to address vulnerability dynamics through the use of socio-economic scenarios, development trends and pathways (Cardona et. al., 2012).

Four approaches (Vulnerability as Threshold, Exposure, Pre-Existing Condition and Outcome) could be used to assess the dynamics of vulnerability (Joakim et al., 2015). Vulnerability 'as pre-existing condition' is the most common approach to understand the causes of vulnerability and also to identify the most vulnerable population groups with a projected timeline. Nearly 80% sub-national risk and vulnerability assessments have approached vulnerability as 'pre-existing condition' as it is suitable for both assessments of current and future risks (Alexandra et al., 2017). Vulnerability as an outcome is related to the concepts of "residual" vulnerability (O'Brien et. al., 2007) and "end-point" vulnerability (Kelly and Adger, 2000). The 'vulnerability as an outcome' is the most comprehensive approach for assessments of future risks, adaptation planning and choosing particular adaptation options (Alexandra et al., 2017; Birkmann et al., 2013; Cardona et al 2012; Oppenheinmer et al., 2014,). If the purpose of an assessment is to choose spatial or socio-economic adaptation measures, 'vulnerability as an outcome' can be chosen. Nevertheless, this approach seemed to be the most data and resource demanding.

In the engineering or industrial sectors, "vulnerability as exposure" approach is popular, where vulnerability is seen as a direct function of hazards, and the object at risk (e.g. population) is a passive actor. The identification of vulnerability thresholds helps to understand level of damage, location of hotspots as well as choice and timing of adaptation measures. 'Vulnerability as a Threshold' approach requires modeling skills and stakeholder involvement to determine level of acceptable damage, status of adaptive capacity and adaptation needs using socio-economic scenarios and trends. Nevertheless, any comprehensive climate vulnerability assessment requires an integration of both top-down & bottom-up approaches and such successful integration requires direct partnerships between stakeholders and scientists (Mastrandrea et. al., 2010). Stakeholders can provide important 'reality checks' for model data generated by researchers (Schröter et al., 2005).

Exposure is a geospatial mapping of people, infrastructure and assets that could be affected by the hazard. In exposure assessment, the inclusion of future spatial data is not essential, if exposure is treated as 'a geographical location' (Elizabeth et. al., 2014). However, mapping exposure as 'a manifestation of a hazard' would benefit from the future spatial data (Alexandra et al., 2017).

Risk-based assessment can provide valuable input to private and public policy decisions (Michel-Kerjan et al. 2013; Mechler 2016). Climate risk assessment offer a systematic approach to capture the character and scale of different risks (estimation of the magnitude & frequency of natural hazards, the exposed assets & people, and vulnerability of assets and people under certain natural hazards), to make informed decisions (Aerts et al., 2014). However, if climate data does not adequately address the consequences of climate change, or If climate risk assessment is not relevant to the local scale, it will be difficult to take timely decisions or to justify new policies (Carter et al., 2015). Ignoring or wrongly interpreting risk data when making decisions can lead to maladaptation (McDermott and Surminski 2018). Addressing the climate risk that society faces requires participatory approaches that produce usable science and link that science to decision making (Kirchhoff et. al., 2015).

Methodological Framework for the Climate Risk Assessment

Vulnerability was a central concept in climate change research until the introduction of risk concept in the Intergovernmental Panel on Climate Change (IPCC) fifth assessment report in 2012. Before that, the representation of risk was based on the different views on vulnerability concepts developed through the disaster research in the past two decades. Disaster research use DR= H x V, as the foundational risk equation, where disaster risk (DR) is a function of hazard (H) and vulnerability (V) of the disaster impact area (Blaikie et al., 1994). Where the vulnerability was based on conditions of elements at risk that makes community more prone to hazard than infrastructures, risk was generally calculated by the equation, *Risk = Hazard X Vulnerability* (where the capacity is incorporated by vulnerability). Conversely, where vulnerability was based on the location of elements at risk, community and infrastructures both were equally prone to hazards, risk was calculated by the equation, *Risk = Hazard X vulnerability/capacity* (where the capacity is separate variable).

The IPCC framing suggest, climate risk (CR) = hazard (H) x exposure (E) x vulnerability (V), as the foundational risk equation for risk calculation. According to the IPCC framework, climate change risk arises from the interplay of climate change related hazards, exposure and vulnerability of human and natural systems. The risk assessment may be qualitative (where risk is described as high, medium, or low), or quantitative, (where risk is described as monetary value, number of potential victims etc.).

The climate risk assessment is the integrated assessment of multiple risk components (hazard, vulnerability and exposure) within the targeted population at a specific geographic location or ecological system to understand the nature of risk and to determine the level of risk using the IPCC foundational risk equation. Combining multiple risk components requires development of composite index through indicator-based spatial mapping. Climate risk components can be assessed by calculating composite indices from indicators. Composite index-based assessment method is more appropriate at local scales (Barnett et al., 2008, Hinkel, 2011) to raise awareness, support decision making, facilitate planning and policy development (Sandra 2014). In any risk assessment framework, maps should be produced as the key communication tool because maps can motivate people to take action.

Within the climate risk assessment framework, hazard component focuses on identifying and quantifying information on both the intensity of the event (or magnitude), and the probability of occurrence (or frequency) based on a catalogue of reliable historical data and observations. Hazards assessment include both slow-onset processes (e.g., increase in mean temperature or decrease in rainfall leading to impacts such as species changes or extinction, vegetation change or ground water shortages) and sudden onset events (e.g., flooding, heatwaves, landslides).

The consequences of hazards are generally measured in terms of damage or losses (Fuchs et al., 2012). Usually a hazard by hazard approach is considered for evaluating the consequences of individual climate-related hazards (e.g. heavy precipitation events, droughts, floods, debris flows, landslides, storm surges) on vulnerable systems (Hinkel et al., 2011). Two methods are common to assess hazards; the index or scoring method and the statistical method (Liu et al., 2014). The index or scoring method identifies hazards and their potential damage levels (Siddique and Schwarz 2015). Hazard scores can be calculated for identifying hazards through consideration of historical disaster data and their potential damage levels (Siddique and Schwarz 2015). The statistical method integrates the observations of past losses attributed to each hazard type (Liu et al. 2013). Nevertheless, in both methods, hazard assessment depends on the past disaster characteristics of a given area. Historical data analysis is a commonly used method for hazard identification (UNDP, 2004). However, this method relies on extensive historical data (at least 20 years) which may be unavailable for a given area.

Within the climate risk assessment framework, vulnerability component covers a variety of elements such as sensitivity or susceptibility to harm and lack of capacity to cope or adapt. To assess vulnerability component, both the biophysical factors (ecosystem features & their interconnections) and the human factors (economy, institutions, infrastructure and land use) should be investigated (Fawcett et al., 2017) and modelled (Penn et al., 2016). The identification of vulnerable people and places is key to enabling local communities to assess their vulnerability to natural disasters, improve their emergency management, and mitigate losses when a natural disaster occurs (Yoon 2012; Emrich & Cutter 2011; Gao et. al., 2014).

Vulnerability and resilience are often presented as opposites although depending on the particular risks, a system can be both resilient and vulnerable at the same time (Cutter et al., 2008; Reed & Stringer, 2016). Resilience refers to the capacity of the population or system to cope with the change in hazard exposures (Cutter et al., 2008). Vulnerability assessments allows investigation of the complex relationships between humans and their socio-physical environments (Fraser et al., 2011). Vulnerability assessment can help to make comparisons between households within the same agroclimatic zone. The vulnerability of a community can be determined by a range of factors such as location; physiography and hydro-geomorphology; structural interventions; climate variability; risk management; economic conditions of exposed communities; social conditions; traditional knowledge; general awareness about problems and solutions; and other survival skills like being able to swim (Das et. al., 2009). Physical vulnerability comprises the basic infrastructures needed to support the production of goods and sustainability of livelihoods (Scoones 1998). Mapping of the spatial distribution of Physical vulnerability of the people residing along the river bank is very much required to understand the severity of the problem. Social vulnerability assessment helps to understand why some communities experience and suffer from a hazard event differently than others. Quantification of social vulnerability is considered crucial for hazard mitigation planning and to better understanding on disaster risk (Tate 2012). In the past, social vulnerability research had largely focused on qualitative assessment methodologies (Dwyer et al. 2004). A few studies (Cutter et al. 2003; Holand et al., 2011) have tried to develop social vulnerability index to measure the overall vulnerability of a region based on a set of selected indicators (such as socio-economic status, education levels, employment status, demographic and ethnic composition, gender equality, political activity and housing).

Vulnerability with regard to livelihood can be determined by Household Livelihood Security Analysis (HLSA). Livelihood security refers to a livelihood that 'can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation' (Chambers & Conway, 1992). Livelihood diversification provides a meaningful way to approach livelihood security (Hussein and Nelson, 1998). HLSA is an asset-based, multidisciplinary framework to understand the broader systems that affect livelihoods (Cannon et al., 2005) using Participatory Rapid Appraisal (PRA) and Rural Rapid Appraisal (RRA) techniques. HLSA looks specifically at the dimensions of economic security, food security, health security, educational security and empowerment (Lindenberg, 2002). The Household Economy Approach (HEA) can also be used to map and profile climate change vulnerable households and zones with regard to livelihood (Seaman et al., 2010). The HEA is based on Amartya Sen's theory of exchange entitlements and economic theories of risk to predict the food and livelihood security across different wealth groups through the quantification of the household economy (Devereux, 2001; Seaman et al., 2010; Nhamo & Chilonda, 2012).

The vulnerability is often highly affected by sensitivity variables than climate exposure and adaptation capacity (Ho Gul Kim et.al, 2016). Sensitivity analysis helps to identify factors that have most influence on the functioning of a system (Dessai & Hulme 2007). Projecting sensitivity is challenging, because limited socio-economic or demographic data may produce high level of uncertainty (Adger et. al., 2009). The involvement of local stakeholders may increase the availability of socio- economic and spatial data through co-production, benefiting both the accuracy of assessment results, and their usability by the local administration and decision-making (Alexandra et al., 2017).

Physical exposure or exposure to hazard is a measure of the population-weighted "frequency and or probability of hazard events at each location" in a given period of time (Mosquera-Machado & Dilley, 2009). The exposure component requires detailed spatial information on the elements at risk (e.g. houses or infrastructure). Exposed elements may refer to agricultural crops, forests and natural ecosystems, protected wildlife areas, etc. Land-use maps can be used in assessing the spatial configuration of exposure and vulnerability (Brown et al 2013).

Large number of eye witness accounts can be used to generate reasonably accurate information of hazard timing (Gourley et al. 2010). To calculate the rainfall probability accurately, understanding the accuracy of past weather data is important. Standardized precipitation index (SPI) method is generally used to identify the wet and dry months from rainfall time series (Mckee et al., 1993). SPI can also be used as an indicator of drought or flood (Giddings et al., 2005). Mann–Kendall trend analysis (Mann, 1945; Kendall, 1975) and the Sen's slope (Sen, 1968) method are generally used to detect the presence of significant change and the magnitude of change, respectively.

The identification of the future landslide hazards requires quantitative prediction of changes in rainfall due to climate change (Lee et al. 2013, 2016). Understanding current and past relationships between rainfall and landslides is central to predicting future landslides. Descriptions of landslide hazards should include the location, volume (or area), classification, intensity and velocity of the existing or potential landslides and any resultant detached material, and the probability of their occurrence within a given period of time (Lee et al., 2016; Fell et al., 2008). Past and present data from remote sensing methods can be used as a reliable and cost-effective source of information on landslides.

Recent study (Jose et al., 2017) suggests that assessment of flooding should not only based on the physical and environmental indicators, but should also include the interaction between flooding and other agroecological & socio-economic factors. Flood hazard maps are used for estimating the danger to people due to flooding (Koks et al. 2015). Drought assessment is required to understand its magnitude in different areas from the past meteorological records (Kampragou et al., 2011; Mishra and Singh, 2010). Drought is a condition of abnormal weather resulting in a shortage of water (Smith and Petley, 2009; McKee et al., 1993). Lightning risk assessment helps to investigate, search for and locate high risk areas, enabling the implementation of mitigation measures for lightning risk reduction (Kaplan and Garrick 1981; Hu et al. 2014). Quantitative information about site-specific lightning risk is critical to public safety and infrastructure planning (Stallins and Rose 2008). To more effectively prevent heat hazards, it is important to determine both the regions and those people within the regions who are at an increased risk of being negatively affected by heat waves (Junzhe Bao, et.al, 2015).

People's Perception & Participation in the Climate Risk Assessment

The assessment of risk is concerned with the production of a shared understanding of reality (Horlick 1998). Individuals incorporate their own observations to assess their own risk and risk perceptions may differ due to social and cultural contexts (Peacock et. al., 2005). People perceive climate change risks through memories of past weather, current experience and future imaginaries and social practices (Geoghegan & Leyson, 2012; Hulme, 2010). The motivation and willingness to take preventive actions are directly related to individual levels of risk perception (Grothmann & Reusswig 2006; Wachinger et.al., 2013). In general, the higher the perceived risk, the higher the probability that the individual is willing to take preventive or protective actions to mitigate the risks (Lindell & Perry 2012; Peters et. al., 2012). Risk perception can be defined as an individual's assessment of risk or attitudes towards risks, which is influenced by the magnitude of potential loss & damage (Keil et al., 2000; Williams & Noyes, 2007).

The risk perception comprises the analysis of people's awareness, emotions and behavior with respect to hazards (Kellens, 2011). By fully engaging multiple stakeholders in dialogue and building networks for sharing knowledge and innovations, risks can be defined more appropriately (Ensor and Berger, 2009; van Aalst et al., 2008). Within a single community, the perception of climate change risks is quite different due to the variation in livelihoods (Ainka, 2014). The inclusion of local community in hazards analysis improves the accurate characterization of both the community and local conditions that may influence disaster impacts (Weichselgartner, 2001). Communities in disaster-prone areas may view extreme events as routine, not to be feared but respected (Galipaud, 2002). Community perceptions of common risks around the year are mostly related to hydro-meteorological phenomena (Sarwar and Kushal, 2010). People's views on risks and their value judgements are not static, but change according to their social values and worldviews (HSE 2001). Social values often define what communities think is worth protecting and doing (O'Brien and Wolf, 2010). Social values and worldviews represent an organized set of standards, including assumptions, beliefs, preferences and interests that guide people's attitudes, behavior, judgements and perceptions of themselves and the world (Rokeach, 1979; Rohan, 2000).

Material wealth, personality traits, preparedness and the perceived role of the individual versus society influence risk perception (Handmer and Penning-Rowsell, 1990). In general, women and older people show greater perception of risk from natural hazards (Kellens et.al., 2011; Grothmann & Reusswig 2006, Zaalberg et.al., 2009). Experience play a role in determining risk perception (Slovic, 1987). When the socioeconomic status of people increases, their perception of risk from natural hazards decreases (Lindell & Hwang 2008; Zhang et.al., 2010). For example, people's perception of flood risk could be low in areas where flood control measures or structures exists (Baldassarre et al., 2013; Terpstra, 2011).

Risk-taking attitude play a central role for determining risk behavior (response to risks) of individuals (Furman et al., 2010) because an individual may be aware of risk but may not want to involve in risk reduction measures. The interactions between hazards and different process like psychological, social, institutional, and cultural processes, influence individual and social risk behavior (Jasanoff, 1998). The public risk tolerance is a function of different factors including risk perception, judgements, aversion, willingness and benefits. The characteristics of the individual decision maker, organizational context and problem itself, influence individuals' risk decision making (Sitkin and Pablo, 1992).

The linguistic framings, vulnerability, place-based attachment and social commitments are key factors in interpretations of risk (Adger et al., 2012; 2011; Pam and Henry, 2012). The level of involvement and representation of the multiple stakeholders at the community level determines how risks are interpreted (Ensor, 2011; Ayers, 2011; van Aalst et al., 2008). Participatory climate risk scenarios (such as exploratory, normative and business as usual) can be developed by involving stakeholders in risk interpretation (Reed et al. 2013, Rounsevell & Metzger 2010). Climate risk scenarios are not predictions about how the future will turn out, rather, believable possibilities or alternatives that may appear. Therefore, through the risk evaluation, appropriate climate risk scenario can be selected using public risk tolerance, costs-benefits trade-offs, socio-political and ethical factors. Risk evaluation provide risk reduction recommendations for the decision-makers at various levels. In many cases, risk evaluation may be a socio-political rather than a scientific matter (Kunreuther and Slovic, 1996). Trust in risk reduction measures play a vital role for response to risk in the present society (Slovic, 1993).

The meanings and values attached to places shape how climate change risks are perceived at the community level (Ainka, 2014). Climate change may cause discontinuity of place due to loss or shifts in landscapes and livelihoods. Such discontinuities can have significant impacts on individual and collective place-based identity (Adger et al., 2012; Fresque-Baxter and Armitage, 2012). Despite recognizing the risks from sea level rise, many island communities do not view migration and resettlement as a viable option due to strong attachment to place (Adger et al., 2011; Pam and Henry, 2012).

Natural resource-dependent livelihoods directly face diverse and distinct climate change risks due to heavy rains, high winds, droughts, fires, glacier retreat, ocean acidification and sea level rise (Salick & Byg, 2007). Livelihoods based on tourism, construction and office work indirectly face climate change risks via impacts to markets, communication networks and infrastructure (Field et al., 2012). Differences in vulnerability can stem from differences in class, wealth, occupation, caste, ethnicity, gender, disability, health status, age, migration status and the nature and extent of social networks (Blaikie, et al., 1994). Differences in socio-economic vulnerability can often be linked to differences in socio-economic status, where a low-level of socio-economic status generally means more vulnerable (Cutter et al. 2003).

The capability of a society to adapt to difficult scenarios is a function of the distribution of wealth, education opportunities, and political participation (Ohlsson, 2000). Adaptive capacity exists at different scales (family, community, region and nation) and is primarily dependent on access to resources (Wall & Marzall, 2006). Adaptive capacity can be improved by poverty reduction, literacy, good governance (Cinner et al., 2012). Social capital is very important to cope with challenges presented by life in general (Putnam, 2000). Kinship networks allow communities to respond to climate-related risks through sharing of resources and labor locally as well as access to remittances externally (Batterbury & Mortimore, 2013). Social ties are critical in enabling coordinated action in response to climate change risks at the community level. However, there has been significant erosion of social ties & kinship networks due to colonial processes, demographic changes, and global market forces (Eriksen and Selboe, 2012). In addition, the knowledge about the importance, presence and potentiality of social ties for managing climate change risks at the community level is still in rudimentary stage.

The urban and rural poor have different vulnerabilities to climate-related hazards. The urban poor have higher risks associated with inequality in access to services, poor infrastructure, and increasing reliance on cash income. The rural poor, on the other hand, have risk factors associated with decreased access to services, the market, and transportation, as well as a reliance on subsistence agriculture (Ruel et. al., 2010; Baud, et. al., 2008).

Shared social learning encourage collective action to tackle a shared problem and improves people's capacity to adapt to an ever-changing world. (Groot & Maarleveld 2000). Shared learning facilitates negotiation within the community about their needs and priorities as well as improved planning for future risks (Tschakert and Dietrich, 2010). Open, inclusive and participatory decision-making practice can lead to better assessment of climate change risks through collective action (Ensor and Berger, 2009). The understanding about politics of community participation is very important to unmask how authority, legitimacy and power are enacted and linked to particular interest groups within the community. Otherwise, the participatory processes can even serve only to legitimate a pre-determined course of action rather than enabling meaningful community engagement on climate change (Dodman and Mitlin, 2011; Few et al., 2007). For example, consultations in preparing Bangladesh's adaptation policy did not engage a wide range of local stakeholders, rather used preconceived objectives (Ayers 2011).

A warning system should empower individuals, communities, and businesses to respond to hazards in a timely and appropriate manner (Rogers & Tsirkunov 2013). Demographic factors such as socioeconomic status, age, and gender influence the processing of information and responding (Lindell & Perry 2012). Females are more likely to respond to warnings than males, due to reasons such as their more dominate roles as caregivers, their heightened perceived risk, and their higher exposure to risk (Bateman & Edwards 2002, Ripberger et.al., 2014). People are more likely to take protective action as a result of being given coping information, rather than information on the threat, which is designed to raise risk perceptions (Ruiter et al., 2014). People are more likely to believe and respond to a warning if they understand the warning, and are knowledgeable about the potential hazard impacts (Michael et. al., 2014; Morss & Hayden 2010). Index-based Early Warning System can be developed from the findings of the risk assessment to improve the timely response to mitigate the risk by taking protective actions (McGregor et al. 2015; WMO 2015). The two-way dialogue between the users of climate information and the scientists who generate it, are needed, in order to tackle the climate change risks and responses more effectively (Lemos et al. 2012).

Importance of Indicators in the Climate Risk Assessment

An indicator is a direct or indirect measure (proxy indicator), or a calculation used to represent an attribute of a system of interest (e.g., demographic, geographic, socioeconomic). Indicators are key tools for measuring climate risk components. An indicator may represent a single variable or a combination of variables. The choice of variables is more important than methods used in index building (Yoon, 2012). Variables are generally a set of information used to determine the status quo or changes of a system (Sullivan, 2002). Variables should be measurable, accessible, transferable, easy to be applied in practice, and not redundant (Birkmann, 2006). It is important to note that any index will be a mathematical expression of a persuasive conceptual model if it is not tested with observational data (Junzhe Bao, et.al, 2015). Weighting of indicators require expert knowledge which may not be available in local level. In this context, it is better to consider that all indicators contribute equally for the assessment.

Potential indicators of exposure are characteristics of the habitat of people, density of population, livelihood and environment (Su et al., 2015; Benassai, et al., 2015; Islam et al., 2014). At large scales (national to district level), population density can provide an approximate indicator of the level of human exposure, while at local scale, exposure assessments must quantify and map more precisely the people, infrastructure and assets that can be affected (Allen et al., 2016). Population exposure indicator considers differences between populations based on their socio-economic characteristics (Balica et al., 2012; Cutter et al., 2013). The land use exposure indicator compares the relative value of exposed elements (such as assets, households and land) in a geographic using either economic valuation or end-user preference valuation (Merz et al., 2010). Landscape change is a clear evidence of climate change. Therefore, indicators that connect landscape changes with climatic factors should be considered.

Rainfall is one of the important weather indicators of climate change (Stringer, 1995). Areas with less or equal to 380mm throughout the dry season has been termed as the rainfall stressed area (Sarker and Ahmed, 2015). The annual rainfall between 25% and 50% deficiency can be considered as moderate drought whereas annual rainfall less than the value of 50% deficiency can be considered as severe drought in a region. Moreover, a year is considered as a drought year, if the total area of the country is affected with more than 20% deficiency of annual rainfall (Keka et al., 2012). Meteorological drought is defined on the basis of the degree of dryness and the severity of drought in a region and can be assessed through annual rainfall (Mckee, et al., 1993; Nagarajan, 2009).

Flood severity, flood duration and flood inundation area are key indicators for characterizing a flood event. The scale of flood events should be based on flood severity, flood magnitude and also on the extent of flood damage, human casualties, psychological impact (Kvočka et. al., 2016).

The heat index combines the influence of relative humidity and temperature to give an ‘‘apparent’’ temperature (McGregor et al. 2015). Sub-seasonal forecasts of heat wave risk may be possible by monitoring soil moisture conditions (Hannah et al., 2017) because vegetation has a significant and negative correlation with temperature and the occurrence of extreme heat events (Stone et al., 2010).

Storm surge elevations and return periods are useful to assess the likelihood of extreme water depths associated with tropical storms or cyclones. Currently, the hazard from storm surge and coastal inundation is described by inundation maps and the base flood elevation maps (Andrew & Sheng 2012). Many studies focus on cyclone genesis frequency or maximum intensity. But when considering impact, the location of the tracks is most important, as it relates to landfall.

Lightning frequency within a defined geographic boundary can help to identify which areas have more lightning. The identification of the number of dangerous lightning events and ground sensitivity to lightning in the past helps to assess future lightning risks. The estimation of ground sensitivity to lightning is linked with topographical features and distribution of earthed structures (Vogt 2011). Natural lightning strikes to trees may help to identify the lightning location.

Current rate of sea level rise is assessed using two techniques: tide gauges and satellite altimetry. Instrumental records of satellite altimetry are being used for assessment of sea level rise trends since 1993. Relative Sea Level (RSL) is measured with respect to the surface of the solid Earth, whereas Geocentric Sea Level (GSL) is measured with respect to a geocentric reference such as the reference ellipsoid. Mean Sea Level (MSL) is defined as the temporal average for a given location. The Global Mean Sea Level (GMSL) is the spatial average of all the MSL (IPCC, 2013a). Due to tectonic uplift or land subsidence, local sea level may down or rise.

The impacts of river bank erosion hazards may be assessed in terms of loss of land, change in occupation, and impacts on social ties and relationships.

A water scarcity index is a measurement of the ability to meet all water requirements for basic human needs: drinking water for survival, water for human hygiene, water for sanitation services, and modest household needs for preparing food (Gleick 1996). The water that is available to each person can serve as a measure of scarcity. Based on the per capita usage, the water conditions in an area can be categorized as: no stress, stress, scarcity, and absolute scarcity. A country can be considered as water scarce if annual withdrawals are between 20 and 40% of annual supply, and severely water scarce if withdrawals exceed 40% (Raskin, et al., 1997). Indicators of physical water scarcity include, acute environmental degradation, diminishing groundwater, and water allocations that support some sectors over others (Molden 2007). It would be more accurate to consider monthly values for evaluating water scarcity (Hoekstra et al. 2009).

Water Scarcity Index: Proposed water requirements for meeting basic human needs (Gleick 1996)

Minimum Drinking Water Requirement	5 liters per person per day
Basic Requirements for Sanitation	20 liters per person per day
Basic Water Requirements for Bathing	15 liters per person per day
Basic Requirement for Food Preparation	10 liters per person per day
Total demand for meeting basic human needs	50 liters per person per day

The Falkenmark water stress index provides a way of distinguishing between climate and human-induced water scarcity. The index thresholds 1,700m^3 and 1000m^3 per capita per year are used as the thresholds between water stressed and scarce areas, respectively (Falkenmark 1989).

Water barrier differentiation (Falkenmark 1989)

Water Stress Index (m^3 per capita)	Category/Condition
>1,700	No Stress
1,000-1,700	Stress
500-1,000	Scarcity
<500	Absolute Scarcity

As vulnerability cannot be directly measured or observed, proxy indicators of sensitivity and adaptive capacity should be used to quantify vulnerability. While debates are ongoing about methods to quantify vulnerability and appropriate indicators, vulnerability indexes typically use census data at the national scale (Birkmann, 2015; Chen et al., 2013; Cutter and Finch, 2008). A vulnerability index can be developed by combining vulnerability indicators to identify areas having a high vulnerability to natural disasters (Yoon 2012; Cutter et al. 2003). The livelihood indicators like education level of household head, age, job experience, number of employed members and per capita income can be used to assess household vulnerability (Inayatullah et al., 2012). The region with highest exposure and lowest adaptive capacity is the most vulnerable region and poor household is the most vulnerable, irrespective of locations (Piya et al., 2012). Social vulnerability assessments utilize different sets of indicators because the indicators used in one setting or context may not be appropriate in another (Rygel et al. 2006). The level of poverty, the differences in access to resources, the volume of migration from peripheral regions towards the centre may provide indicators which can help to assess and quantify the social consequences. Lack of energy, damage in the infrastructure, industrial damages, diseases, higher mortality rates caused by the heatwaves, food shortages and water scarcity are key social vulnerability indicators (Gasper, R. et al. 2011).

Demographic and economic characteristics of communities effectively represent social vulnerability in each country (Yoon 2012; Yoon & Jeong 2016). From previous studies (Armas & Gavris 2013; Chen et. al., 2013; Emrich & Cutter 2011; Gao et. al., 2014; Kim et. al., 2012; Prashar et. al., 2012; Yoon 2012; Yoon & Jeong 2016; Yang et. al., 2015; Zhou et. al., 2014), demographic indicators can be categorized into age (ratio of elderly and younger people), minority (foreigners and ethnic minorities), gender (sex ratio), population (number of dwellings, migration, population density, and population growth), education (education level, illiteracy rate, awareness and perception of hazards), and household (household types, living space, and household size).

The indicators that contribute to exposure, sensitivity and adaptability are different from place to place. The lack of the knowledge necessary for responding to extreme weather events or disasters limits capacity of the less-educated people to understand warning information for coping with natural disasters. The less-educated population can be calculated as the percentage of the population without elementary school education. Higher the literacy rate means higher adaptive capacity. Economic indicators can be categorized into income (poverty, unemployment rate, household income, household assets, gross domestic product (GDP), income of rural households, savings, and distribution of wealth), social capital (public assistance, property tax, investments, medical services, budget, subsidies and resources for disaster prevention & hazard mitigation, relief, and adaptation assistance), and business (business types and job types). Consumption could be a better proxy indicator for welfare (utility and the standard of living).

From the vulnerability literature (Seunghoo and Yoon 2018), the natural environment indicators can be categorized into Geological (mean slope, stream length, low-lying areas, proximity to higher ground, and distance to a river), Meteorological (precipitation, past experiences, intensity and frequency of natural hazards, and depth of flood waters) and Buffer area (open space, ecosystem, degradation of the environment, soil erosion, rate of protected and organic farm areas, filter and buffer capacity, and water retaining capacity). The built environment indicators can be categorized into land use (type of land use, industry density, residential area); building characteristic (building age, number of old buildings, reinforcement concrete building, number of building floors, improper building construction, and building types), infrastructure (roads, bridges, dams, schools, railways, ports, police station, fire station, hospital, shelter, electricity & water supplies, public transportation system, sanitation, waste disposal sites and early warning systems), and urbanization (impervious surfaces, urban population, and urbanization rate).

Precipitation, frequency of natural disasters (for example, cyclone) or extreme weather event (such as heavy rain), location of a community and buffer zone (open space consisting of trees & vegetation) could be considered as indicators related to the degree of damage by extreme weather events or natural disasters (Yoon & Jeong 2016; Prashar et. al., 2012; Qiu et. al., 2006; Felsenstein & Lichter 2014). Disaster damage is more severe in communities where annual precipitation is high and natural disasters happen frequently. Open space as a buffer zone play a significant role in diminishing disaster damage and reducing future climate vulnerability (Qiu et. al., 2006; Seunghoo and Yoon 2018). Dense housing (number of homes per square kilometer) can maximize open spaces, and is known to decrease vulnerability to natural hazards (Berke & Campanella 2006).

Health related factors like illness, life expectancy, reduction in nutrition; food and water related factors like household dependent on family farm for food, crop diversity index, time for fetching drinking water, number of months household faces difficulty to provide food, insufficient water supply, depletion in natural water resource can be considered as indicators for sensitivity. Among the sensitivity indicators, share of income from salaried job decreases the overall household sensitivity. On the other hand, households with higher share of income from natural resource were more sensitive to climate change and extremes. In areas where there is low exposure, sudden onset of extreme events will have great impact if the households have low adaptive capacity.

Sensitivity can be reduced by improving adaptive capacity. Adaptive capacity has two dimensions; a generic dimension and a specific dimension. The generic dimension refers to indicators such as education, income, and health, whereas the specific dimension refers to indicators regarding a determined impact (e.g., drought, flood, or hurricane) and can be associated with the institutions, knowledge, and technology characteristics of the system (Tol & Yohe, 2007). Adaptive capacity is inversely related with vulnerability; higher the adaptive capacity, lower is the vulnerability (Rao et al., 2016). Households that are more linked to banks and credit societies have more adaptive capacity and are less vulnerable (Piya et al., 2012). Higher qualification and training increases adaptability while dependency ratio decreases adaptability.

Exposure can be derived from the combination of a set of quantitative indicators mapping the distribution of population and assets or goods that can be affected by both short-term and long-term hazard events. Household data on climatic variation in the past 10 years like percentage of household reported as less rain, drought, flood, occurrence of unusual rain, increase in temperature, less rain in a year than average rainy season can be used as indicators for climatic exposure. The frequency of occurrence of flood, drought, hailstorms over the last 10 years, change in annual precipitation, and change in annual maximum and minimum temperature could be used as indicators for exposure of rural households (Piya et al., 2012). The annual rainfall, maximum temperature, minimum temperature, frequency of heat wave, cold wave, frequency of drought and flood, frost, dry spells and occurrence of extreme rainfall events can also be used as indicators of exposure to assess vulnerability of agriculture to climate change (Rao et al., 2016).

Factors that may Influence Climate Risk Assessment

Discourses form a set of concepts and institutions by framing particular places and community are at risk and justify interventions to address the risk (Foucault, 1980; Hajer, 1995). Decades ago, discourses on disasters was largely about natural hazards and their characteristics (Noy and Yonson 2018). Three global studies of population risk assessments of hazard events have influenced policy discourses worldwide (Mosquera-Machado & Dilley, 2009); the Disaster Risk Index (DRI) by the United Nations Development Program (UNDP 2004); the Global Natural Disasters Risk Hotspots (GNDRH) developed by Columbia University, the World Bank, and the Norwegian Technical Institute (Dilley et al., 2005); and the biennial global assessment reports (GAR) by the United Nations International Strategy for Disaster Reduction (UNISDR, 2013).

Discourses about the climate change should be seen as an intellectual resource because it plays a significant role in how climate change and its risks are interpreted and made meaningful for communities (Hulme 2009; Boykoff et al., 2009). The discourse about the role of social agency, uncertainty, feedback loops and learning mechanisms allows to understand risk, vulnerability and resilience more integrated way (Muriel & Nightingale 2012). Climate change risks and responses must be understood and interpreted in relation to ideas of 'what is a good life' and 'ought to be' (O'Brien & Wolf, 2010). The public responses to risks can be amplified or reduced depending on how the reporting of the risk interacts with psychological, social, cultural, and institutional processes (HSE 2001). However, scaring people with doom-laden scenarios about the effects of climate change proves counter-productive and media campaigns are found less effective than face-to-face communication (Moser & Dilling, 2011).

Risk itself can be reduced by understanding the types of hazards in a community, protecting the environment, and preventing development in hazardous areas. Resilient communities would feature high levels of solidarity, low levels of socioeconomic inequality, and empowered citizens (Barry 2012). The institutional capacity significantly influences community resilience through its influence on processes of gaining and using resources of social groups (Adger, 1999). A country's social welfare system can mitigate vulnerability to natural hazards (Holand et al. 2011). Social capital has been recognized as necessary to build community capacity for a sustainable future (Hall 1999).

Politics plays a critical role in the process of negotiating multiple stakeholders' experiences and meanings of climate change risks and enabling collective responses (Dodman & Mitlin, 2011; Ensor, 2011; Few et al., 2007). More knowledge does not necessarily lead to changes in political action, because science alone cannot resolve disagreements that are deeply rooted within the political or ethical context (Sarewitz 2004). Besides, studies have exposed that scientists, practitioners and policy-makers often tend to overshadow or drive community concerns by their own framing of climate change risk, (Ayers, 2011; Barnett & Campbell, 2010). There is a long history of privileging techno-bureaucratic expertise in risk management related to environmental issues, leading to paternalistic and prescriptive measures (Douglas & Wildavsky, 1982). The globalized, impersonal, techno-scientific accounts of climate change are not only creating confusion within communities but also obscuring how risk is experienced and interpreted within the communities (Ayers, 2011; Leonard et al., 2013).

One of the identified bottlenecks in assessing vulnerability and exposure dynamics and projecting them into future is poor availability of data, particularly future socio-economic data. Even if datasets that can be used in assessing current vulnerability are available, they often offer little help in assessing future vulnerability (Alexandra et al., 2017). Since there is widespread uncertainty in predicting future vulnerability because of scarcity and reliability of data, a combination of multiple sources of information, as well as the inclusion of a range of uncertainties, can provide more robust understanding of change, regardless of spatial resolution (Hewitson et al, 2014).

History shows that human societies are even capable of causing their own collapse by destroying resources on which they depend (Diamond 2005). On the other hand, communities are quite capable of devising responses to collective action to address climate change problems without top-down management (Ostrom 2009). Communities are also able to deal with uncertainties within the particular local context (Woodley, 1991). However, the top-down framing of risk assessment often undermines local discourse and pave the way for justifying foreign intervention via aid, technology transfer and climate information provision (Pam & Henry, 2012; Barnett & Campbell, 2010).

As climate impacts are locally experienced, implementation must be tailored to local context, and the top-down approaches are unlikely to succeed (Ayers & Forsyth, 2009; Dodman & Mitlin, 2011). At local or regional levels, risk management focuses more on existing risks rather than long-term scenarios (Maria et.al, 2016). Local knowledge systems and rituals for predicting and responding to weather variability are grounded in localized encounters (Marin, 2010). The detailed assessment on the influence of climate change on socioeconomic aspects, has received less attention.

Climate change can undermine basic human rights. Protecting vulnerable communities is the key to climate justice. All people have a right not to suffer from climate impacts that undermine their basic needs (Caney 2010). Climate change has significant implications for intra-generational and inter-generational equity (Halsnæs et al. 2007). Nevertheless, the world has not taken serious attempts to address climate change using justice perspective (Gardiner 2011). The procedural and distributive dimensions of equality and equity are important in determining (Otto et al., 2017) and addressing (Ikeme 2003) the variation in the degree of household vulnerability in the community and the effectiveness of climate policies.

Gender, religion, age, disability and ethnic identity play a significant role in how climate change risks are experienced and distributed within communities (Jones & Boyd 2011). Gendered values and attitudes have profound effects on all social aspects (Jarviluoma et al., 2003). Gender is a contributing factor to increased mortality rates during heat waves, where elderly women are generally in a larger risk of dying during a heat wave. Religion can motivate morality to protect future generations, those most vulnerable to the effects of climate change, and nature (Gottlieb, 2006). Discrimination plays a major role in increasing the vulnerability of ethnic minorities.

Demographic growth in hazards-prone locations can increase the population exposed, and ultimately lead to increased risk (Forzieri et al., 2017). The geographic space influences the implications of risk while risk situations affect geographic space and the spatiality of risk is always multifaceted (November 2008; Healy 2004). The creation of vulnerability and exposure for extensive risk is more closely linked to underlying drivers such as poverty and inequality, environmental degradation, poor urban planning, vulnerable rural livelihoods and weak governance than with the physical hazard itself (Bull-Kamanga et al.,2003). The occupancy characteristics (e.g. settlement location and types, livelihoods, land uses, etc.) may influence exposure and sensitivity (Smit and Wandel, 2006). There are certain developmental factors (such as poverty, health status, economic inequality and elements of governance) that are likely to influence vulnerability to some specific hazard in different geographical and socio-political contexts (Brooks et. al., 2005).

Climate change vulnerability is multifaceted, with interactions between socio-economic and biophysical aspects (Dessai & Hulme, 2004; Nair & Bharat, 2011). Environmental (threat and exposure in geographic perspective) and social (cultural and historical background) contexts determine specific effects of vulnerability (Anderson-Berry and King, 2005). Deeper understanding of vulnerability requires detailed consideration of economic, social, geographic, demographic, cultural, institutional, governance, and environmental factors (IPCC, 2012). Root causes, dynamic pressures, and unsafe conditions contributes to the development of vulnerability (Blaikie et al. 1994). Root causes are processes (economic, demographic, and political) of a society that influence the inequality of power and assets within the society. When dynamic pressures (attributes of a society such as population growth or urbanization) impacted by the hazard, root causes become unsafe conditions.

Despite similar magnitudes, the impact of natural disasters is unevenly distributed among communities with different social and physical aspects (Yoon 2012; Yoon & Jeong 2016). The social and physical characteristics of a community determines the level of vulnerability (Yoon 2012; Yoon & Jeong 2016; McEntire, D., 2012). Demographic patterns and economic status are factors related to social vulnerability and physical vulnerability vary across different geographic regions (Cutter et al. 2003; McEntire, D., 2012; Perrow, C. 2011). Economic conditions also affect the level of vulnerability. Economic vulnerability is highly dependent upon the economic status of individuals, communities and nations. Social fabric (interaction amongst community members) and environmental context (geographic context) influence hazard or hazard potential (Cutter, 1996; Cutter et al. 2000).

Poverty, poor structure of housing, lack of adaptive capacity and nature-dependent livelihood can increase vulnerability (Rawlani et al., 2014; Collins, 2014). Rural population is vulnerable to climate change due to heavy dependence on climate-sensitive livelihood options (agriculture in particular) and limited adaptive capacity to cope with changes. Internal (household income, social networks or access to information) and external socio-economic drivers (national policies, international aid or economic globalization), not only affect a person's vulnerability, but also generate challenges for measuring a person's vulnerability. For example, with a quantitative method, it is difficult to measure a person's social networks while household income could be easily measured quantitatively.

Social vulnerability consists of two distinct aspects: collective and individual vulnerability, which differ in their indicators and scales (Adger 2006). Collective vulnerability is often analyzed at community, national or regional scale, while individual vulnerability is linked to the household and individual scale. Most social vulnerability assessments adopt top-down approaches which rely on existing national scale data for analyzing collective vulnerability. Social vulnerability is linked to the level of well-being of individuals, communities and society. Changes in the current situation of society like population density, population ageing, literacy, income source, income distribution, existing mitigation measures, road density, access to insurance, access to forecasting information, access to health care, diversity of economic assets and informal social security influence the vulnerability of a society to the natural hazard (Adger 1999; Doch et al., 2015; Heng et al., 2013; Mallari, 2016).

The capacity of a household to cope with climate risks depends to some degree on the enabling environment of the community is reflective of the resources and processes of the region (Yohe and Tol 2002). The lack of or limited access to livelihood assets increases the incapacity to avoid risks and it increases the shocks and stresses to which an individual or household is exposed to. The higher the level of economic assets available to a household in a particular district, the higher the level of their adaptive capacity, since they would likely be unable to afford changes to their livelihoods in case of hazard exposure. At the household level, a lack of financial resources will adversely affect a household's ability to recover from the impacts of extreme events in terms of rebuilding infrastructure and reinvesting in damaged sectors. The ownership of radio, television and telephone can increase the adaptive capacity through access the weather-related information.

People who are highly vulnerable to climate change generally rely on climate-sensitive resources for their livelihoods (Füssel, 2012; Okpara et al. 2017). People living in poor housing conditions, such as lacking sufficient living space or access to safe drinking water and sanitation, are more sensitive to climatic hazards. Children are more sensitive to extreme events than adults (Morrow, 1999). Common individual characteristics including age, race, gender, income, ethnicity, dwelling, employment, disabilities and level of education influence social vulnerability (Cutter et al. 2003; Rygel et al. 2006). Families with large numbers of dependents will reduce the resilience of the whole family (Frigerio & Amicis, 2016).

Studies (Oudin Åström et al., 2011) show a relationship between heat/heat waves and increased mortality rates (mainly due to respiratory or cardiovascular) in elderly population. Further, being elderly or person with disability living alone are more vulnerable than elderly who are not living alone. The elderly person also means less ability to work or too old to work. Low-income people tend to be more vulnerable to natural disasters, due to limited access to the resources needed to recover from disaster losses. The poor may have difficulties in placing their dwellings in safe areas, leading them to live in hazard prone areas (McEntire, D., 2012).

Technology, knowledge, institutional strengths, access to information, social networking, and physical assets are key factors of the adaptive capacity (Rawlani et al., 2014; UNISDR et al., 2015). Education level is a significant factor in determining income levels, health problems, quality of life, and employment status. Education helps vulnerable people access and act on hazard information, which helps them to prepare for, respond to, and recover from natural disasters (Zhou et. al., 2014; Chen et. al., 2013).

Cities are the source of over 70 percent of global greenhouse gas emissions (Rosenzweig et al. 2011; Komeily & Srinivasan 2015; Macomber 2013). In the near future 40 % of the global urban land will be located in areas highly prone to flooding (Guneralp et al. 2015) and 66 % of the world's population will live in urban areas by 2050 (UN 2014). Given the particularities of urban areas, the rapid pace of urban growth and increasing intra-inequalities, vulnerabilities related to urbanization processes need to be assessed separately (Szabo et al. 2015b; Szabo 2015). Urban areas are the potential hotspots of climate risks (Hunt & Watkiss 2011). Increased flooding, storms, and sea level rise will drastically increase vulnerability to urban water systems, contributing to the degradation of materials important to urban water infrastructure. Urbanization affects the thunderstorm climatology of cities and surrounding areas (Huff and Changnon, 1973). Urban heat islands (UHI) may modify the formation and movement of convective storms (Bornstein and Lin, 2000). Heat island-induced atmospheric convergence may also initiate new storms over or downwind of a city depending upon the strength of regional flows (Changnon, 2001).

Geophysical environmental factors (e.g., Earth's magnetic field, solar impulse, movement of tectonic plates, geomorphic and geologic process) are the basic conditions for the occurrence of hazards (Shi, 1996; McGuire et al., 2002). Different combinations of the geophysical environmental factors can induce different hazards. The magnetic field intensity at Earth's surface highly depends on the geographical location. Earth's gravitational interaction with the Moon and the Sun influence tide-raising forces. Hence hazard-forming environment analysis is useful in both hazard identification and hazard interaction analysis. However, as the formation of some hazards is not fully understood, there are some limitations to hazard-forming environment analysis. The understanding of the hazard interactions is very important for identifying the realistic hazard impact because any natural hazard might trigger other natural hazards or may change the probability of occurring another hazard (van Westen et al., 2014).

The inter-annual, monthly and daily distribution of climate variables (e.g., temperature, radiation, precipitation, water vapor pressure in the air and wind speed) involves a number of complex and diverse physical, chemical and biological processes to drive occurrence of the hazards, for example, the intensification of the water cycle results in the occurrence of hazards like excessive rainfall, flooding, storms, drought, etc. (Heng et al., 2013).

Wind is a vital indicator of the atmospheric circulation. Wind is the most destructive natural phenomenon, over 70% of the damage and deaths caused by the nature are due to the wind (Tamura and Cao, 2012; Ulbrich et al., 2013). A climatologic condition in which wind phenomena of different nature coexist (e.g. extra-tropical and tropical cyclones, monsoons, tornadoes, downslope winds and thunderstorms) is referred to as a mixed wind climate (Gomes and Vickery, 1978). Tornado damages are caused by the high wind speed and high difference in atmospheric pressure between the tornado and its surroundings. The cause of hail is instant and massive amounts of heat lightning discharge in the cumulonimbus clouds (Ismailov, 2014).

Water is a medium through which climate change influences the Earth's ecosystem. Rainfall associated with tropical cyclones is as important as wind in determining damages (Park et al 2015, 2016). Waves are an important hazard component as they lead to an additional elevation in mean water level near the coast (Bertin et al. 2012), to drive coastal erosion and wave induced flooding. The combined interactions of wind-generated waves, tidal waves and currents from rivers influence the coastal erosion. The glacier mass loss is the key trigger factor for changes in the global sea level (Church et. al., 2011). Changes in the volume of the ocean basins; as well as changes in the volume of sea water due to melting of glaciers causes eustatic sea-level changes. Riverbank erosion occurs primarily through a combination of three mechanisms: sub-aerial weakening and weathering, fluvial erosion, and mass failure (Mengoni and Mosselman, 2006). Erosion mainly depends on land slope where convex slope is more prone to erosion than the concave slope.

The changing frequency, intensity and patterns in rainfall also have implication for replenishment of groundwater storage, and inform the choice of appropriate technology for sanitation among other. Rainfall distribution varies across regions and depends on factors such as the direction of moisture-bearing winds, the presence of mountain systems, and others. Rainfall has a major influence on landslide occurrence. Tropical cyclone formation is influenced by many factors, but the role of warm sea-surface temperatures as the primary source of energy for cyclones is paramount (Walsh et. al., 2016). The drivers of flood risk are influenced by human and economic development, climate change, and disaster risk management.

Cloudburst is a sudden heavy downpour over a small region and causes devastating flash floods. The cloudbursts are among the least known mesoscale weather systems, characterized by very high intensity rainfall greater than 100 mm per hour occurring over short duration (Das et al. 2006). Ground monitoring stations are hardly able to capture the storm characteristics due to its highly localized occurrence (Renoj et al. 2012). Several driving forces have been causing to increase in frequency and intensity of cloudbursts-triggered disasters in the Himalaya, and climate change has been observed as a major driver (Ives and Messerli 1989).

Soil erosion is a naturally occurring environmental process by which soil materials are displaced, transported, and deposited in downstream areas by wind, water, or gravitational forces (Boardman, 2013). Though soil erosions are the result of the interaction between soil erodibility (vulnerability of soil to erosion), rainfall erosivity (rainfall and associated runoff driven erosion processes) and wind factors, inappropriate human practices (such as cultivation in upslope areas, deforestation, extension of urban areas, and overgrazing) aggravate the problem (Aksoy & Kavvas, 2005; Meshesha et. al., 2014; Mekonnen et. al., 2017). Soil erosion increases as a result of heavy rainfall.

Climate variables, such as precipitation, surface runoff, and temperature can play a big role in affecting saltwater intrusion. As sea level rises, there is greater potential of intrusion of sea water into aquifers, reducing the available fresh water volume. Human activities are considered as the great influential factor for changing the chemistry of river properties and thus affect its existing ecological system because the human population has increased rapidly in coastal regions throughout the world in recent years (Alongi, 1998). Reduced river discharges imply a lower dilution capacity that could be translated to higher salinity concentrations (Crowther and Hynes, 1977).

Challenges in Climate Risk Assessments

As the concept of 'climate risk' has emerged few years back, clarity is still lacking on how to measure risk, hazard, exposure and vulnerability concepts at the sub-national or local level (IHCAP, 2017). Climate risk assessments are often not optimally designed to deliver the kind of actionable information decision-makers need because the mode of climate risk assessment in scientific domains varies widely (Doro-on 2011; Sayers 2012; Weaver et al. 2017). More methodological developments are needed in addressing climate induced future socio-economic changes at the sub-national or local level (Alexandra et al., 2017) because analyzing the social dimensions of climate change is as important as scientific analysis (Geoghegan & Leyson, 2012). In the social science paradigm, emphasis is placed on vulnerability and hazard receives minimal attention. Social scientists generally view vulnerability and resilience as a set of socio-economic factors that determine people's ability to cope with changes (Field et al., 2012). In the natural science paradigm emphasis is placed on characterization of hazard and exposure while vulnerability is considered as a static factor that modifies the amount of loss caused by threats. In addition, coping capacity receives very little attention in the natural science paradigm. Natural scientists and engineers often view vulnerability and resilience as the likelihood of occurrence of specific hazards and impacts of the hazards on the built environment such as buildings, roads, pavements etc. (Papathoma-Köhle et al., 2011). The development of new methods and tools in the context of multiple hazards is a major challenge for climate-related research (Gallina et al., 2014). There is still a need for robust and meaningful comparisons between the climate risks arising from individual hazard types occurring in the same area (Kappes et al. 2012, Marzocchi et al. 2012).

While there is some agreement on large-scale climate risk assessment by global climate models, there is significant divergence in the local climate risk projections as they related to climate variables at the local scale. A global climate model is a numerical representation on the basis of well-established physical laws, and observations of physical processes that take place in the Earth's atmosphere, ocean and land surface (McGuffie & Henderson-Sellers 2005). Climate science and model projections can only offer a rough guide for localized actions at present (Ensor, 2011). While climate modelling can predict average changes in temperature and sea level rise with reasonable confidence, there is much uncertainty around projections in rainfall, ocean acidification and extreme weather events at specific localities (Stainforth et al., 2007; Wilby et al., 2009). Nevertheless, no modelling exercise can ever cover all possible climate eventualities, and the potential for climatic surprises is always present (Stainforth et al. 2007).

Risk assessment often lacks a common framework allowing for the comparability of quantitative risk assessments, both in terms of comparable spatial and temporal scales and also the issue of uncertainties has not usually been considered for comparing natural hazard risk (Fleming et. al., 2016). The relationship between vulnerability, resilience, and adaptive capacity is still not well articulated (Adger, 2006; Cutter et. al., 2008). Multiple definitions of vulnerability and resilience exist within the literature, with no broadly accepted single definition (Klein et al., 2003; Manyena, 2006). The lack of a common terminology to identify the scale is a major issue in risk information management and processing (Vagelis et al., 2010).

Numerous methods use climate exposure, sensitivity, and adaptive capacity to assess vulnerability, which may differ according to the scale of analysis, property of field, and availability of data (Sullivan and Meigh 2007). Nevertheless, there is yet no consensus on how to measure vulnerability (Hinkel, 2011). Moreover, the development of any one-size-fits-all solution for assessing vulnerability to climate change is problematic because vulnerability is bound to a specific location and context (Cutter, et al., 2003; Hinkel, 2011). Most of the current climate change projections go up to 2100, whereas vulnerability assessments are mostly based on present socio-economic data (Cardona et al 2012). The vulnerability of the critical infrastructures (road network, utilities) and the consequences for the population not exposed to the hazard but dependent of these services is often not considered (Viavattene et al., 2017).

The term exposure has been used in a variety of meanings in the literature (Räsänen et. al., 2016). Exposures to different hazard types cannot be easily compared due to the specific nature of each hazard type (rapidity of onset, spatial extent and destruction potential). Risk assessment often ignores future exposure scenarios because it requires a high amount of data that are rarely available.

Too much uncertainty in climate information is often used as an explanation for not engaging with adaptation problems, in what has been referred to as the “uncertainty fallacy” (Lemos & Rood 2010). This fallacy arises on the basis of expectation, that one day we will have highly certain predictions about the future, and when we have them, then we will act.

The magnitude of potential damage is an influential factor in shaping risk perception (Keil et al., 2000). However, the overestimation of the probability or magnitude of damage may lead to lowering of risk perception (Vlek and Stallen, 1980). The public prefers clear information regarding risks and associated uncertainties, including the nature and extent of disagreements among different experts in the field (Frewer 2004). More research is needed to develop innovative approaches for climate induced damage modeling (Merz et al., 2013).

Most assessments of flood risk are based on the static inundation approach, which typically over-estimate flood extents (Bertin et al. 2014; Gallien 2016; Hinkel et al. 2014; 2010; Ramirez et al. 2016; Vousdoukas et al. 2016). Although severity is an important flood characteristic, it does not provide information on flood duration or the extent of flooding (Kundzewicz et al. 2013). Temporally inconsistent and potentially unreliable global historical data hinder the detection of trends in tropical cyclone activity (Kossin, et. al., 2013). The specific projections for future cyclone impact assessment is linked with high level of uncertainty. Hail is frequently associated with thunderstorm events, however, due to its local nature, it is poorly represented in the long-term data of the traditional meteorological stations.

Climate effects on river salinity are difficult to predict because they involve predictions for precipitation and temperature patterns, and the dynamic interactions between ground and surface water (McNeil and Cox, 2007). Scientists are still unsure about where and under what conditions lightning strikes occur. There are not many published research outcomes for the relationship between lightning and land properties (DongHwan Cha, et.al., 2017). The published literature on the exposure to heat is substantial but quantitative assessments are relatively rare.

Although a few studies (Chow, et.al, 2012; Hansen, et.al, 2013; Frazier et al., 2010; Ali 1999) have examined the impact of sea-level rise on coastal inundation, these studies did not use any storm surge and inundation modeling system, nor did they include the effect of climate change on cyclone or hurricane intensity and frequency; hence, the results are questionable. The present-day coastal inundation hazard analysis does not include any effect of climate change and anticipated sea level rise (Lin et al. 2010). Several studies relating to the effect of climate change on surface water bodies have been undertaken but very little research exists on the potential effects of climate change on groundwater (Holman 2006; Bates et. al., 2008).

Cultural and political factors are critical in understanding why communities perceive and respond to climate change risks in particular ways but remain relatively unexamined (Adger et al., 2012). The role of place and landscape on risk perception remains a fertile ground for exploration within the climate change field (Brace and Geoghegan, 2011; Adger et al., 2011; Fresque-Baxter and Armitage, 2012).

Human migration is the most significant consequence of climate change of today and coming decades (Glaserm et. al., 2017; Steiner, 2008). However, there is no generally agreed definition on climate induced migration or displacement. There exists difficulty to identify forced versus voluntary migration (Dun and Gemenne, 2008). People who are most vulnerable to climate change are not necessarily the ones most likely to migrate (Brown, 2008). On the other hand, permanent or forced migration occurs when the people lose all other alternatives to survive in one area; for instance, loss of land and settlements due to tidal surge and river erosions.

Much of the climate economics research to date has focused on identifying the indirect economic impacts of climate changes (for example, impacts of heat on crop yields or impacts of sea level rise on infrastructure). One study recent (Geoffrey and Parky, 2016) suggests that there may be substantial direct economic consequences arising from the direct impact of extreme heat on labor inputs. However, most climate risk assessments do not include labor productivity impacts from temperature stress.

Learnings from the Literature Review

Climate change risk results from the interaction of three components; vulnerability, exposure and hazard. The changes in the climate variables (temperature, wind and precipitation) over a longer period of time influence the characteristics of the climate risk components. Climate risk assessment helps to identify natural hazard prone areas, exposure of the existing assets at risks and potential risk scenario due to hazard occurrence. Risk assessment creates risk profiles by using variables on different scales through an index-based approach. An index-based risk assessment method is more appropriate if there is a lack of financial resources, because it does not require the support of models or software and easy to apply.

Climate change imposes risks to livelihoods, communities, cultures, human health and natural environment. The magnitude of climate risks is expected to increase human casualties and economic losses in the future. People in low-income countries are much more vulnerable than the people in high-income countries. Climate risks are expected to increase inequities among socioeconomic groups. An assessment of the community perception of climate risks can uncover the nature of the risk and its underlying factors and associated consequences. Climate risk identification and assessment at community level should be conducted through participatory process. Using participatory methods can lead to community empowerment and commitment to address the risks.
Gender, religion, ethnic identity and place influence climate risks perception within the community. Discourse play a key role in understanding climate risks perception within the community. Social context & geographic perspective determines social vulnerability while socio-economic drivers within the society determines personal vulnerability. Poverty, settlement characteristics, land uses, housing structure and infrastructure density & age influence exposure and sensitivity. Natural resource-dependent livelihoods are more vulnerable to climatic hazards. Shared social learning & collective action through social ties and kinship networks helps in addressing climate change risks.

Climate risk assessment practices are having difficulties in defining and agreeing on principles. Climate change risk and vulnerability have been defined in different ways by different disciplines or organizations with different needs. Besides, climate risk & vulnerability assessment approaches are still guided by scientific and technical factors, and often neglects the socio-cultural and political economy factors. Too much attention on the techno-scientific expertise often not only create a disconnection between national priority and local priority, but also may overshadow community concerns or mislead community perceptions. For example, national policy may prioritize physical exposure to risks, while local communities may prioritize risks to livelihoods.

Climate risk assessment both at global and national level do not provide the level of information required for local and regional policies. Although national level risk assessment provides basic inputs for helping decision makers to make better and informed decisions, it may not necessarily provide answers to questions concerning the level of risks, trade-offs in risk control, costs and benefits at local level. On the contrary, local risk assessments provide specific information which is often not up-scalable or reproducible in national context. The downscaling of global and national data models to the local level can result in 'coarse assessments' of climate risk. The climate risk assessment at local level helps to identify, prioritize and implement the climate risk management options. The local level climate risk assessment has greater practical usefulness because of it captures context-specific concerns. Availability of appropriate data is essential for climate risk assessment. Local data are needed to perform a quantitative assessment of the potential hazards under current or more extreme conditions. Vulnerability is commonly assessed using indicators highlighting a person's or system's sensitivity to a certain risk or phenomena. Complementary strengths of natural science and social science paradigms can improve the analysis of vulnerability. Actions to reduce the vulnerability to one hazard could also lead to increased vulnerability to other hazards. For example, flood protection embankments that isolate the coastal plain from its natural sediment source could produce water logging.

Natural hazards that exist under current conditions could be worsened under future climatic conditions because climate change may increase the frequency and severity of natural hazards. Wind is a key triggering factor for natural hazards. Small-scale severe weather phenomena include hail, lightning, straight-line winds, tornadoes and heavy rainfall occur widely, but are often short-lived and local in extent, so it is difficult to establish their climate patterns. Abnormal flooding and rapid riverbank shift seriously disrupt human settlement and activities. Sea-level changes are so slow, that they are often not considered as a hazard. Although a few studies have examined the impact of sea-level rise on coastal inundation, these studies did not use any storm surge and inundation modeling system, nor did they include the effect of climate change on cyclone intensity and frequency; hence, the results are questionable. Most of the sea-level rise driven inundation projections had not used the dynamic wind data. Human productivity declines with temperature stress. Extreme heat stress on human can affect output in major industrial sectors such as manufacturing or construction, and possibly influence the overall growth rate of the national economy. The mortality responses to temperature stress appear to be much larger in developing countries and among lower-income groups within countries than in rich countries or among high-income groups.

The knowledge about the type of climate change impacts and the community exposure to climate change risks is a fundamental requirement for enhancing community resilience. Community resilience is dependent on local observations of the frequency, magnitude & duration of the climatic hazards (flood, droughts) or changes in climate variables (e.g. decrease in rainfall or increase in temperature). The knowledge about the importance, presence and potentiality of social ties for managing climate change risks at the community level is still in rudimentary stage. In urban areas, climate change is projected to increase risks for people, assets, economies and ecosystems due to heat stress, storms and extreme precipitation, inland and coastal flooding, landslides, air pollution, drought, water scarcity, sea level rise and storm surge.

The difference between resilience and adaptive capacity is not well articulated in the literature. Countries with stronger social welfare system can reduce the general vulnerability in a society. Considering the slow pace of mitigation and adaptation up to now, it is almost certain that in many climate vulnerable countries, negative impacts of climate change will exceed adaptive capacities. Adaptation measures need to be implemented in order to protect the system from the exposures and to reduce its sensitivity to adverse impacts of climate change. Climate risk assessment approaches and methods may support disaster risk reduction and promote sustainable development goals.

Conclusions

Climate risk assessment is important to reduce future human casualties. Making sense of climate change risks and responses at the community level including loss and damage requires an integrated climate risk management (risk analysis, risk reduction and risk transfer strategies) approach that includes both climate variability and social vulnerability. Risk assessment should not wait for the future when the science will predict climate change more accurately. The climate resilience concept should focus on restoration of the disturbed system by enhancing system's adaptive capacity for risk tolerance. In contrast, adaptive capacity concept should focus on adjustment or coping with the disturbed system by enhancing adaptive capacity of individuals and groups within the system. Research can play an important role for building political consciousness and public action on addressing climate risks. Political consciousness and democratic practice (open, inclusive and participatory decision-making) is very important for collective action in addressing climate change risks. More research is required to understand the degree of uncertainty because assessments of future climate risks may lead into uncertainty. More efforts need to be dedicated to bottom-up risk assessment rather than conventional top-down meteorological approaches.

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ISBN: 978-984-34-7046-1