Current knowledge on relevant methodologies and data requirements as well as lessons learned and gaps identified at different levels, in assessing the risk of loss and damage associated with the adverse effects of climate change

Background paper

Swenja Surminski, Ana Lopez, Joern Birkmann, Torsten Welle

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I. Executive summary

1. The concept of loss and damage associated with the adverse effects of climate change, while being widely discussed and analyzed, has not been clearly defined under the Convention. In addition, no comprehensive risk assessment model for climate change loss and damages exists. This paper responds to the request of the Conference of the Parties (COP) at its seventeenth session to prepare a technical paper summarizing current knowledge on relevant methodologies, and addressing data and capacity requirements as well as lessons learned and gaps identified at different levels, in the context of the first thematic area of the work programme on loss and damage: Assessing the risk of loss and damage associated with the adverse effects of climate change and the current knowledge on the same.

2. The paper aims at supporting decision-makers and adaptation practitioners in understanding the challenges of assessing loss and damage and providing an overview and analysis of some of the key existing methods and tools that can be employed.

3. The selected approaches are rooted in two major schools of thought: disaster risk reduction (DRR) and climate change adaptation (CCA). The recent analysis provided by the IPCC Special Report "Managing the Risk of Extreme Events and Disasters to Advance Climate Change Adaptation" (SREX 2011) can be seen as an effort to combine the two different schools of thought in the context of extreme events.

4. Within these different frameworks, a range of perspectives on loss and damage assessment has emerged, ranging from purely quantitative calculations of economic loss to more holistic approaches, incorporating qualitative analysis and capturing intangible impacts. An interesting new dimension of tools is emerging from those schools and concepts, combining knowledge and technical skills from DRR, catastrophe modeling and the newer but fast emerging field of climate change assessment.

5. To illustrate this, the paper provides an initial overview of 18 different approaches focusing on the assessment of loss, damages and risks – outlining their scale, scope, conceptual background and analytical context. The paper provides a closer review of six approaches and tools, in light of the availability of information on the methodologies as well as their relevance in the context of loss and damage:

- Catastrophe risk models, specifically the (CATSIM) model;
- Comprehensive Approach for Probabilistic Risk Assessment (CAPRA);
- Integrated assessment models;
- Scenario-driven approach;
- UK Climate Change Risk Assessment;
- WorldRiskIndex.

6. Investigating the data requirements, capacity needs and applicability for decision-making of those different methods and tools, the following challenges are identified:

7. The scarcity of quality climate and vulnerability information in developing countries is a major barrier for furthering the understanding of loss and damages;

8. Capacity needs for conducting risk assessments in developing countries are linked to overall adaptive capacity, yet some very specific technical needs exist for loss and damage;

9. Some of the impacts of climatic change, such as sea-level rise, are not sufficiently represented in global loss data bases since the corresponding slow-onset impacts are rather difficult to capture (e.g. losses due salinization, forced migration);

10. Most of the approaches analyzed focus on a relative narrow definition and quantification of loss and damage, which may lead to some underestimation of the full impacts;

11. All the tools and methods come with clear limitations that need to be recognized and understood – particularly in the context of uncertainty (climatic and non-climatic) and the scope and extent of capturing direct and indirect losses. Transparency in terms of limitations and uncertainties of the models is important, as is clear communication with the end-user community;

12. The majority of the models and approaches presented are quite complex and require technical skills and in-depth knowledge that have to be developed especially in developing countries. Capacities need to be developed within the country, such as at national universities, to ensure that knowledge and expertise will also increase in these countries that are at high risk for loss and damage in the face of climate change;

13. National, sub-national and local loss databases need to be enhanced, as well as the continued monitoring of environmental and climatic stimuli and of socio-economic transformation processes at those levels.

14. The analysis concludes that complex systems, such as communities, societies or social-ecological systems, involve multiple facets (physical, social, cultural, economic, institutional and environmental) which require a holistic perspective. Integrating various socio-economic and environmental factors and combining risk and vulnerability assessment (including scenarios for vulnerability and exposure) with climatic changes, plus recognizing dynamic processes while meeting the needs of decision-makers at various different levels and within different sectors is challenging.

15. Full quantification may not be needed in all decision-making contexts, however, the choice of tool must be matched to the intended application and the relevant loss and damage categories – which differ between countries and regions, taking into account local constraints of time, resources, human capacity and supporting infrastructure. A sequential step-wise application of different methods and tools may offer best value to developing countries. To this end, it is important to improve the linkages and synergies between qualitative and quantitative approaches at various scales.

16. The paper concludes with potential issues for further consideration in the context of the UNFCCC work programme on loss and damage.

II. Introduction

A. Mandate

17. The Conference of the Parties (COP), at its seventeenth session, requested the secretariat, in the context of the work programme on loss and damage and under Thematic Area I, to prepare a background paper summarising current knowledge on relevant methodologies, and addressing data requirements as well as lessons learned and gaps identified at different levels, drawing on existing relevant work, and in collaboration with relevant organizations and other stakeholders.

B. Objective

18. The aim of Thematic Area I of the work programme on loss and damage is to assist Parties to improve their understanding on issues related to assessing the risk of

loss and damage associated with the adverse effects of climate change and the current knowledge on the same, by taking into account the following four questions:

(a) What are the data and information requirements for assessing impacts and climate risk, at different levels and for a broad range of sectors and ecosystems? What data are available and where are the gaps?

(b) What methods and tools are available for risk assessment, including their requirements, strengths and weaknesses, and can they address social and environmental impacts?

(c) What are the capacity needs for applying risk assessment methods on the ground, including for facilitating their application in developing countries?

(d) How can the results of risk assessments be optimally formulated in order to support decision-making? What are the desired methods for presenting the results of risk assessment exercises so that they drive decision-making?

19. This paper aims to facilitate a deepening of the understanding of the extent and limitations of existing approaches for assessing the risk of loss and damage, and to address data requirements as well as lessons learned and identify gaps at different levels, with a view to providing input to the expert meeting to take place in Tokyo, Japan, 26-28 March, under the same thematic area.

20. In particular, the aim of this paper is to:

(a) Introduce a conceptual understanding of loss and damage;

(b) Provide an overview of existing methodologies and tools for assessing the risks of loss and damage associated with climate change;

(c) Assess selected methods and tools in terms of their data and information requirements, strengths, weaknesses, lessons learned and relevance for social and environmental impacts;

(d) Discuss capacity needs for applying risk assessment methods in developing countries;

(e) Consider risk assessment application to decision–making.

C. Background

21. The COP, by its decision 1/CP.16, adopted the Cancun Adaptation Framework (CAF) as part of the Cancun Agreements, to enhance action on adaptation in order to reduce vulnerability and build resilience in developing country Parties, taking into account the urgent and immediate needs of those developing countries that are particularly vulnerable. Under the CAF, the COP established a work programme to consider approaches to address loss and damage associated with climate change impacts in developing countries that are particularly vulnerable to the adverse effects of climate change.[1] The COP also requested the Subsidiary Body for Implementation (SBI):

(a) To agree on activities to be undertaken under the work programme;

(b) To make recommendations on loss and damage to the COP for its consideration at COP 18.

22. At the thirty-fourth session of the SBI (June 2011), Parties agreed on the following three broad thematic areas in the implementation of the work programme on loss and damage:

(a) Thematic area 1: Assessing the risk of loss and damage associated with the adverse effects of climate change and the current knowledge on the same;

[1] Decision 1/CP.16, paragraphs 25–29.

(b) Thematic area 2: A range of approaches to address loss and damage associated with the adverse effects of climate change, including impacts related to extreme weather events and slow onset events, taking into consideration experience at all levels;

(c) Thematic area 3: The role of the Convention in enhancing the implementation of approaches to address loss and damage associated with the adverse effects of climate change.

23. At the seventeenth session of the COP (November–December 2011), Parties agreed on activities to be undertaken in the course of 2012, including the aforementioned expert meeting and a technical paper to serve as an input to the expert meeting, to focus on issues related to Thematic area 1 mentioned above.[2]

D. Scope

24. A review of existing approaches to assess the risk of loss and damage due to climate change related hazards is challenging. While a dedicated and comprehensive climate 'loss and damage' assessment methodology has not yet been developed, we can find relevant elements in methods and tools rooted in two major school of thought:

(a) Disaster Risk Reduction (DRR);

(b) Climate change adaptation (CCA), including impacts research.

25. Within these two groups, a range of different approaches exist that respond to scale, sectoral scope, use of probabilistic estimations, community-based input and policy-focus. The paper illustrates this by providing an overview (Figure 2) of the broad range of relevant methods and tools and a more in-depth analysis of some of the most relevant and commonly used methods. This may help decision makers to look beyond the complexities and technical aspects, and also consider practical aspects important to the application of these assessment approaches.

26. The paper closely reviews the following three different types of approaches:

(a) Loss and damage assessments that are developed primarily within the CCA community;

(b) Loss and damage assessments that are primarily linked to DRR;

(c) Emerging broader risk assessment concepts within the DRR community.

27. This paper does not intend to provide an exhaustive and complete assessment of all existing methodologies, but provides indicative illustrations of characteristics, limitations and constraints to inform the discussions and development of further activities under the work programme on loss and damage.

E. Structure of the paper

28. The paper is structured as follows:

(a) Chapter II outlines the different aspects of loss and damage in order to discuss different conceptual frameworks currently applied to the assessment of the risk of loss and damage, thereby setting the scene for an overview of relevant methods and tools (see Figure 2 and Table3);

(b) Chapter III investigates selected approaches and the applicability of selected methods and tools in the context of loss and damage risks. The focus is on developing countries, with detailed descriptions of some of the most relevant methodologies and a specific assessment of information needs, capacity requirements and their relevance for decision-makers;

[2] http://unfccc.int/6597

(c) Chapter IV summarizes the findings and indicates lessons learned and gaps, while pointing to possible issues for further discussion within the UNFCCC work programme on loss and damage.

III. Overview of existing approaches to assess loss and damage in the context of climate change

A. Fundamentals: Overview of frameworks for assessing risk and vulnerability

29. Risk assessment can be described as a process to comprehend the nature and determine the level of risk (ISO, 2009). Risk is a function of hazard, exposure and vulnerability. Any approach taken for assessing climate related risk depends, therefore, on a coherent understanding of the underlying concept of risk and the interplay of hazard, exposure and vulnerability. Thus, the review of methodologies on how to assess the risks of loss and damage in the context of climate change cannot be based solely on an evaluation of tools or individual approaches, rather it also needs to be based on a discussion of major frameworks used to systematize key elements and concepts.

30. The DRR and CCA schools of thought have developed a variety of approaches. However, three frameworks are particularly important to better understand the different perspectives on how to assess the risk of loss and damages, including vulnerabilities and adaptive capacity that determine the likelihood of loss and damage due to climate change related hazards:

(a) The framework presented by the IPCC AR4 (see annex II);

(b) The frameworks developed by the disaster risk reduction (DRR) community (see in annex II exemplary the UN/ISDR framework for DRR);

(c) The analysis provided by the IPCC Special Report “Managing the Risk of Extreme Events and Disasters to Advance Climate Change Adaptation” (SREX 2011), which can be seen as an effort to combine the two aforementioned frameworks in the context of extreme events.

31. The DRR community has developed various frameworks for vulnerability and risk assessment, ranging from qualitative and participatory methodologies to quantitative modelling approaches taking not solely into account a pure economic damage and loss assessment approach but rather a wide consideration of social, environmental and physical risk factors (e.g. International Federation of the Red Cross 2008, Birkmann 2006, Wisner et al. 2004). The DRR approaches set vulnerability (often including a capacity analysis) side by side with the hazard or physical event to assess risk. Hence, the interaction of both – the vulnerable society or economy with a hazard or extreme event – can create risk. Consequently, the frequency and magnitude of climate change and extreme weather events are characteristics of hazards and not of vulnerability. Vulnerability in this regard is understood as a predisposition to be affected or as an internal risk factor, while the hazard event is rather viewed as an external factor to the society or system exposed (see Birkmann 2006).

32. The approach presented by the United Nations International Strategy for Disaster Reduction (UNISDR) shows that vulnerability can be differentiated into various thematic dimensions, such as economic, social, environmental and physical. Hazards can be further classified into hydrometeorological (that may be influenced by climate change), geological, technological, biological and environmental (see annex II).

33. The CCA approach views vulnerability as *“the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its*

sensitivity, and its adaptive capacity" (IPCC 2007, p.783; see annex Figure 2). This understanding of vulnerability is significantly different from the DRR school.

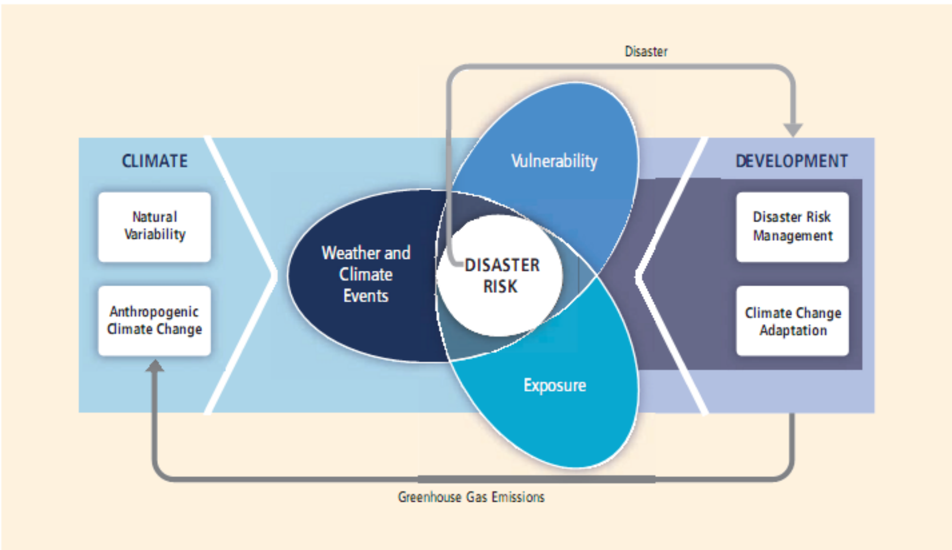
34. The latest IPCC Special report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) included authors from the DRR and CCA schools working together on how to assess risks and vulnerability in the light of extreme events. The main framework presented in the Summary for Policy Makers of the IPCC SREX report (see Figure 1) underscores that vulnerability is different from weather and climate change related stressors i.e. vulnerability is not primarily related to the hazard but rather to societal or systemic attributes. The interaction between extreme weather events or climate stressors and the vulnerable conditions determines disaster risk. Hence, disaster loss and damage is caused by the interaction between hazard events and the characteristics of the exposed object or subject that make them susceptible to damage. The destructive potential of a hazard is linked to its magnitude, duration, location and timing of the specific event (Burton et al.1993).

35. To experience damage, however, exposed elements have to be vulnerable. The framework also shows that risk assessments and the identification of risk of losses and damages should not only consider climate change related factors, but also the development pathways that a country or community takes. Development pathways heavily influence and determine the level of exposure (e.g. urban development in low-lying coastal areas) and the vulnerability (e.g. poverty, social cohesion, economic structures, environmental conditions/qualities). Hence, the framework developed in the IPCC SREX (2012) also challenges existing risk assessments that have often examined the status quo without giving further attention to the potential influence of different socio-economic development pathways on exposure and vulnerability.

Figure 1

Systematization of climate change related events, vulnerability, exposure, risk and development (IPCC SREX 2012)

SREX SPM Graphics



SPM. 1

B. Different perspectives on loss and damage

36. This section introduces different conceptual understandings and definitions of loss and damage and outlines difficulties in quantifying different types of losses.

37. No agreed definition of the term ‘loss and damage’ under the UNFCCC exists, but the Cancun Agreement provides the boundaries by referencing impacts from extreme weather and slow onset events, including sea level rise, increasing temperatures, ocean acidification, glacial retreat and related impacts, salinization, land and forest degradation, loss of biodiversity and desertification.[3]

38. Loss and damage assessments can be based on the analysis of losses that have occurred in the past or the estimation of future losses and damages (see Handmer et al. 2005), usually with a strong focus on the quantification of direct and indirect impacts. Cascading impacts such as those resulting from the March 2011 earthquake that struck of the east coast of Japan (the earthquake caused a tsunami – which alone was responsible for considerable loss and damage and a further set of losses resulting from explosions and the release of radiation fronm damaged reactors at a nuclear power station) are a clear reminder that indirect losses, for example due to the disruption of economic activities or damage to critical infrastructure, can be considerably higher than the direct damages of an extreme event.

39. In addition to this economic dimension there is a wider range of less measurable impacts, including impacts on social vulnerability and resilience. Quantification of these poses conceptual, ethical and empirical challenges. Even where monetization of impacts is possible, a large degree of uncertainty remains. Loss and damage in the climate change context also adds a time dimension to the debate, requiring a differentiation between current and future risks.

40. Loss and damage assessment is a part of risk assessment and its goal is to measure, mostly in monetary terms, the impact of disasters on society, economy and environment of the affected country or region (ECLAC 2003) in order to estimate the cost of a specific event, either actual (post-impact) or hypothetical. In practice, damage assessments usually quantify physical and economic past or future impacts of an event while less attention is paid to social, environmental or psychological damages embedded in disasters (Kelly, 2008). Since important social and environmental aspects of loss and damages, such as loss of cultural heritage, environmental qualities, governance and trust cannot be easily quantified, qualitative approaches such as community based disaster risk management (CBDRM) and vulnerability capacity assessment (VCA) should complement other existing approaches.

41. The Damage and Loss Assessment (DaLa) methodology[4] defines damage as the monetary value of partially destroyed assets, assuming that assets will be replaced in the same condition – in quantity and quality – as before the disaster. Losses are defined as changes in the flow of goods and services that will not be forthcoming until the destroyed assets are rebuilt, over the time span that elapses from the occurrence of the disaster to the end of the recovery period.

42. The Australian Government, represented by the Emergency Management Agency (EMA) provided the Disaster Loss Assessment Guidelines in which they differentiated between direct and indirect losses as well as tangible and intangible items (see Table 1). The examples in Table 1 illustrate that, compared to direct losses, which are mostly in the form of visible damages, the evaluation and assessment of indirect losses (tangible and intangible) are more difficult in terms of their quantification and assessment. However, as previously indicated, losses due to interruption of business or loss of community, such as access to networks, services and assets including recreation areas, can have more severe effects and pose greater challenges to adaptation strategies than damages assessed as a direct result of a hazard or extreme weather event. The Guidelines by EMA (2002) underscore that loss assessment approaches may be based on:

(a) An averaging concept (e.g. average loss per sq m);

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[3] Decision 1/CP.16, paragraph 25

[4] http://www.aseanpostnargiskm.org/knowledge-base/assessments/damage-and-loss-assessmentdala

(b) A synthetic approach – which is often based on damage curves;

(c) A survey approach that is applied often after a disaster occurs in order to collect actual and new data from the disaster to derive loss functions and damage curves (see Table 2, and EMA 2002).

43. Overall, the averaging and synthetic approaches focus primarily on tangible losses while the survey methodology also allows the capture of less tangible losses. However, these surveys are often applied in post-disaster contexts.

Table 1
Identification of loss types defined by the Disaster Loss Assessment Guide (EMA 2002)

Can the lost item be bought and sold for dollars?	Direct loss Loss from contact with flood water	Indirect loss No contact, loss as a consequence of flood water
Yes—tangible	For example, Buildings and contents Cars Livestock Crops Infrastructure	Disruption to transport etc. Loss of value added in commerce and business interruption where not made-up elsewhere Legal costs associated with lawsuits
No—intangible	For example, Lives and injuries Loss of memorabilia Damage to cultural or heritage sites Ecological damage	Stress and anxiety Disruption to living Loss of community Loss of non-use values for cultural and environmental sites and collections

Table 2
Basic elements of the three approaches to loss assessment (EMA 2002)

Loss assessment approach	Direct loss			Indirect loss	Intangible loss
	Houses/small business	Commerce, farming (>1000m^3)	Infrastructure		
I Averaging	Average loss per flooded structure	Average loss per m2 for types of enterprise and surveys	Average per km of road and surveys*	Examine $ flow and use surveys or % of direct	Identify types and magnitude Surveys
II Synthetic	Standard stage: damage curves for types of property	Stage: damage curves applied to m3 for different types of business	Stage: damage and average loss per km depending on type of infrastructure	Examine $ flow and use surveys	Identify types and magnitude Surveys
III Survey (based on sampling)	Surveys: new stage–damage curves	Surveys	Surveys	Surveys	Surveys

C. Overview of selected existing methodologies and tools to assess risk of loss and damages

44. The discussion of conceptual frameworks underscores that there are several perspectives and methodologies. Figure 2 presents an overview of selected approaches for loss and damage, and risk assessment that are examined in this paper. Other methods and tools exist but, in this paper, contemporary approaches that are well documented and internationally applied or recognized have been chosen.

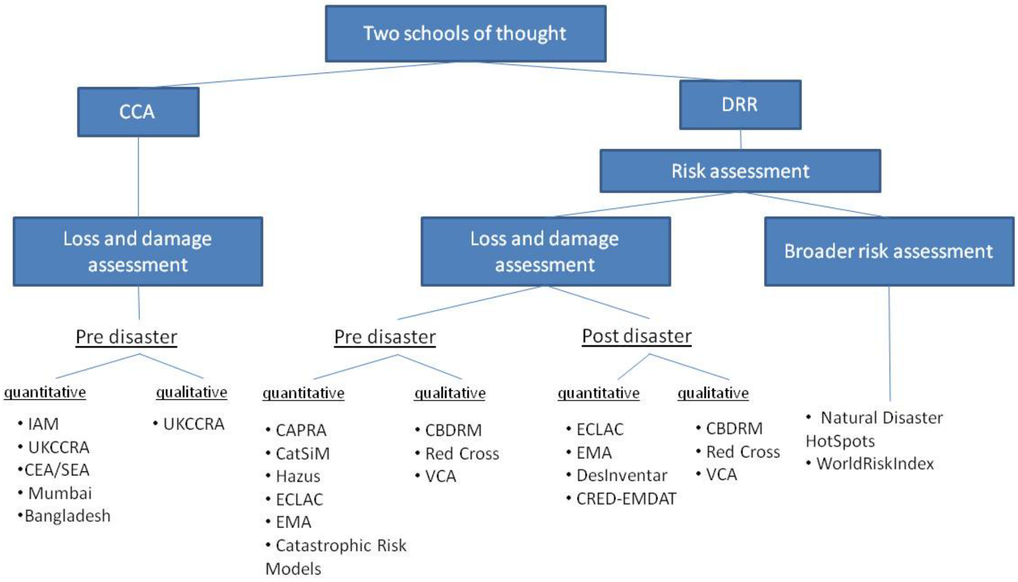
45. One of the key differences among current methodologies and tools is their pre- or post-disaster assessment focus. Post-disaster assessments provide relevant information of disaster loss and damage which is often crucial for validating and calibrating pre-disaster assessment (e.g. damage curves, potential impact estimation etc.). Data on past impacts can also be used to build, calibrate and refine knowledge and measure of vulnerability. Disaster loss databases such as DesInventar and EM-DAT are used for developing sound information to estimate risk and damages and to prioritize public investment and DRR measures.

46. Nevertheless, it is also evident that much of climate change related (future) impacts are up to now not captured within these databases, such as the impacts and losses due to process-related or slow onset events, such as salinization, sea level rise. Hence, these databases also face severe constraints in the assessment of climate change related loss and damage. In this regard also the assessment of losses, damages and risks due to creeping processes and accumulated shocks from non-extreme events is still a challenge (Birkmann/Chang Seng/Krause 2011, p. 24).

47. Databases developed in the insurance industry are also often referenced in terms of global and regional loss trends, such as Nat Cat SERVICE by Munich Re or the Sigma disaster loss estimates by Swiss Re. While these databases have been developed to inform the industry, they have also proven very useful for general awareness-raising about the magnitude of the challenge posed by disaster loss. But for the application in the context of DRR and CCA there are some limitations: these databases only capture large loss events above pre-defined loss-thresholds while smaller events remain largely unaccounted for (a cascade of small events can have severe consequences).

48. TheWorldRiskIndex (Birkmann et al. 2011) or the Natural Disaster Hotspots Study (World Bank 2005; Dilley et al. 2005), provide a global perspective of the different facets of risk. The WorldRiskIndex does not focus solely on loss and damage but indicates different aspects of underlying risk factors such as aspects of governance and health that heavily influence the risk of loss and damage in an extreme event. Figure 2 provides an overview of selected approaches linked to the two schools of thought described above. While the largest databases for loss and damage (EM-DAT, DesInventar) have a clear post-disaster focus, most of the models focus on pre-disaster contexts.

Figure 2
Overview of different approaches, methodologies and tools for loss and damage assessment



49. The overview presented in Table 3 categorizes methodologies and tools in terms of school of thought, scope, the hazards examined and the spatial scale of the approach. In addition, the table shows whether the approach is rather qualitative or quantitative and which user-requirements are linked to it. The overview sets the scene for the more in-depth analysis of selected approaches in chapter III.

Table 3
Overview of different methodologies and tools applying selected assessment criteria

Tool name	*School of thought*	*Agency*	*Scope*	*Hazard type*	*Spatial scale*	*Sectors*	*Quanti-tative (+) / quail-tative (o)*	*Pre-/ or post-disaster assessment*	*User requirements*	*Country focus*
Integrated Impact Assessment Models	CCA	Different models from different institutes	Integrated Impact assessment models of climate change model the dynamics of carbon accumulation in the atmosphere and their influence on the economy.	No specific hazard, uses the impact of CO2 increase in the atmosphere	Global. Regional	Economic of several sectors	+	Pre disaster	High level of expertise/ training required	All over applicable
IIASA CATSIM model	DRR	International Institute for Applied Systems Analysis	CATSIM uses Monte Carlo simulation of disaster risks in a country or region, and examines fiscal and economic risk based on an assessment of the ability of governments to finance relief and recovery.	Floods, hurricanes, weather and climate related hazards, earthquake	National	public	+/o	Pre disaster	High level of expertise/ training required	Applied to many country cases, stakeholder processes with about 25 countries
Disaster Loss Assessment Guideline	DRR	Emergency Management Australia	These Guidelines provide an explanation of the process of loss assessment, and then will lead the reader through the steps required to carry out an economic assessment of disaster losses. There is a separate worked example of a loss assessment, in the accompanying case study, to show how the steps described in these Guidelines have been applied.	Floods, hurricanes, weather and climate related hazards, earthquake	National; Sub-national; Local;	Suitable for several sectors	+/o	Pre and post disaster	Medium level of expertise/ stepwise explanation of the assessment method within the guidelines	Australia but applicable to other countries
UN ECLAC Handbook for Estimating The Socio-Economic And Environmental Effects Of Disasters	DRR	ECLAC (Economic Commission for Latin America and the Caribbean)	The ECLAC Handbook describes the methods required to assess the social, economic and environmental effects of disasters, breaking them down into direct damages and indirect losses and into overall and macroeconomic effects.	Floods, hurricanes, weather and climate related hazards, earthquake	National; Sub-national	Social; Infrastructure; economic	+/o	Pre and post disaster	Medium level of expertise/ stepwise explanation of the assessment method within the handbook	All over applicable

Hazards U.S. Multi-Hazard (HAZUS-MH)	DRR	Federal Emergency Management Agency (FEMA)	It is a risk assessment methodology for analysing losses from floods, hurricanes and earthquakes. It applies geographic information systems (GIS) technology to produce estimates of hazard-related damage before, or after, a disaster occurs.	Flood, hurricane, earthquake	Sub-national	Several sectors	+	Pre and post disaster	High level of expertise/ training required	USA
Catastrophic risk models	DRR	Different models from different institutes	Catastrophe risk models allow insurers, reinsurers and governments to assess the risk of loss from catastrophic events, such as hurricanes. These models rely on computer technology and the latest earth and meteorological science information to generate simulated events.	Hurricanes; Floods; earthquakes	National; Sub-national	Various sectors	+	Pre disaster	High level of expertise/ training required	All over applicable
Central American Probabilistic Risk Assessment (CAPRA)	DRR	Consortium in Latin America	The model is based on a GIS platform for risk assessment linked to selected hazards. The approach is using probabilistic methods to analyze different natural hazards, e.g. including hurricanes and floods. For the risk assessment hazard information is combined with exposure and vulnerability data. The GIS information system allows focusing on single hazard risk and multi-hazard risks.	Earthquakes, tsunamis, hurricanes, floods, landslides and volcanoes	Regional National, Sub-National	Holistic approach	+	Pre disaster	High level of expertise/ training required	Selected countries in Latin America
Vulnerability and capacity assessment (VCA)	DRR	e.g. International Federation of Red Cross and Red Crescent Societies (IFRC).; CARE	Vulnerability and capacity assessment is a basic process used to identify the strengths and weaknesses of households, communities, institutions like National Societies and nations. The VCA is an important tool to support decisions made in relation to disaster preparedness and the development of mitigation programmes and to raise public awareness of hazards by society.	Droughts; Floods; earthquake	Local	Sectors related to livelihoods of households	o	Pre and post disaster	Medium level of expertise/ training required	All over applicable
Community-based disaster risk management (CBDRM)	DRR	e.g. Asian Disaster Preparedness Center (ADPC)	Community-based disaster risk management denotes the application of measures in risk analysis, disaster prevention and mitigation and disaster preparedness by local actors as part of a national disaster risk management system. A key feature is multisectoral and multi-disciplinary cooperation with special responsibility borne by the municipal authority.	Droughts; Heat waves; Floods; hurricanes Earthquakes; volcano	Local	Sectors related to livelihoods of communities and households	o	Pre and post disaster	Medium level of expertise/ training required	All over applicable

Climate risk assessment at community level in the agriculture sector (case study of Bangladesh)	DRR	Ministry of Food and Disaster Management (MoFDM), Bangladesh	The ministry developed a module to identify methods and tools for assessing climate-related risk at community level, focusing on the agricultural sector. The module presents: participatory tools and processes for assessing climate-related hazards, vulnerabilities and risks in agriculture, identify key climate risks that have significant impact on communities in general and livelihoods in particular, and assess the community perception of risks associated with past and current climate variability.	Droughts; Heat waves; Floods; Sea level rise	Local	agriculture	o	Pre and post disaster	Medium level of expertise/ training required	Bangladesh
DesInventar	DRR	Corporacion OSSO, La Red, UN/ISDR	DesInventar is a conceptual and methodological tool for the construction of databases of loss, damage, or effects caused by emergencies or disasters. A software tool was developed	All hazards	National; Sub-national	several sectors	+	Post disaster	Medium level of expertise/ training required	29 countries
EM-DAT	DRR	Centre for Research on the Epidemiology of Disasters - CRED	The main objective of the database is to serve the purposes of humanitarian action at national and international levels. It is an initiative aimed to rationalise decision making for disaster preparedness, as well as providing an objective base for vulnerability assessment and priority setting.	All hazards	National	Economy, social	+	Post disaster	Low level of expertise	All countries
Country environmental analysis (CEA); Strategic environmental assessment (SEA)	DRR and CCA	Various e.g. ADB, UNDP, World Bank	CEA or SEA are relatively new analytical tools, that a number of multilateral and bilateral development organizations are beginning to apply, for the integration of environmental consideration into policies, plans and programmes at the earliest stage of decision-making. SEA/CEA should include the prioritisation of environmental issues in terms of their effect on economic development and poverty reduction.	Droughts, degradation, floods, hurricanes	Sub nation; local	Energy, Transport, Urban development, mining, Agricultural	o	Pre and post disaster	Medium level of expertise/ training required	All over applicable
UK Climate Change Risk Assessment (UK CCRA)	DRR and CCA	DEFRA	The CCRA has reviewed the evidence for over 700 potential impacts of climate change in a UK context. Detailed analysis was undertaken for over 100 of these impacts across 11 key sectors, on the basis of their likelihood, the scale of their potential consequences and the urgency with which action may be needed to address them.	Hazards related to climate change	National; Sub-national	Various sectors	+/o	Pre disaster	High level of expertise/ training required	UK

WorldRiskIndex	DRR	UNU-EHS	The World Risk Index presents a global view on risk, exposure and vulnerability. The Index is based on 28 indicators that are worldwide available. The selected indicators represent four components of risk, namely exposure and vulnerability whereas vulnerability is composed of susceptibility, coping capacities and adaptive capacities.	Earthquakes; storms, floods; sea level rise; drought	National; Sub-national	No, holistic approach	+	Broader risk assessment	Medium level of expertise/	All over applicable
Natural Disaster HotSpots	DRR	World Bank (Interdisciplinary research consortium)	Natural Disaster Hotspots presents a global view of major natural disaster risk hotspots—areas at relatively high risk of loss from one or more natural hazards. Data on six hazards are combined with state-of-the-art data on the subnational distribution of population and economic output and past disaster losses.	earthquakes, volcanoes, landslides, floods, drought, and cyclones	National	No, holistic apporach	+	Broader risk assessment	Medium level of expertise/	Natural Disaster HotSpots

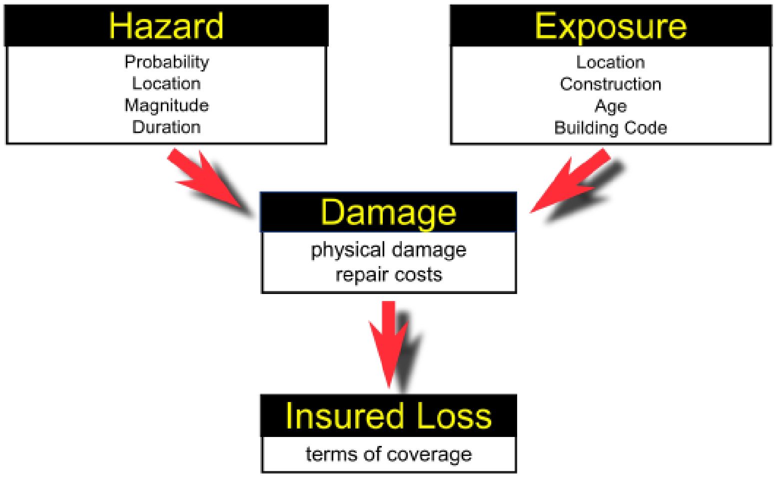
IV. Analysis of the applicability of selective methods and tools in the context of loss and damage

A. In-depth analysis of selected approaches

50. Based on the overview of approaches in Table 3 above, the following section provides an in-depth analysis of selected approaches that can often function as representatives of larger groups of models and concepts used to assess the risk of loss and damage. The approaches presented developed from different research schools, for example the catastrophic risk model and the CATSIM, model were developed within the DRR school, whereas the Integrated Assessment models (IAM) appeared initially in the Climate Change school. A trial to integrate key aspects from both communities was attempted with the development of the WorldRiskIndex.

51. ***Catastrophe risk models*** are specialized computer models, such as from Applied Insurance Research (AIR). The different software tools, such as EQECAT use probabilistic scenario analysis to provide estimates of the probability of different scale of losses occurring in well-defined insurance systems. It is important to emphasize that catastrophe models are not pricing models, their results do not lead directly to insurance and reinsurance prices. Figure3 provides a basic overview of the concept of catastrophe risk models and relevant information needed.

Figure 3
Concept and information needed for catastrophe risk models



52. Catastrophe risk models are well advanced for developed economies where there is a demand for such models, for example from insurance and reinsurance companies that offer catastrophe coverage to their clients. In developing countries, where the property insurance market is usually underdeveloped, the demand for catastrophe insurance is almost non existent, consequently, the use of catastrophe risk models is scarce. Catastrophe models use Monte Carlo[5] techniques to generate 10,000 years or more of simulated losses. Using this approach, a catastrophe model would generate random occurrence, e.g. of hurricanes in simulated years, and overlay those random hurricanes on the fixed property distribution. The damage function then translates the incidence of hurricanes on property into realized

[5] Monte Carlo methods are stochastic techniques based on the use of random numbers and probability statistics to investigate problems.

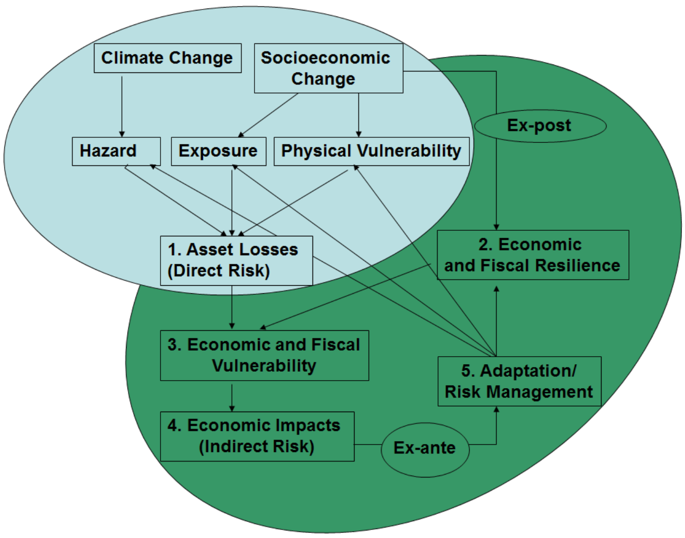
losses, the end result being the generation of losses over many simulated years. The results of catastrophe model loss simulations are most often summarized in the form of a loss exceedance curve (LEC). A LEC essentially contains all the information of a cumulative distribution. In particular, it gives the annual probability that a pre-determined loss is exceeded every year.

53. In general, it is difficult to incorporate new or alternate data into the model setup. Especially the integration of new hazards or damage algorithms with respect to climate change is a complex issue. The challenges of many disaster-prone developing countries associated with managing the economic aftermath of disasters and rebuilding public assets as well as providing relief raises the question of how policymakers can reduce fiscal and economic vulnerability and risk.

54. ***The IIASA CATastrophe SIMulation (CATSIM)*** model was developed to provide insights to this question (for a detailed discussion of CATSIM see Hochrainer, 2006; Mechler et al. 2006).

55. CATSIM uses Monte Carlo simulation of disaster risks in a specified region and examines fiscal and economic risk based on an assessment of the ability of governments to access savings to finance relief and recovery. CATSIM can provide an estimate of a country or region's public sector financial vulnerability and associated risks. It is interactive in the sense that, employing a user interface, the user can change the parameters and test different assumptions about hazards, exposure, sensitivity, general economic conditions and government's ability to respond. The CATSIM methodology consists of five stages as described below and illustrated in Figure 4.

Figure 4
CATSIM methodology (Hochrainer, 2006; Mechler et al., 2006)



- Step 1: Risk of direct asset losses (in terms of probability of occurrence and destruction in monetary terms) is modeled as a function of hazards (frequency and intensity), the elements exposed and their physical vulnerability. Changes in drivers of risk such as climatic and socioeconomic change can be taken account of.
- Step 2: Financial and economic resilience for responding to shocks is measured. Resilience is defined as a government's accessibility to savings for financing reconstruction of public infrastructure and providing relief to

households and the private sector. Resilience depends heavily on the general prevalent economic conditions of a given country.

- Step 3: Financial vulnerability, measured in terms of the potential resource gap, is assessed by simulating the risk to the public sector and the financial resilience of the government to cover its post-disaster liabilities following disasters of different magnitudes.
- Step 4: The consequences of a resource shortfall on macroeconomic development of a country on key macro variables such as economic growth or the country external debt situation are identified. These indicators represent consequences to economic flows as compared to consequences to stocks addressed by the asset risk estimation in Step 1.
- Step 5: Strategies can be developed and illustrated that build resilience of the public sector or contribute to the risk management portfolio. The development of risk management strategies has to be understood as an adaptive process where measures are continuously revised after their impact on reducing economic and financial vulnerability and risk has been assessed within the modeling framework.

56. CATSIM was originally developed for informing the Regional Policy Dialogue of the Inter-American Development Bank on risk management, where it was applied to Latin American case studies (see Hochrainer, 2006; Mechler, et al. 2006) . CATSIM was further extended and applied to stakeholder workshops organized for and by the World Bank and Caribbean Development Bank for client countries in Asia, Africa and Latin America. Its prime objective is to inform economists, fiscal experts, disaster managers and policy makers, who are interested in taking account of the fiscal and economic consequences of disaster risk. CATSIM has also been used successfully for devising risk financing instruments, such as catastrophe bonds for covering fiscal disaster risk in Mexico. Lately, it has been used for the World Bank's World Development Report 2010 to provide an estimate of global disaster risk and funding needs for donors willing to pick up extreme event layers of disaster risk (Mechler et al., 2010). The graphic user interface makes CATSIM a truly participatory, interactive tool for building capacity of policymakers by allowing them to devise and assess multiple disaster risk management strategies. An online version is available at <http://www3.iiasa.ac.at/CATSIM>.

57. CAPRA (Comprehensive Approach for Probabilistic Risk Assessment) is a scientific methodology and information platform, composed of tools for the evaluation and communication of risk at various levels. The model allows the evaluation of losses of exposed elements using probabilistic metrics, such as the exceedance probability curves, expected annual loss and probable maximum loss, in order to perform multi-risk analyses. The basic question that a probabilistic analysis attempts to answer is, given that there is a set of assets exposed to a hazard or a multi-hazard situation, how often will losses over a certain value occur? (see CIMNE, ITEC SAS, INGENIAR Ltda 2011).

58. The platform is conceptually oriented to facilitate decision making; using CAPRA is possible to design risk transfer instruments, the evaluation of probabilistic cost-benefit ratio, providing an innovative tool for decision makers to analyze the net benefits of the risk mitigation strategies, such as building retrofitting. This model is useful for land use planning, loss scenarios for emergency response, early warning, online loss assessment mechanisms, and for the holistic evaluation of disaster risk based on indicators. Hence, the approach aims to serve different stakeholders involved in risk reduction.

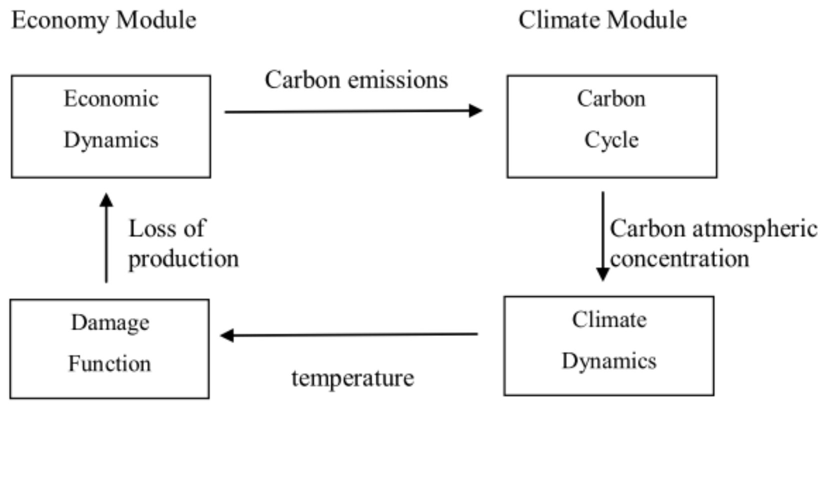
59. The probabilistic risk model, built upon a sequence of modules, quantifies potential losses arising from hazardous events. The hazard modules of CAPRA define the frequency and severity of a hazard or physical phenomena in a specific place. This is completed by

analyzing the historical event frequencies and reviewing scientific studies performed on the severity and frequencies in the region of interest. Once the hazard parameters are established, stochastic event sets are generated which define the frequency and severity of stochastic events. In addition, the model also estimates the effects of the event to the site under consideration, and evaluates the propensity of local site conditions to either amplify or reduce the impact (see CIMNE, ITEC SAS, INGENIAR Ltda 2011).

60. CAPRA, developed as open source platform, provides different types of users with tools, capabilities, information and data to evaluate disaster risk. CAPRA applications include a set of different software modules for the different types of hazards considered, a standard format for exposure of different components of infrastructure, a vulnerability module with a library of vulnerability curves and an exposure, hazard and risk mapping geographic information system (GIS). The probabilistic techniques of CAPRA employ statistical analysis of historical datasets to estimate hazard and frequencies across a country's territory. This hazard information can then be combined with the intensities data on exposure and vulnerability of the cities, and spatially analyzed to estimate the resulting potential damage. This measure can further be expressed in quantified risk metrics such as a probable maximum loss for any given return period or as an average annual loss. The model is also in the position to compare and aggregate expected losses from various hazards, even in the case of future climate risks associated with climate change scenarios. The platform's architecture has been developed to be modular, extensible and open, enabling the possibility of harnessing various inputs and contributions.

61. ***Integrated assessment models*** of climate change comprise a broad range of scientific efforts to support decision-making about objectives and measures for climate policy. They model the relationship between emissions, effects on the climate and the physical, environmental, economic and social impacts caused by climate change. Hence many different approaches and models have been developed to provide policy-relevant information about climate change. Integrated Assessment models (IAM) are scientific tools that contain simplified representations of relevant components that describe the coupled economic and climate systems. They were built on the results of simple climate models (simplified versions of Global Climate Models – GCM), which describe some of the physical process of climate change, to assess the benefits and costs of climate policy options. Economists use IAMs to identify the "optimal" policy response, the option that maximizes the difference between benefits and costs (i.e. net benefits). A simple framework of the interaction between economy and climate systems is shown in Figure 5.

Figure 5
Interactions between Economic and Climate System (Ortiz et al. 2009)



62. A key component of any IAM is the damage function, where damage estimates are related to CO2 concentration levels and the corresponding climatic changes, mainly global average temperature changes. Damages are presented as a fraction of income and are derived from estimates for specific sectors and world regions, extrapolated from underlying studies and figures. De Bruin et al (2009) provide a summary of the components of the damage function of the DICE/RICE model family, developed by Nordhaus 1996 and 2007.

63. The damage function includes estimates of damages to major sectors: agriculture (based on studies of crop yield variation using the FARM model); sea-level rise (based on US estimates and extrapolated based on coastal vulnerability index); health (estimates for damages incurred by Malaria, dengue, tropical disease and pollution); other vulnerable markets (damage estimates for energy and water sector based on US data); non-market damages (estimate of change in people's leisure activities); catastrophes (based on an estimation of Willingness to Pay to avoid catastrophic events); and settlements (based on estimation of willingness to pay for climatic proofing of highly sensitive settlements).

64. Nordhaus 2007 applies regional estimates for these categories for twelve world regions (geographical and based on income levels). These regional estimates are then weighted on the basis of GDP to arrive at the aggregate damage function. This approach translates climatic changes into impacts, and then estimates the relevance for human welfare, by distinguishing between tangible and intangible effects.

65. For 'market impacts', quantification is based on prices and changes in demand and supply. For non-market impacts the quantification is mainly based on willingness to pay assessment. The formalized modeling framework which links the damage function to climate (temperature rise) and economic (economic growth function) modules can be updated and adjusted when new knowledge becomes available, as seen with DICE 2007.

66. Some of the limitations of IAMs include:

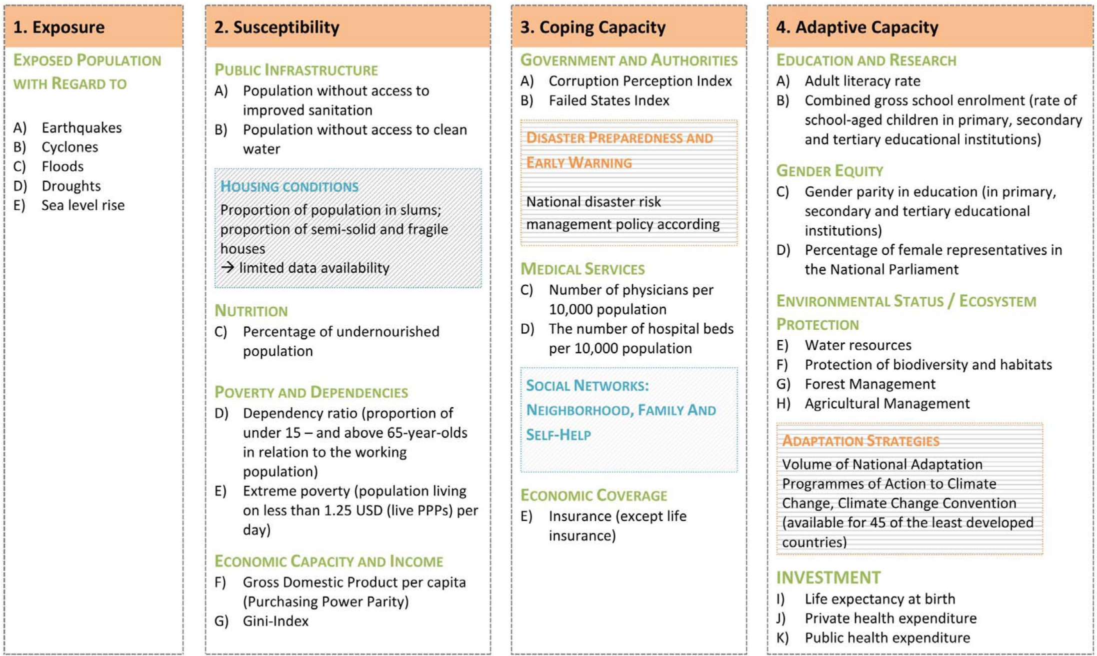
- The simplicity of their approach, using only one or two equations associating aggregate damages to one climate variable, in most cases temperature change, which does not recognize interactions between different impacts. (Ortiz 2009 and De Bruin 2009);
- IAMs capture only a limited number of impacts, often omitting those difficult to quantify and those showing high levels of uncertainty (Watkiss et al. 2005);
- Damages are presented in terms of loss of income, without recognizing capital implications (Stanton et.al.2008);
- The application of willingness to pay quantification could also lead to relative low results in the context of developing countries.

67. This highlights a key challenge faced by IAMs, which make a wide range of assumptions and use simple extrapolations due to the scarcity of underlying data. IAMs have very specific applications and are important tools for policy advice, specifically in the context of mitigation policy. Their relevance to adaptation has been subject of recent discussions. The key question is how to account for adaptation, in particular private adaptation, as a factor that reduces damages. Adaptation is either ignored or captured as a cost element in the total climate change damage calculation, which combines adaptation expenditure with residual damage. But adaptation could also be considered as a decision variable. This has been explored in the context of the AD-WITCH and AD-DICE models (De Bruin 2009), but the level of aggregation makes an application to local and regional decision making limited.

68. The ***WorldRiskIndex*** is not a model quantifying loss and damages per se, but it is an indicator based approach for disaster risk reduction (DRR). The index valuates the

combination of exposure to natural hazards (e.g. floods, droughts – based on PREVIEW data) and the potential threat of continuing sea level rise with the vulnerability of a society. Whereas vulnerability includes social conditions and processes in terms of susceptibility as well as coping and adaptive capacities. This concept stresses that risk is determined by the structure, process and framework conditions within a society that can be affected by natural hazards and climate change. Figure 6 displays the four components of this approach, namely exposure, susceptibility, coping capacity and adaptive capacity, whereas each component has its own sub-categories which are assessed with relevant global available indicators (see <http://www.weltrisikobericht.de>).

Figure 6
Components, subcategories and selected indicators of the WorldRiskIndex (Source: Birkmann et al. 2011)



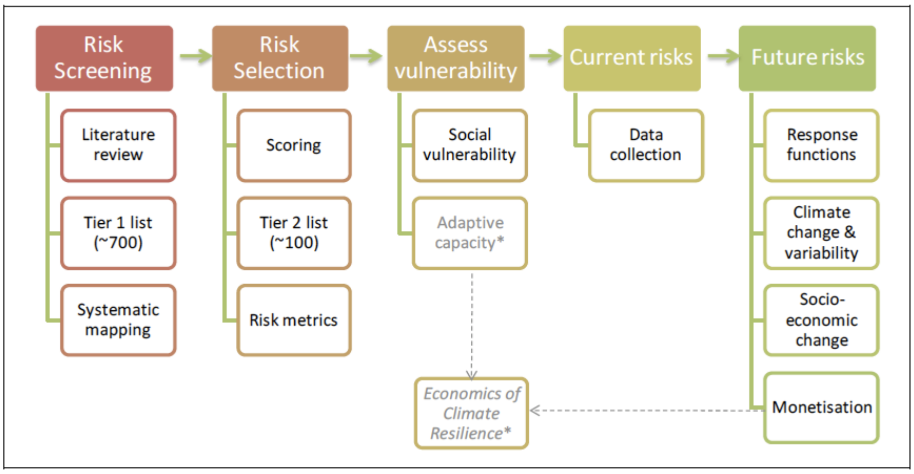
69. Social, economic and environmental factors as well as governance aspects were described and quantified in order to assess vulnerability and the risk of harm and loss. The WorldRiskIndex is a global index (with national scale resolution) covering just some aspects of the complex reality, but it gives an indication of the factors that require special attention in the context of risk reduction. The index also underscores the need to move attention from analyzing the hazard or climatic stressor towards an improved understanding of the various vulnerabilities that make societies susceptible to climatic stress (Birkmann et al. 2011).

70. The first version of the ***UK Climate Change Risk Assessment* [6] *(UK CCRA)*** was completed and published in January 2012. It follows the requirement for the UK Government to regularly assess the impacts of climate change in the UK – as laid out by the UK Climate Change Act 2008. It aims at presenting the latest evidence on the risks and opportunities of climate change for the UK to 2100. The evidence base is relatively broad and includes the UK Climate Projections 2009 (UKCP09), stakeholder workshops, the findings from other Government reports, peer reviewed literature and new analysis completed for the project. (DEFRA 2012). The results are presented in five themes:

[6] For more information see: <http://www.defra.gov.uk/environment/climate/government/risk-assessment/>.

Agriculture & Forestry; Business; Health & Wellbeing; Buildings & Infrastructure; and Natural Environment. Figure 7 provides an overview of the methodology applied. From an initial risk screening activity, which identified over 700 risks across a range of sectors, this was then prioritised down to 100 based on magnitude of impact and confidence of impact (Defra 2012).

Figure 7
Simplified summary of the CCRA methodology and links with the Economics of Climate resilience project (Source: Defra 2012)



* Ongoing studies to inform the National Adaptation Plan

71. The UKCCRA investigates the magnitude of threats and opportunities by applying specific risk metrics such as estimated areas of habitats potentially affected by change, the number of people at significant risk of flooding and the exposure of economic sectors to climate risks for future time periods and a range of scenarios. For some risks a monetary valuation was completed, applying a methodology developed in the UK's HM Treasury Green Book and its Supplements (<http://www.hm-treasury.gov.uk/data_greenbook_index.htm> and <http://www.hm-treasury.gov.uk/data_greenbook_supguidance.htm>) (Defra 2010). Based on this approach, the UKCCRA values risks from the perspective of social welfare, considering environmental, social and economic consequences, applying both quantitative and qualitative analysis.

72. The UKCCRA acknowledges the limits of the underlying economic analysis and points to the need of further methodological improvements, particularly in the context of valuation of ecosystem services. An additional excercise, the Economics of Climate Resilience (ECR), is currently ongoing with the aim of applying the UKCCRA information to adaptation decision making (Defra 2012). Other limitations of the approach, highlighted by the UKCCRA developers (DEFRA 2012), include:

- Lack of accounting for wider societal change, including socio-economic and demographic, as well as political and private adaptation trends for most risks;
- Lack of data meant that not all risk areas could be quantified;
- No assessment of complex interplay between risk factors such as multiple infrastructure failure or overall risks to ecosystems;
- The international dimension of climate risks and the potential impacts on sectors and regions in the UK is not included;

- The development of the UKCCRA methodology has also been accompanied by controversy about the usability of the underlying UKCP09 climate projections. A further discussion of the applicability is provided by Webb (2012).

73. The ***Mumbai flood risk assessment case study***[7] demonstrates an approach for assessing future flood risks in the context of climate change. The overall aim is to quantify the benefits of different adaptation options at city scale and to demonstrate the current vulnerabilities. The case study applies the "principles of catastrophe risk modeling commonly used in the developed world but simplified for application for a more data sparse region and coupled with downscaled climate model projections.." (Ranger et.al.2011). The study is based on three stages of analysis:

- Characterizing current levels of vulnerability and potential future sensitivities;
- Quantifying relevant risks;
- Identifying adaptation options and evaluating their benefits.

74. The study investigates the direct economic costs of flooding, defined as "the costs of replacing and reconstructing damaged buildings and infrastructure", and the indirect costs "as the reduction in production of goods and services, measured in terms of value-added" (Ranger et.al. 2011). The risk quantification is based on a typical catastrophe modeling framework, which allows a calculation of the direct economic damages and population exposed to flood events. Indirect losses are considered by applying an Adaptive Regional Input–Output model, which allows consideration of "changes in production capacity due to productive capital losses and adaptive behaviour in disaster aftermaths" (Ranger 2011). The hazard quantification is based on rainfall observation data (over 30 years) extended by simulations using a weather generator. Future precipitation projections for the 2080s are taken from the PRECIS model, which is a high resolution regional climate model based on HadCM3. The exposure mapping is based on public census data and proprietary insurance data about values of properties, which is then combined with the observed flood footprint from the 2005 flood in Mumbai. The damage modeling applies mean damage ratios, based on the 2005 loss experience. This is informed by published economic loss estimated, insured loss estimates and a vulnerability curve typical for flooding in Mumbai from a commercial catastrophe model. While the approach provides decision-relevant information, the case study also hints at some limitations of the approach:

- Population growth and future economic growth are not taken into account;
- It addresses at river flood and not other forms of hazard;
- Limited historic loss data for extreme rainfall events;
- Inadequacy of climate models in predicting changes at city scale.

B. The data requirements for assessing the risks of loss and damage

75. Any risk assessment of loss and damages from climate change needs to incorporate two key components:

- Information about the climatic hazard, including current climatic variability and future, long-term projections;
- Information about vulnerability and exposure.

[7] Ranger et.al. An assessment of the potential impact of climate change on flood risk in Mumbai, Climatic Change, Volume 104, Number 1, 139-167, DOI: 10.1007/s10584-010-9979-2

76. Table 4 below outlines the data requirements for selected methods and tools investigated in section III.A above. The table is limited to a small set of approaches, since each approach might have different data requirements that might be of interest for specific users, but that does not really provide more insights into the various concepts and methods to assess loss and damage.

Table 4
Data requirements for selected approaches focusing on main components

Approach	*Hazard and risk modelling*	*Exposure*	*Vulnerability*
Catastrophe Risk Modelling	Needs probability of occurrence, location, magnitude and duration of event Uses MonteCarlo to generate statistics	Needs information about age, destruction, building code and location	Needs information about physical damage and repair costs
CatSim	Requires intensity and return periods of damaging events	Probability of occurrence and destruction in monetary terms) is modeled as a function of hazards (frequency and intensity)	Focus on fiscal and economic data Financial vulnerability, measured in terms of the potential resource gap, is assessed by simulating the risks to the public sector and the financial resilience of the government
CAPRA	Needs probabilities of occurrence of events	Georeferenced assets in a given area such as population data and data about physical structures	Components and elements at risk that could be quantified such as socio economic data based on local, regional and national statistics
IAM	Global scale climate change projections	Damage function estimates for sectors and regions based on extrapolated study results and presented as a fraction of income	Considered as an aggregated function of per capita income (FUND)
UKCCRA	UK Climate Projections 2009: probabilistic projections of climate change for the UK	Socio-economic and demographic factors, fixed in time	Social vulnerability Adaptive capacity
Approach in Mumbai case study	Rainfall observations (30 years), extended empirically using weather generator Projections: one RCM (Precis), SresA2 scenario, statistically downscaled to station level, and empirically extended using weather generator	Exposure map including population and properties	Refers to damage cost to a property for a given water depth, uses average mean damage ratio per type of property, applies 2005 flood event footprint

77. Information about climate hazard relates to physical phenomena (meteorological events or climate stressors) that contribute to the hazard, such as large cyclonic storms or long term reductions in precipitation, and some of their consequences (such as flooding or water resources system failure), but not human or other contributions to the hazard, nor the exposure or vulnerability components of the overall risk of loss and damage. This hazard information constitutes the input to estimate the magnitude and frequency of damaging meteorological events in DRR approaches such as CATSIM and CAPRA, or future projections of climate variables as required by the IAM models and the UKCCRA assessment.

78. In order to perform a climate risk assessment, there is a need for observations of current and past climate variables such as temperature or precipitation, projections of future climate provided by for example Global Climate Models (GCMs) and Regional Climate Models (RCMs), and impacts models to evaluate how climate change and variability affect a particular system. In what follows we describe the characteristics and purpose of the data and tools needed to estimate the climatic risk.

1. Observations

79. These are needed to define the climatic characteristics of the region of interest and to estimate current climate variability.

80. Historical records: In many sectors, estimation of probabilities of occurrence of a particular event (such as heat waves) under the stationary assumption,[8] are based on historical records obtained through direct measurements in meteorological stations, satellite observations, etc. The data must be accurate, representative, homogeneous and of sufficient length if they are to provide useful statistics. The value of the inferences depends on the data representing the range of possible values occurring over time. It is not unusual to find that the estimated magnitude of a particularly damaging flooding event for instance, changes following the observation of a previously unrecorded flood event, or an improvement in the quality of the data (an example of this effect is illustrated in the Mumbai case study, section III.A above);

81. Availability and quality of data can induce large uncertainties in the estimation of climatic risks. While data for temperature and precipitation is widely available (see for instance NASA: <http://data.giss.nasa.gov>; Climate Research Unit: <http://www.cru.uea.ac.uk/cru/data/temperature>, and NOAA: <http://www.ncdc.noaa.gov/cmb-faq/anomalies.php#anomalies7>), other variables such as soil moisture are poorly monitored, or extreme wind speeds are not monitored with sufficient spatial resolution;

82. Paleodata: Paleoclimatology can provide information about rare, large magnitude events in places where long enough observational stations records are not available, but good proxies to estimate the magnitude of past events such as floods or droughts can be found. For instance, during the last few years paleo-hydroclimatology has contributed to a better understanding of flood hazard, particularly in some parts of Europe and USA. Paleodata consist of climate variables such as temperature and precipitation that are reconstructed using time series of geophysical or biological measurements. Availability of paleodata is limited to certain variables at specific locations, or to some large scale averages (global, hemispheric). See the data base at the World Data Center for

[8] This assumption presupposes that the system is stationary, and that the observed record provides an exhaustive sampling of all possible events. That is clearly invalid if, for instance, local climate is affected by local or global climate variations, and/or changed by human activities such as land use changes.

Paleoclimatology: http://www.ncdc.noaa.gov/paleo/data.html (an annotated list of available data can be found at: <http://www.ncdc.noaa.gov/paleo/recons.html>).

2. Climate model projections

83. Projections of changes in future climate are based on climate model simulations. Even though the physical and chemical processes in the climate system follow known scientific laws, the complexity of the system implies that many simplifications and approximations have to be made during modeling. The choice of approximations creates a variety of physical climate models that can be broadly divided into two groups: simple climate models and Global Climate Models (GCMs). Uncertainties in climate model projections occur partially due to the fact that future socioeconomic development is inherently unpredictable, but also as a consequence of incomplete knowledge of the climate system, and the limitations of computer models used to generate projections (Stainforth 2007). The relative and absolute importance of different sources of uncertainty depends on the spatial scale, the lead-time of the projection, and the variable of interest. At shorter time scales, in many cases the natural variability of the climate system and other non-climatic risks would have a higher impact than climate change. For example, in the near term, changes in urbanization and building housing developments on flood-prone areas could increase significantly the risk of flooding and damage to the aforementioned infrastructure, independently of climate change. Over longer time scales, it is expected that climate change might play a more significant role. In this context, any strategy adopted to manage climate hazards has to take into account the fact that projections of climate change have large uncertainties, and even more importantly, acknowledge that in many cases, particularly at local scales, current tools to generate projections cannot predict future changes (Oreskes et al. 2010, Risbey et al 2011).

84. The Intergovernmental Panel on Climate Change (IPCC) Data Distribution Centre (DDC) (www.ipcc-data.org) provides access to GCMs data sets, and other materials such as technical guidelines on the use of scenarios.

85. While GCMs simulate the entire Earth with a relatively coarse spatial resolution (e.g. they can capture features with scales of a hundred km or larger), regional climate projections downscaled from GCMs have a much higher resolution (simulating features with scales as small as a few km). Downscaling can be accomplished through one of two techniques: ‘dynamical’ or ‘statistical’ downscaling. ‘Dynamical’ downscaling refers to the process of nesting high resolution Regional Climate Models (RCMs) within a global model, while ‘statistical’ downscaling relies on using statistical relationships between large-scale atmospheric variables and regional climate (often station level) to generate projections of future local climatic conditions.

86. Downscaling approaches do not provide magical fixes to possible limitations in the data being downscaled (Kerr 2011). As long as key dynamical instabilities are not well represented in ocean models for instance, there will be errors in the atmospheric flow at large and regional scales that cannot be meaningfully quantified. However, dynamical limitations in GCMs are potentially important for regional applications, in particular for applications relying on regional rainfall projections in specific locations (Risby 2011). If GCM data is being downscaled using an RCM or a statistical downscaling technique to obtain information at the local catchment scale, the resulting information will not be robust if the input data wasn't either. In fact, the downscaling approach will only introduce one more source of uncertainty and/or ignorance in the resulting output. In this case, the generation of climate projections using downscaling techniques will almost certainly increase the level of uncertainty in the original GCMs projections. It is important to notice that this uncertainty will have significant effects in the estimation of probabilities of occurrence of damaging events in DRR models and climate risks assessments.

87. There are several modeling experiments aimed at making regional climate modeling data publicly available, some of them currently under development. The Coordinated Regional Climate Downscaling Experiment (CORDEX) will produce regional climate change projections world-wide for impact and adaptation studies (<http://wcrp.ipsl.jussieu.fr/SF_RCD_CORDEX.html>). This experiment includes the results of the NARCCAP programme in North America (<http://www.narccap.ucar.edu>), and the ENSEMBLES project in Europe (<http://ensemblesrt3.dmi.dk>).

88. In the case of statistical downscaling, considerable knowledge and experience is required to work from first principles (see for instance Wilby et al (2010), including a discussion about limitations of this approach).

3. Impacts models

89. Climate model projections provide information about climate variables such as temperature, precipitation, sea level, etc. However, climate risk assessment involves understanding how changes in these variables will affect particular systems. In some cases, such as with heat waves, changes in temperature are the only information needed. In other cases, such as floods, an intermediate modeling step is required. This step is carried out by impact models, which are computational models that take as inputs observed or simulated time series of climate variables such as temperature, precipitation, soil moisture content, wind speed, etc., and use them to simulate the variables that are relevant to analyze a particular climate impact. For instance, as illustrated in the Mumbai case study in Section III.A, extreme rainfall events can cause floods. But to estimate the extent of the flooded area, a storm water management model is used that can generate the flood footprint for each particular event. Models to evaluate particular impacts are not freely available in most cases.

90. It is important to notice that data generators, databases and meta-data platforms that provide climate information, including databases with GCMs and RCMs outputs, are not very user-friendly. In many cases, good knowledge of the climate of the region of interest and the limitations of climate models is required in order to understand the advantages and limitations of using these results for decision support (UNFCCC 2008).

91. The data needs for analyzing vulnerability and exposure depend on the tools, scope and methodology applied to assessment of risk. It can range from historical loss information to current property databases, as often used in the cat modeling context for insurance companies, to a more holistic approach considering demographic, socio-economic and environmental data such as the WorldRiskIndex. In addition, approaches such as the CATSIM model also require information about the capacity to cope with economic losses and damages due to extreme events. Hence, the model also focuses on macroeconomic resource gaps and development implications, which require in-depth information about such factors as budgetary constraints and external debt. These data needs might require a strong engagement of financial institutions (e.g. finance ministry) in the development and application of the approach.

92. Furthermore, data for intangible aspects of loss and damage are important but difficult to obtain. Intangible impacts and aspects that are not valued by a market are often not sufficiently recognized and captured, for instance in Integrated Assessment Models (IAM). For example, the loss of cultural heritage sites or the loss of landscapes and damage to ecosystems as well as ecosystem services are areas that cannot sufficiently or usefully be expressed in monetary terms. However, such factors can heavily influence vulnerability and the risk of loss and damage as seen in past disasters, such as the recent cascading crises in Japan and the disaster in Haiti.

C. Capacity needs for applying risk assessment methods in developing countries

93. This section explores what is needed to apply the above methods and tools in developing countries. The capacity of countries and stakeholders to undertake climate risk assessments is a subset of their overall capacity for disaster risk reduction and adaptation. A range of recent reports has explored this in greater detail (for example Parry et al. 2007; UNISDR, 2009; GAR 2011), referencing lack of financial resources to invest in adaptation, weak institutions and governance, poverty, and environmental degradation as key reasons for this low capacity. In the context of disaster risk reduction the most comprehensive summary is provided by the Hyogo Framework for Action (UNISDR 2005).

94. Another source of evidence comes from within the UNFCCC, where efforts to identify those needs go back to 1999, ranging from a number of workshops and expert meetings, to detailed analysis of National communications and National Adaptation Programmes of Action (NAPAs) Based on this evidence and the information available for the methods and tools assessed above, the following key capacity needs for risk assessment for loss and damage emerge.

95. The application of tools depends heavily on **data availability**. The underlying hazard, vulnerability and exposure data, including climate change information, determine the scale and scope of any assessment of loss and damages. Therefore the access to and availability of relevant, verifiable, consistent and reliable data is a key capacity need. Data in developing countries is often scarce and unreliable (GAR 2011), with observation networks and data infrastructure often in need of modernization and upgrading (WMO 2009). Much of the focus has been on climatic data and observation infrastructure, but for loss and damage, exposure and vulnerability data is equally important. Accessing and integrating these different types of information is a challenge. Government asset databases or sectoral disaster loss data is not available in all countries, or it may be very limited in scope, not capturing intangible impacts (Mechler et al 2010), The lack of standardized hazard data products and methodologies for statistical analysis of hazard characteristics and mapping (WMO 2009), as well as the state of observation networks and data infrastructure are limiting factors. While most countries have some observation stations, they can differ widely in terms of type of observation and data. Lack of maintenance can also endanger continued access to historical data (Westermeyer et.al 2011). Furthermore, the data needs and data availability differ from sector to sector and across geographical scales. Downscaling and extrapolating sectoral data can limit the applicability of the information, as seen in the case of IAMs. Another challenge is the documentation and integration of local knowledge. A data stocktake for all types of data appears to be a useful first step in order to identify the existing gaps and establish where observation and statistical needs are most pressing.

96. Another key capacity area is **technical know-how and skills** required running as well as interpreting methods and tools. For model developers, this means transparent and clear communication about the limitations and uncertainties of the tools. To ensure coherence in the application of data and to evaluate the usefulness, end-users need to be familiar with the technical aspects of the methodologies. Training in data analysis and data generation are important, in the climatic context but also in the socio-economic and environmental area. A commonly referenced capacity need is the ability to distill information from the data provided and share this with relevant stakeholders (Hammill 2011). Training and public awareness raising are often applied to overcome this barrier, as well as guidance to appropriate resources including information on best practice in applying different methods (FCCC/SBSTA/2008/3).

97. The development and application of a risk assessment tool requires **funding.** The more sophisticated the risk assessment approach, the more expensive it can be. Donor funding as well as the finance for National Communications under the UNFCCC are aimed at overcoming this barrier. The selection of the approach also depends on the function the assessment should serve. If local participation is an important goal together with the development of a common understanding of loss and damage due to climate change and socio-economic changes, a qualitative and local assessment might be more optimal than an expert driven approach that is also limited by the availability of quantitative information. While the resource needs for climate observation and modeling have been relatively extensively evaluated (FCCC/SBSTA/2008/3), there are clear needs for support for the compilation of vulnerability and exposure data, such as government asset databases for example and an overview about sub-national and local approaches (quantitative and qualitative). The application of new technologies such as Earth Observation may offer quicker and cheaper solutions. Ultimately, the level of public funding depends on the level of awareness amongt governments and key stakeholders, of the importance of data and its various applications.

98. Overcoming existing **institutional barriers** such as departmental silos between those responsible for managing disaster risks, climate mitigation and adaptation, and finance, is seen as an important factor for developing capacity for innovative and holistic assessment approaches. The need for joined-up approaches, as highlighted above, appears fundamental for the advancement of loss and damage risk assessment. This aspect is being picked up by some of the methods and tools such as CatSim, with its fiscal resilience component, making this model possibly more relevant for Finance officials. Recent case studies suggest that political commitment, combined with clear ownership and responsibility allocation are important for the successful application of risk assessment tools (Hammill 2011). Clear mandates of institutions holding the data to share, the need for participatory approaches to secure stakeholder-buy in; addressing user needs and enhancing collaboration between the climate community and other sectors (particularly agriculture, coastal zones and health); greater collaboration between providers of climate information and the sectoral users of such information for raising awareness among policymakers of the need for sustained systematic observation and monitoring systems for use in understanding climate change impacts and the need to strengthen National Meteorological and Hydrological Services (NMHS). Of similar importance is the broader enabling environment, where good governance and support for local institutions can achieve important gains.

D. Use of risk assessment information for decision making

99. Risk information can only be effective if it is relevant for the decision making process. Therefore the selection of a tool or method needs to be seen in the context of the specific decision-making question and the relevant stakeholders. The methods described in sections II and III.A are being applied by a range of different stakeholders such as governments, donors, private sector and civil society for different purposes.

100. For example the IAM models target policy makers at the global level, while the CatSim and CAPRA approaches focus primarily on public and private stakeholders at national and sub-national level. Within the CatSim approach, Government Departments such as Finance are also involved or at least have an important role in terms of addressing resource gaps and macroeconomic development issues. Hence this approach would best be applied and used by national institutions. The UKCCRA represents another approach that aims to inform a variety of different stakeholders, such as policy makers, the private sector and the general public.

101. Overall, recognizing the end users is an important prerequisite for getting the communication strategy right. Facilitating user networks to aide a better understanding, and support knowledge sharing and exchange may be useful approaches to achieve a better integration of end-user needs. Recent experience points to a couple of important criteria in order to make risk assessments relevant for decision-makers such as the provision of clear guidance on how to use information for policy making (Hammill 2011), visualization approaches (as seen in CAPRA), or the development of technological platforms and one-stop-shops. These provide information, but also offer a user-interface, allowing end-users to be involved in the enhancement and development of the methods and tools. The provision of atlases and maps are the most common information display modes. In addition to the return period and size of expected losses, the spatial and temporal dimensions of information are also relevant to decision-makers, as some management tools may only be suitable for current to short term risks (such as insurance). Here, a classification of loss levels can be useful, differentiating between low, medium and high-level risks, based on return periods and/or scale of impacts.

102. Climate change and variability adds a new dimension to the decision making process. In this case, the key question for decision makers is not just how to cost-effectively reduce current vulnerability, but also how to enhance adaptation in order to build resilience in the future, taking into account climatic and non-climatic risks factors that change over time.

103. Different methods and tools are being applied to a range of policy areas such as mitigation, adaptation or DRM, but there are limits to the transferability, as seen with the IAMs. There are clearly opportunities to increase the application areas by adjusting the tools and addressing their limitations. Recognizing the original aims and purposes behind the development of the methodologies and tools is therefore important.

104. All the tools have practical limitations and their application comes with a high degree of uncertainty. Providing transparent guidance and advice on how to interpret outputs are important requirements for preventing mis-use and mis-interpretation.

105. In order to achieve the decision making goals, choosing an appropriate method to understand the scale and distribution of climate related losses and damages is fundamental. However, equally important is the adoption of a decision making framework that can make the best use of this information to develop successful adaptation pathways. Two decision making frameworks that have been developed in recent years are discussed here: the ‘top down (or science driven)’ and the ‘bottom up (or policy driven)’ frameworks.

Top down (or science driven or end-to end) approach:

106. In this approach to adaptation decision making, the prediction of future impacts based on climate modeling information is used to subsequently plan adaptation measures in response to these projected impacts. Climate projections are derived from GCMs driven by well-defined emissions scenarios. As discussed in section 3.2, these climate projections have a too coarse spatial (and sometimes temporal) resolution to be used directly to drive impacts models, therefore the information is then downscaled to bring it to the adequate spatial and temporal scales to be fed into the impacts models. These “first order” impacts are sometimes carried forward to “second order” impacts on economic sectors such as water resource management or agriculture. Adaption options are only considered at the end of the process. An example of this approach is the Mumbai Case study.

107. This approach to adaptation decision making has serious limitations. Firstly, it relies heavily on the projections of future climatic changes generated by climate models. However, the accuracy of climate predictions is limited by fundamental, irreducible uncertainties that can arise from limitations in knowledge, from human actions and due to the chaotic nature of the climate system. Some of these uncertainties can be quantified,

such as to some extent the uncertainty due to future greenhouse gas emissions. But many cannot, leaving some level of irreducible ignorance in our understanding of future climate.

108. Secondly, even though it is accepted that GCMs provide credible quantitative estimates of future climate changes at continental scales and larger (Solomon, Qin et al. (2007)), these scales are in general not useful for adaptation decision support at the regional and local scales. In particular, simulations of extreme events that are most relevant for example for floods or droughts are seriously affected by the limitations that climate models have in representing the climate processes that drive extreme events. In addition, the actual losses and damages are often heavily determined by the vulnerability and exposure (see IPCC 2011), hence climate models might provide little insights on how loss and damage patterns will really develop and materialize.

109. Thirdly, the projected impacts are highly conditional on the assumptions made to project them. For instance in many cases different results are obtained when using different combinations of GCMs or different weighting schemes to combined them (Merz 2010, Tebaldi and Knutti 2007, Hall 2007). If the accuracy of the projections is overstated and uncertainties are ignored, this approach could give a false sense of security, potentially leading to maladaptation.

110. Finally, uncertainties accumulate at every step of the climate change impact assessment, from emissions scenario, through to climate and impacts modeling, generating a cascade of uncertainties that could potentially paralyze any decision making process (Dessai 2009).

111. The general challenges for decision makers when being required to switch from a backward looking approach to a future oriented style have been well documented in recent years (see Ranger 2011, Hallegatte 2009, Wilby 2010). As suggested by the above discussion, uncertainty is clearly one of the key challenges for decision-makers, especially when competing with concerns about daily lives. But the uncertainty that comes with the described methods and tools does not just stem from climate change; in fact the climate dimension just adds to the uncertainty derived from the wide range of socio-economic and environmental factors considered, often referred to as the 'cascade of uncertainty' (Schneider 1983) or the “uncertainty explosion” (Henderson-Sellers 1993).

Bottom up (or policy first or vulnerability driven) approach:

112. This approach (Willows 2003, Ranger 2010a,b) starts with the definition of the particular problem/decision to be addressed. This includes defining the objective or decision criteria, identifying present and future climatic and non-climatic risks that make the system vulnerable, identifying institutional and regulatory constraints, and identifying the possible options. In this context, the evaluation of climate risks is just one component of the estimations of all the environmental and social stressors and changes in socio-economic conditions that can induce system failures.

113. The next step consists in defining possible adaptation pathways and the most appropriate decision theory approach to achieve the objective. Clearly, the uncertainty in the risk information available and the prospect of this information changing in the future will require from decision makers the need to design flexible adaptation pathways that allow for periodic adjustments as new information becomes available, and the possibility of changing to new routes when or if incremental adjustments are no longer considered sufficient according to the evidence available at the time (Lopez et al 2010, Wilby 2010). Moreover, part of the decision making process will have to consider the fact that the future might involve climate change events not predicted, not even imagined, combined with technological and societal developments inherently unpredictable. The “bottom up“ approach is an adequate tool to use in this context, since it is compatible with and encourages the use of measures that are low regret, reversible, build resilience into the

system, incorporate safety margins, employ ‘soft’ solutions, are flexible, and deliver multiple co-benefits (Hallegate 2009, Hulme, Pielke et al. 2009).

114. The last step in this framework consists of the implementation of adaptation plans, incorporating mechanisms to constantly evaluate and monitor the adopted plans in order to incorporate new information as it becomes available, and to apply corrective measures if necessary.

115. In this approach, modeling capabilities can be used to generate climate projections that, in combination with socio-economic scenarios, result in suitable tools to assess vulnerabilities in different regions including, where possible, the study of vulnerability to changes in frequency of occurrence of extreme events. It is important to note that in the framework of scenario planning as an approach to support strategic decision making, scenarios are intended to be challenging descriptions of a wide range of possible futures In this sense, the combination of climate and socio-economic scenarios we refer to cannot be, by construction, representative of the full range of possible futures. On the climate modeling side for example, missing feedbacks and unknown uncertainties in climate models limit the ability to represent all plausible futures. Notwithstanding these constraints, scenarios can still be used as tools to consider a range of possible futures, and their associated consequences. Then, an analysis of the options available could be carried out, and feedback can be provided on what information about the likely futures would be most valuable for decision makers.

116. The emphasis on choosing adaptation options that reduce current vulnerability and enhance resilience is consistent with the CAF objective “to enhance action on adaptation in order to reduce vulnerability and build resilience in developing country Parties, taking into account the urgent and immediate needs of those developing countries that are particularly vulnerable”. The fact that plans should be flexible and able to incorporate new information as it is produced resonates with one of the best practice recommendations derived from the NAPA process: “Many Parties have affirmed that it is not necessary to await a complete scientific understanding of the impacts of climate change before acting, and that in adapting to climate change, there are many actions that can be undertaken to enhance adaptive capacity and reduce the impacts and costs of addressing climate change at a later date”.[9] This approach is also consistent with the SREX framework discussed in Section II, that considers that risk assessments and the identification of risks of losses and damages should not only take into account the climate change related factors, but also the development pathways a country or community takes, since these heavily influence and determine the level of exposure and the vulnerability.

117. Another dimension of the decision-making relevance of loss and damage assessments lies in the context of attribution of damages to the incremental risk of anthropogenic climate change. For this to be possible, the incremental fraction of loss and damage that can be attributable to anthropogenic climate change should be computable. The probabilistic Event Attribution (PEA) approach has been developed as an attempt to quantify the meteorological part of the attributable incremental risk. More specifically, the PEA approach computes what is the change in the probability of occurrence of a given weather event, due to human influences on the climate system (Stone et al(2005), Pall et al (2011)). Some climate scientists argue that the science of PEA can potentially support decisions related to obtaining compensation for damages caused by attributable natural disasters, since it will allow distinguishing between genuine consequences of anthropogenic climate change from unfortunate climate events (Stone et al (2005), O.Hoegh-Guldberg et

[9] See :Best practice and lesson 9: “Adaptation planning with an initial focus on urgent and immediate needs can capitalize on existing knowledge”, <http://unfccc.int/cooperation_support/least_developed_countries_portal/items/6513.php>.

al 2011). On the other hand, other authors (Hulme et.al 2011) challenge the idea that the science of weather event attribution has a role to play in this context, in particular because PEA probabilities are dependent on the ability of climate models to reliably simulate what the climate would be with and without human influences. However, due to the fact that these models have the limitations already discussed, PEA probabilities can only be subjective Bayesian probabilities that reflect judgment about uncertainties in climate model experimental designs. Therefore relying on them to make decision about economic compensation could potentially be misleading.

V. Preliminary Conclusions

118. The concept of loss and damage, while now being widely discussed and analyzed, has not been clearly defined under the Convention process, and no comprehensive risk assessment model for loss and damage due to the impacts of climate change exists. This section summarizes current knowledge on selective methodologies for assessing the risk of loss and damage, and key gaps identified in terms of required data for such assessment.

119. Most of the approaches analyzed in this paper focus on a relatively narrow definition and quantification of loss and damage. Meanwhile, slow onset changes, such as salinization or the degradation of ecosystems and ecosystem services may be underestimated or not sufficiently taken into account.

120. Most DRR approaches are based on post-disaster information as a basis to estimate pre-disaster and risk models. In this regard, the enhancement of national, sub-national and local loss databases is important. In addition, some loss and damage patterns are also rather difficult to predict due to the interlinkages with socioeconomic factors, for example in a case of major floods or salinization in urban megacities in low-laying coastal areas. Therefore, the continued monitoring of environmental climatic stimuli as well as socio-economic transformation processes is important to further enhance the assessment of the risk of loss and damage.

121. The majority of the models and approaches presented in this paper are complex and require substantial technical skills and in-depth knowledge. This poses further challenges, especially in developing countries due to limited in-country technical and financial resources. It will not be sufficient to just apply methods from outside but it will be essential to build respective capacities for the assessment of risks of loss and damage at national and sub-national levels, possibly by including in the university curriculum.

122. Availability and access to underlying data is important for all the methods and tools reviewed. The specific requirements depend on the scale of analysis:

(a) At the local level, a key gap is the hazard information – availability of observed climate data is highly variable depending on the country and variable of interest, and climate projections are rarely available beyond the regional scale, as highlighted in the Mumbai case study on the scenario-drive approach. Downscaling of GCMs and RCMs data to the local scales has some clear limitations, which need to be fully understood when using this data for decision-making. Information about exposure and vulnerability is often not available in the required format, with gaps in terms of historic data sets, but local knowledge and observations, combined with new technologies such as Earth Observation, can play important roles in overcoming this;

(b) At national level the availability and applicability of exposure and vulnerability data is an important limiting factor, as seen in the context of UKCCRA. Even where government databases and cross-sectoral information is available, the quantification and integration within a risk assessment framework is challenging and requires long and often costly data gathering or simulation exercises. The quality and coverage of observational data varies from country to country. Climate projections are usually available at the country scale, but as above, a clear understanding of their limitations is crucial when using them for decision making;

(c) Globally, the lack of underlying regional and national assessments of vulnerability and exposure makes assumptions and extrapolations necessary, which add to the uncertainties posed by climatic information.

123. At every scale, access to climate data, hazard, vulnerability and risk information as well as their adequate interpretation for decision support, requires a certain level of technical knowledge that may not be available in every country. The choice of methods and tools clearly depends on the aim of the assessment, the scale, resources availability and technical skills. In this context, a sequential step-wise application of different methods and tools may offer best value to developing countries. Loss and damage assessments could build, for example, on more general methodologies, such as EMA and the ECLAC methodology, while the CAPRA or the CatSim models (see Table 3) require more in-depth mathematical modeling knowledge. In addition, it will also be important to acknowledge existing bottom-up approaches in the process of conducting loss and damage assessments within the broader framework of risk assessment and adaptation planning.

124. The use of climate change scenarios and DRR or IAM modeling tools to evaluate loss and damage due to climate change can meet some, but not all, of the needs of adaptation planning. Particularly in the context of developing countries, the choice of tool must be matched to the intended application and the relevant loss and damage categories, taking into account local constraints of time, resources, human capacity and supporting infrastructure.

125. In the context of adaptation planning, detailed numerical modeling may not be feasible (due to costs or technical constraints), or necessary if the measure delivers benefits independently of the climate outlook. For instance, improved hazard forecasting and dissemination, and emergency response and post disaster management would help to improve adaptive capacity irrespective of which currently uncertain climate projection is eventually realized.

126. In some cases, qualitative knowledge about the expected trend of the climatic change could provide enough information for stakeholders to find more resilient options that meet the desired criteria. To this end, a quantification of loss and damage may not be needed in all decision-making contexts.Transparency, in terms of limitations and uncertainties of the models is important, as is learning across the end-user community. Often model descriptions do not sufficiently reveal their limitations.

127. Lastly, the review of existing approaches clearly shows that it is important to acknowledge that characteristics and patterns of risk of loss and damage are different at various scales (e.g. national versus local) and cannot sufficiently be expressed in monetary terms at national level (e.g. loss of cultural heritage, loss of trust, loss of ecosystems).

128. Overall, it is important to recognize that complex systems, such as communities or societies or social-ecological systems, involve multiple facets (physical, social, cultural, economic, institutional and environmental) that are not likely to be measured in the same manner. In order to measure and manage risk, a holistic perspective is required. Integrated and interdisciplinary focus can more consistently take into account the non-linear relations of the parameters, the context, complexity, and dynamics of social and environmental systems, and contribute to more effective climate risk management by the different stakeholders involved in decision-making.

129. As this paper demonstrates, there is a significant new dimension of tools emerging, combining knowledge and technical skill from DRR, catastrophe modeling and the newer but fast emerging field of climate change assessment, however, there is a range of challenges which should be taken into account:

(a) Capturing the scope and extent of direct and indirect losses as well as the growing interconnectedness of impacts (such as cascading effects);

(b) Further clarification of the strengths, weaknesses and limitations of the available methods and tools with a view to avoiding misunderstandings and misuse – particularly in the context of uncertainty (climatic and non-climatic);

(c) Enhancing methods and tools for assessing the risks from slow onset changes, such as sea level rise, salinization or the degradation of ecosystems and ecosystem services;

(d) Improving the linkages and synergies between qualitative and quantitative assessment approaches at various scales, including the possibility for adopting a sequential step-wise application of different methods and tools;

(e) Enhancing enabling environments in developing countries (e.g. technical capacity, skills, fiscal tools, etc.) for utilizing the available methods and tools for assessing the risk of loss and damage.

Annex I

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Annex II

Overview diagrams of frameworks for assessing risk and vulnerability

Figure 8
Conceptual framework for a second-generation vulnerability assessment (Füssel and Klein, 2006); this understanding corresponds largely with the vulnerability definition used in the IPCC AR4.

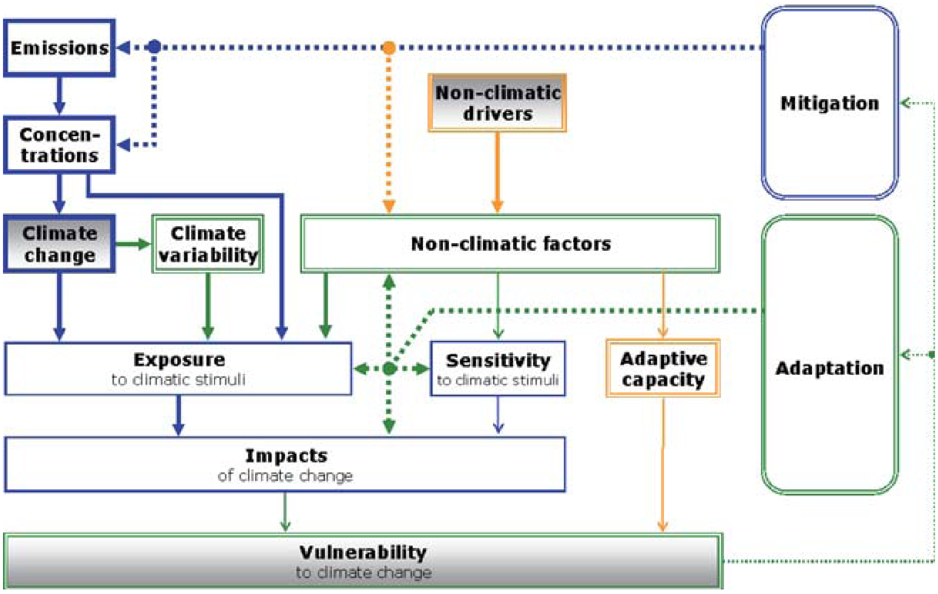

Figure 9
Framework for Disaster Risk Reduction presented by UN/ISDR (2004)