Technical Assistance - TAAS-0036

Climate Change Risks and Opportunities in Uttarakhand, India

Inception and Desk Review Report

Month October, 2013

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INRM Consultants Pvt Ltd
(Incubatee Company established through TBIU system of IIT Delhi)
Integrated Natural Resource Management - Solutions with Modeling and Geoinformatics

CENTRAL HIMALAYAN ENVIRONMENT ASSOCIATION
CHEA

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1. INTRODUCTION

1.1 Context

Developing countries face huge challenges in developing infrastructure to meet the growing demand in their economies and developing climate resilient infrastructure further toughens the challenge. The impacts of climate change on developing economies are evident in the increasing vulnerability of their economies to climate change. While climate change science is gaining increasing acceptability and impacts of climate change become more visible, the same science is increasingly being used to make economies more resilient to these changes or in other words ‘climate proofing’. This approach is now being increasingly accepted by governments in all levels, national, state and local as well as by multilateral lenders like the World Bank, Asian Development Bank and others.

In India, the coastal and the mountainous states are generally seen as more vulnerable to climate change. The Government has recognized the importance of mainstreaming climate change in developmental planning and country’s 12th (twelfth) Five Year Plan seeks to fulfill ‘Faster, Sustainable, and More Inclusive Growth’. India has also put in place an advanced framework for tackling climate change, including a National Action Plan (NAPCC) with eight accompanying sectoral ‘missions’. As a federal state, policy turns to action at the state level. However, a lack of resources and capacity in many states puts this at risk. Climate & Development Knowledge Network (“CDKN”) is, therefore, focusing efforts at this level and providing the necessary support to ensure national policies are adapted to the local context and implemented effectively.

At Uttarakhand, streamlining climate actions in growth planning started with preparation of the Uttarakhand Action Plan for Climate Change (UAPCC). The State has constituted the State Council for Climate Change (SCCC) under the Chairmanship of the Chief Secretary supported by 29 members from various line departments with mandate to oversee all aspects of the State’s preparations and initiatives to address climate change and its impacts. The UAPCC document articulates overarching State level vision and commitment towards climate change and recognizes the importance of detailed climate vulnerability assessment prior to investment planning. Thus, CDKN approached the State Government of Uttarakhand to support in conducting climate change vulnerability assessment that would feed-in the actions plan stated in UAPCC.

While vulnerability assessment can inform development of adaptation strategies to increase resilience, the approach to vulnerability assessment differs in its purpose, applicability and uses. Vulnerability assessments can be applied to many types of projects, in different sectors, and at any spatial or temporal scale, and therefore there is no “one-size-fits-all” approach. Thus, scoping of vulnerability assessment is of importance to achieve desired benefits from the assessment exercise.

Scoping a Vulnerability Assessment – Key questions to ask and issues to address

- What is the concern? Is it Food supply, Water availability, or Health and or Regional impacts?
- Who may be affected? Is it Community, Cities, Government, Economy, and or State as a whole?
- How far into the future is of concern? Or is the concern about current risk?
- For what purpose is the assessment to be conducted? It is for engaging stakeholders, or for scientific understanding and or designing adaptation strategy or formulating adaptation projects.

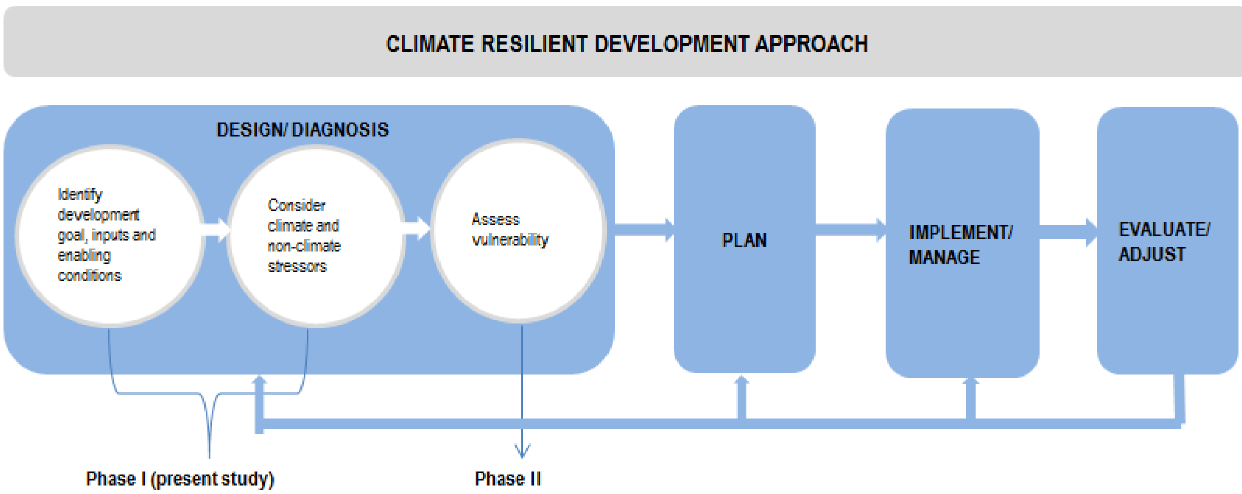
For the state of Uttarakhand, CDKN proposed to approach Vulnerability Assessment in two phases:

- Phase I – Design/ Diagnosis phase
- Phase II – Delivery/Assessment phase.

In this context, CDKN engaged ICF International ("ICF") and its partners, Indian Institute of Science (IISc), INRM Consultants Pvt. Ltd. (INRM) and Central Himalayan Environment Association (CHEA), for developing a Framework for Vulnerability Assessment to Climate Change as first phase (Phase I) of the study which will then feed to the next phase (Phase II) of actual vulnerability assessment.

Exhibit 1 illustrates the common stages of approach adopted frame Climate Resilient development initiatives (Source – ICF)

Exhibit 1 – Climate Resilient Development Approach



The, Phase I/ Design Phase, i.e. this study would effectively address the above mentioned idiosyncrasies of vulnerability assessment and aim to deliver the following:

- Define the goal and the scope of the assessment, depending upon its purpose, use and resource availability;
- Derive the approach and the methodology for conducting the assessment as per defined goal and scope, and
- State the expected output of the assessment work to be actually carried out in Phase II/ Assess Vulnerability

1.2 Objectives of Phase I

The purpose of this study is to describe how to conduct the first step in the process of planning for climate change, i.e. – Assess Vulnerability. Thus, the overall objective of this study is to design the scope, methodology and approach and detail out the work plan for assessment of vulnerability to climate change, risks and opportunities for the State of Uttarakhand for short, medium and long-term.

The study intends to address the following objectives:

- To help evolve ownership and agreement across the Uttarakhand government on the scope, methodology and use of vulnerability assessment of the climate change risks
- Identify potential opportunities in building resilience to climate change through an assessment of existing capacities
- Provide a context for incorporating climate change concerns in development planning by identifying likely impacts of climate change in Uttarakhand state
- Establish a baseline for implementing adaptation strategies for increasing resilience to climate change in the state
- Raise awareness at state and national level on climate change vulnerabilities and opportunities
- To provide CDKN and the Government of Uttarakhand a work plan for delivering the assessment

1.3 Outcome of Phase I

This entire framework of deliberating the scope and the goal, the approach and the methodology and the outcome would be delivered using participatory approach. This would essentially build buy-in from the State Government, who would be the owner and user of the derived framework. Thus, outcome of this study would be of many folds:

- A relevant framework for assessing vulnerability of the State to current and future impacts of climate change, and the opportunities that can be utilised to deliver action plans;
- Build government buy-in for the framework being proposed, the scope of the assessment, its purpose and use, the methodology, including data source, work plan including outputs, program governance and timeframes;
- As well as, build capacity within the Government machinery to Plan, Implement/ Manage and Evaluate/ Adjust action towards climate change

1.4 Approach and Methodology for Phase I

The overall approach has been divided into the following steps. Exhibit 2 details out the Task and the Timeline for the entire study.

Exhibit 2: Task and the Timeline

Task	Activities
Task A: Kick-off meeting Week 1	• Confirm scope, timeline and outcome of the study • Identify stakeholder for participatory discussion
Task B - Desk Review Week 2- 4	• Review exisiting methodologies • Discuss outcomes of any past studies • Identify data and document resources
Task C - Stakeholder Consultation Week 4 - 6	• Conduct workshop/ one-to-one discussion • Analyse limitation felt by experts around vulnerability assessment
Task D - Scope and Design Assessment Week 5 - 6	• Develop scope and methodology for vulnerability assessement • Design outreach programe/ capacity building • Define monitoring and evaluation framework
Task E - Stakeholder Feedback Week 8 - 9	• Conduct workshop/ one-to-one discussion
Tasck F - Agreed Framework for Vulnerability Assessment 9 - 11	• Finalize the Framework for Vulnerability Assessment • Define Terms of Reference for Phase II • Other reccomendation
Task G - Blogs and Articles 11 - 12	• Produce blogs (2 numbers) for CDKN's website of the findings from the study

2. CLIMATE CHANGE

2.1 Climate Change and the State of Uttarakhand

In 2012, the world authority on climate science, the Intergovernmental Panel on Climate Change (IPCC) through its published report[1] concluded that even without taking climate change into account, the risk of disasters will continue to increase in many countries as more people and assets are exposed to weather extremes. The report underlines how our heavy alteration of ecosystems – such as turning forests into agricultural land and overfishing of protective coral reefs – decreases the natural world's resilience to climate extremes and disasters and our ability to ride them out. And State like Uttarakhand is perhaps experiencing the said.

> Environmental activists in India are pointing to unplanned development and rampant felling of forests in the hills of Himalaya are to blame for turning flash floods hazard into a disaster. Journalists are asking questions about the series of dams which are reported to have upset the ecological cycle and hill slope stability, as well as a lack of urban planning leading to construction of buildings in the high-risk areas.
>
> Source: CDKN, Blogs by individuals

Climate change is expected to manifest quite significantly in India (UAPCC) and is already experiencing a warming climate, and further warming is expected (World Bank[2]). According to the observations by National Communications (NATCOM, 2004), temperature is likely to increase by more than 4ºC in Northern India during the 2050s (robust prediction). Using the second generation Hadley Center Regional Model (Had RM2) and the IS92a future scenarios of increased greenhouse gas concentrations, the report also project little change in monsoon rainfall at overall country level. However, Himalayan foothills (Uttarakhand) may experience increase of rainfall day by 5-10 days with increase in rainfall intensity by 1-4 mm/day (varies across models). Thus, any shift in the climatic conditions will show marked impacts in terms of biodiversity, water availability, agriculture, and hazards that will have an impact on general human wellbeing and country's economy as India continues to depend on monsoon patterns (rain-fed agricultural practice) and winter months to boost its agricultural growth.

The projected climate change is likely to impact natural ecosystems as well as socio-economic systems of Uttarakhand. With fragile and poorly accessible mountainous landscape, scattered settlements and devastated state of infrastructure in some parts from recent climate induced disaster, makes the State more vulnerable to extreme weather events. The natural resources of the State provide livelihoods and ecosystem services (water, forest and tourism) to millions of local people. About three-fourth of state's population is rural and virtually all depend on agriculture which is primarily rain-fed. Tourism and animal husbandry are other sources of income. With over 15 tributaries of rivers Ganga and Yamuna and over a dozen major glaciers, Uttarakhands' economy is primarily supported by Hydropower sector (UAPCC).

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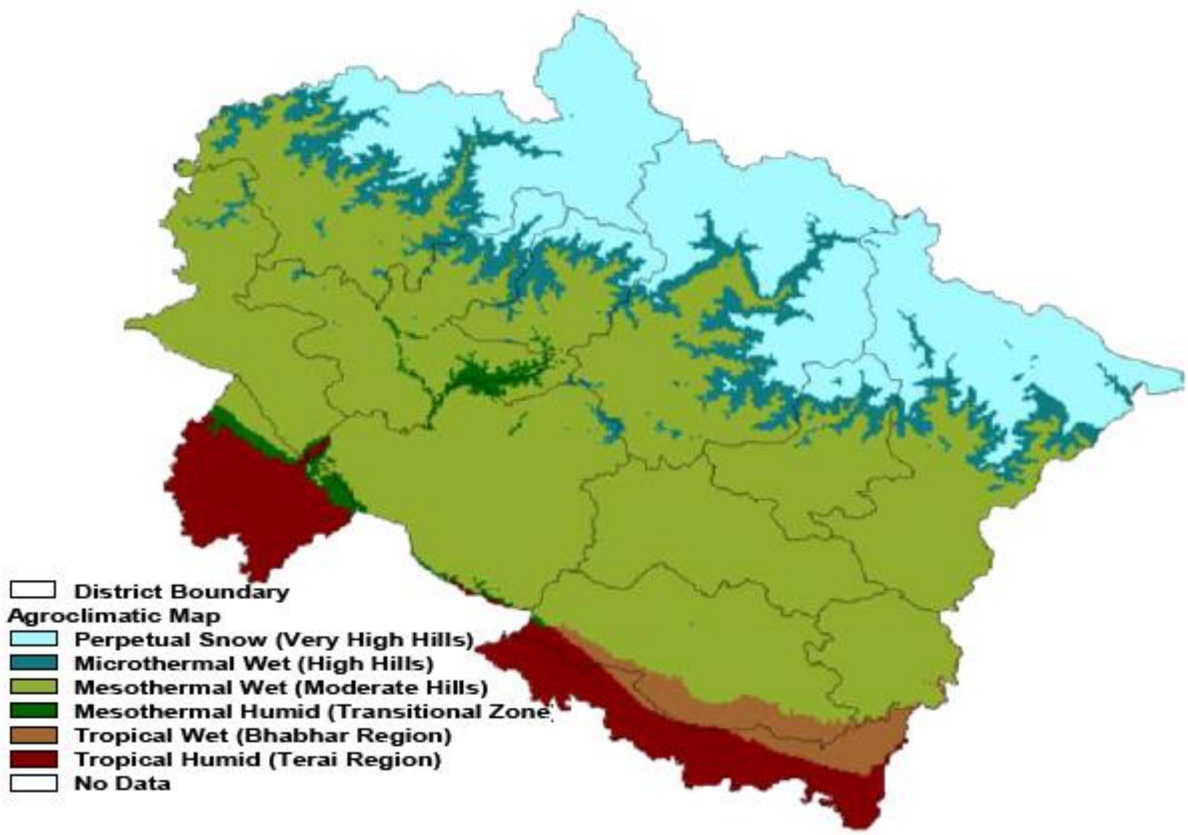
[1] 'Managing the Risks to Extreme Events and Disasters to Advance Climate Change Adaptation' (SREX), http://ipcc-wg2.gov/SREX/

[2] Turn Down the Heat: Why a 4°C Warmer World Must be Avoided, World Bank, 2013, http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf

Thus, climate change is highly likely to have direct impacts on the livelihoods of the people of the state, and also impact the poor, women, children, aged and differentially abled persons, comprising more than 50 % of the total population[3].

Uttarakhand is divided into the distinct non-mountain (plain) and mountain (hills) physiographic zones and thus encounter two distinct climatic exposures: the predominant hilly terrain and the small plain region (UAPCC). The climatic condition of the plains is very similar to its counterpart in the Gangetic plain and hilly region of the state is greatly influenced by Himalayan ranges due to close proximity. Exhibit 3 illustrates the agro-climatic map of Uttarakhand (Source: Uttarakhand State Action Plan for Climate Change – UAPCC)

Exhibit 3 - Agro-climatic map of Uttarakhand



[3] Source - "Uttarakhand at a Glance (2012-13)", Directorate of Economics and Statistics, Uttarakhand; Census of India, 2011 http://www.census2011.co.in/census/state/uttarakhand.html; Census Of India 2001, POPULATION PROJECTIONS FOR INDIA AND STATES 2001-2026.

Total Population of Uttarakhand (2012 – 13), Nos. – 10117000; % of rural women – 35%; % children (0 – 6 age) – 13%; % disabled population – 2%; % old age (+60yrs) – 7%

2.1.1 Climate Change and Himalayan Region – Hills of Uttarakhand

This section brings out highlights of the various studies conducted by International Centre for Integrated Mountain Development (ICIMOD) on climatic impacts on Hindu Kush-Himalayas region and the hilly terrains of Uttarakhand being part of the Eastern Himalayas.

Mountains are among the most fragile environments on Earth. They are also rich repositories of biodiversity and water and providers of ecosystem goods and services on which downstream communities, both regional and global, rely (Hamilton 2002; Korner 2004; Viviroli and Weingartner 2004). Under the influence of climate change, mountains are likely to experience wide ranging effects on the environment, biodiversity, and socioeconomic conditions (Beniston 2003). Changes in the hydrological cycle may significantly change precipitation patterns leading to changes in river runoff and ultimately affecting hydrology and nutrient cycles along the river basins, including agricultural productivity and human wellbeing.

Climate change increases the risk of extinction of species that have a narrow geographic and climatic range (Hannah et al. 2007; Sekercioglu et al. 2008). This is a special risk factor for highland species, which are sensitive to climate change (Pounds et al. 2006) and more likely to be at risk of extinction.

Natural hazards in the Eastern Himalayas are mainly linked to water, amplified by the fragile environment, which is extremely sensitive to external perturbations. The extreme relief of the mountains, coupled with monsoonal vagaries, has left communities vulnerable to water-related natural hazards (Pathak et al. 2008); over the past three decades, the region has witnessed an increased frequency in events such as floods, landslides, mudflows, and avalanches affecting human settlements (Shrestha 2004; WWF 2005).

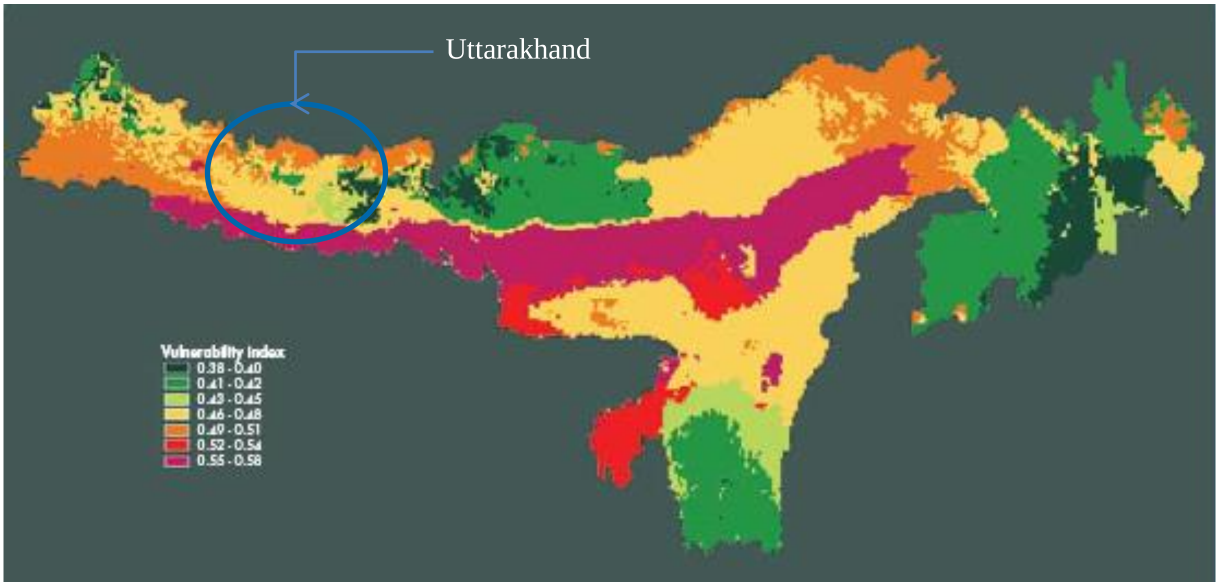
The negative impacts of climate change on wetlands and freshwater resources and their ability to provide goods and services is also predicted by many studies. The impact on hydropower plants could affect human wellbeing through reduced quality of life, reduced productivity, and loss of revenue from power export for States like Uttarakhand where economic success is premised on sustained hydropower generation. This problem could be more prominent in the lower parts of the river basins.

Climatic changes are predicted to undermine regional food security. Several studies in the past showed that the production of rice, corn, and wheat has declined due to increasing water stress arising partly from increasing temperatures and a reduction in the number of rainy days (Fischer et al. 2002; Tao et al. 2004). The net cereal production in the region is projected to decline by at least 4 to 10 per cent by the end of this century, under the most conservative climate change scenario (Lal 2005).

Changes in temperature and precipitation could also expand vector-borne diseases into previously uninfected high altitude locations. Expanding the geographic range of vectors and pathogens into new areas, increasing suitable habitats and numbers of disease vectors in already endemic areas, and extending transmission seasons could potentially expose more people to vector-borne diseases (ICIMOD, 2009).

Exhibit 4 illustrates collective vulnerability, i.e., vulnerability integrated across different components of mountain ecosystems and dimensions of susceptibility to climate change impacts, of the region (Source - Climate Change Impacts and Vulnerability in the Eastern Himalayas, ICIMOD, 2009).

Exhibit 4 - Collective vulnerability of Eastern Himalayas



2.1.2 Climate Change and Upper Ganges Plains – Plains of Uttarakhand

Himalaya also acts as a massive fresh water reservoir and a number of perennial rivers and their tributaries have their source in this region. Two of largest river systems of the sub-continent, Ganges and Indus originate in the glaciers of this region and are fed by myriad lakes, glacial melts and streams. These perennial rivers provide water for household, industrial and irrigation purposes and are also the primary source of energy in the region. These bring huge quantities of silt and clay that get deposited in the Indo-Gangetic plains and thus regularly replenish the soil fertility. It is because of these river systems that these plains are in a position to sustain dense population (USAPCC). Average population density in the Ganga River Basin is 520 persons per square km as compared to 312 for India (2001 census)[4].

The climatic condition of the plains is very similar to its counterpart in the Gangetic plain, i.e. tropical. Summers are relatively hot and winters are chilly with temperatures going below 0°C. It is reported that the temperature increase is more prominent in the plains, compared to hills. The plain land of the State is covered with a vast expanse of alluvium and unconsolidated sedimentary material of varying size fractions (ranging from boulder to clay) and is a promising zone for ground water development. Thus, out of the 3.47 lakh ha (1999-2000) of net irrigated area, mostly is confined to the plains. Further the plains are more approachable and irrigation facilities are limited to the plain areas, thus, productivity of districts in plains such as Udham Singh Nagar, Haridwar, Nainital and Dehradun are very high, on the other side; productivity of the hilly area is very low, although the valleys are equally fertile.

According to scientific studies done by Botanical Survey of India (BSI), Uttarakhand is floristically super-diverse state of India, mostly harboured by Gangetic plain.

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[4] http://moef.nic.in/downloads/public-information/Status%20Paper%20-Ganga.pdf

The plains of the State also face migration from the hills, making it further vulnerable in terms of resource scarcity and overpopulation. Most of its major industrial infrastructure has been developed in the plains. Some of its major projects include the Integrated Industrial Estate at Bharat Heavy Electricals Limited in Haridwar, the Integrated Industrial Estate at Pantnagar, an IT Park in Dehradun, Pharma City in Selaqui, Dehradun, the Growth Centre at Pauri, and the Integrated Industrial Estate at Sitarganj.

The Living Ganga Programme under the HSBC Climate Partnership of WWF – India is an initiative which aims to develop and implement strategies for sustainable energy and water resource management within the Ganga Basin, in the face of climate change. This section of this report, thus, highlights the findings of the study to understand the vulnerability of the plains in the State of Uttarakhand.

The Ganga Basin faces a number of climatic and non–climatic stressors. The Himalayan glaciers that feed Ganges are melting more rapidly, and as potential consequences of glacier changes geohazards like glacier-lake expansion, glacier-lake outbursts and flooding might threaten the livelihoods and wellbeing of those in the downstream regions of Ganga basin.

With projection of climate change, many studies conducted on the river basins of India reflect increase in precipitation for majority of the river basins including Ganga. The implications of changes in precipitation level; temperature (impacting evapotranspiration rate) and water withdrawal (mainly by dams and barrages) results in changes in water yield of the river basin. Studies also predict overall increase in sediment load. A study by IIT Delhi and INRM suggest evidencing moderate to extreme drought severity in Ganga basin by 2050s despite the overall increase in precipitation.

A report by International Water Management Institute on "The Impacts of Water Infrastructure and Climate Change on the Hydrology of the Upper Ganges River Basin" projects non-climatic stressors modulating the flow of the river. The report project decrease of average annual water flow by 2-8% compare to naturalized conditions due to operations of various dams and barrages constructed till date. Flow regulation through dams and barrages has also changed the timing of annual extreme water conditions such as the date of minimum and maximum flows[5]. These changes are likely to impact the population highly dependent on Ganga River in one or many ways.

[5] http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB142/RR142.pdf

3. DESK REVIEW

3.1 Objective of Desk Review

The objective of this desk review is two folds: -

a) To review the work that has already been done by various agencies for the state of Uttarakhand to highlight

   - The limitations of such studies in terms of data, geographic and sectoral scope
   - The resultant gaps in the analysis
   - Identify relevant stakeholders

b) The possible ways to improve vulnerability assessment and provide inputs for the next phase of developing a methodology for assessment

Thus, this report has been structured to bring in the concept of Vulnerability Assessment as well as how various other studies have approached to assess the vulnerability either conducted on the State and or in the region as study area.

3.2 Outcome of Desk Review

This desk review is expected to be able to highlight the different approaches and methodologies set by the reviewed studies, their outcome, application areas and focus, as well as limitation thus faced. This analysis would then be considered as base for discussion and further framework to be fine-tuned, such that it is relevant, practically implementable, and understood by the beneficiaries to carry as ongoing process.

3.3 Approach to Desk Review

Assessing vulnerability to climate change has no standard approach and or set indicators to apply. As each and every ecosystem and socio-economic combination is unique, various kinds of methodologies have been proposed and used for such studies. Further, as mentioned earlier in Section 1.1 of this report, 'approaching vulnerability assessment differs with its purpose, use and applicability', it is thus important to select an approach that is best suited for assessment as well as relevant both in context of the given ecosystem and socio-economic set-up.

Since many studies have assessed vulnerability to climate change of Uttarakhand and/ or the region (Eastern Himalayas and Ganges plains) and/ or the priority sectors of concern for the State, it is felt that a review of such methodologies will provide a wide spectrum of understanding of the State, its vulnerability and adaptive capacity to climate change, availability of data and information used for assessment and limitation therein, as well as fine tune the methodology to be developed as the outcome of this study.

The concept of vulnerability and capacity assessment to climate change got popularised with IPCC climate change assessment reports. Thus, this review of methodologies started with reading and understanding the relevant chapters of latest Assessment Reports published by IPCC. Then a regional focus was selected to understand the regional climatic trends and vulnerability assessment approaches. Out of many studies, ICIMODs' studies titled – the Climate Change Impacts and Vulnerability in the Eastern Himalayas and Framework for Community- Based Climate Vulnerability and the Capacity Assessment in Mountain Areas and the Facing the Facts: Ganga Basin's Vulnerability to Climate Change, by WWF-India, were selected for review. The review process then extends to host country approaches, such as Climate Change and India: A 4X4 Assessment A sectoral and regional analysis for 2030s by Indian Network for Climate Change Assessment (INCCA), under Ministry of Environment and Forest, Government of India and National Mission for Sustaining the Himalayan Eco-system as one of the eight missions of National Action Plan on Climate Change. This review also captures the sectoral approaches to understand vulnerability to climate change and selects few priority sectors based on latest edition of Uttarakhand State Action Plan for Climate Change. The sectors thus selected are Agriculture, Livestock, Forestry and Biodiversity, Water Resources, Human Health, Energy and Tourism and cross-cutting socio-economic indicators common for all sectors. And in each report the review focused to understand the following features of the study:

- Geographical scope i.e. spatial resolution
- Study area i.e. national, regional, local or sectoral approach
- Assessment Methodology applied
- Assumptions and limitations stated
- Data collection method i.e. primary and or secondary sources,
- Outcome/ outputs achieved

This is not meant to be an exhaustive review of all the literature. Therefore those studies that are most relevant in understanding the evolution, measurement, and application of vulnerability assessment and its relevance to the State of Uttarakhand in terms of physiology of the state, matching the sectoral priorities have been reviewed in the study.

3.4 Review of Existing Approaches and Methodologies to Vulnerability Assessment

Report: Assessing key vulnerabilities and the risk from climate change. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC 2007

Schneider, S.H., S. Semenov, A. Patwardhan, I. Burton, C.H.D. Magadza, M. Oppenheimer, A.B. Pittock, A. Rahman, J.B. Smith, A. Suarez and F. Yamin, 2007: Assessing key vulnerabilities and the risk from climate change. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 779-810.

Assessment Methodology

The aim of this IPCC assessment chapter is to provide a conceptual framework for the identification and assessment of key vulnerabilities. The chapter also identifies seven criteria from various literatures that may be used to identify key vulnerabilities, and then describes some potential key vulnerabilities identified using these criteria. The criteria listed are:

- magnitude of impacts,
- timing of impacts,
- persistence and reversibility of impacts,
- likelihood (estimates of uncertainty) of impacts and vulnerabilities, and confidence in those estimates,
- potential for adaptation,
- distributional aspects of impacts and vulnerabilities,
- importance of the system(s) at risk.

The chapter recommends consideration of the response of biophysical and socio-economic systems to changes in climatic and non-climatic conditions over time (e.g., changes in population, economy or technology), important non-climatic developments that affect adaptive capacity, the potential for effective adaptation across regions, sectors and social groupings, value judgements about the acceptability of potential risks, and potential adaptation and mitigation measures. It defines key vulnerabilities as are found in many social, economic, biological and geophysical systems, and associated with many climate sensitive systems, including, food supply, infrastructure, health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets, and modes of oceanic and atmospheric circulation. It further explains how key vulnerabilities may be linked to

Application

Geographical scope i.e. spatial resolution –

Provides global examples

Study area i.e. national, regional, local or sectoral approach –

Global and sectoral approach

Data collection method i.e. primary and or secondary sources –

Integrates inputs from various studies and literatures systemic thresholds where nonlinear processes cause a system to shift from one major state to another (such as a hypothetical sudden change in the Asian monsoon or disintegration of the West Antarctic ice sheet). Systemic thresholds may lead to large and widespread consequences that may be considered as 'dangerous'.

Outcome/ outputs achieved

The chapter has suggested that key vulnerabilities may be a useful concept for informing the dialogue on dangerous anthropogenic interference, however also indicates this to be an indicative list and further elucidation of this concept requires highly interdisciplinary, integrative approaches that are able to capture bio-geophysical and socio-economic processes. In particular, it is worth noting that the socio-economic conditions which determine vulnerability (e.g., number of people at risk, wealth, technology, institutions) change rapidly. Better understanding of the underlying dynamics of these changes at varying scales is essential to improve understanding of key vulnerabilities to climate change.

Synthesis of this IPCC chapter suggests wide variance in methodological approach by different studies in carrying out vulnerability assessment. A summary of the synthesis from the chapter is provided below:

- Most of the literature in Vulnerability and Capacity assessment focused in key elements and processes in geophysical, biological and socio-economic systems that are sensitive to climate change and have limited adaptation potential
- In a majority of the literature, key impacts are associated with long-term increases in equilibrium global mean surface temperature above the pre-industrial equilibrium or an increase above 1990-2000 levels.
- There is considerable potential for adaptation to climate change for market and social systems, but the costs and institutional capacities to adapt are insufficiently known and appear to be unequally distributed across world regions. For biological and geophysical systems, the adaptation potential is much lower. Therefore, some key impacts will be unavoidable without mitigation.

Assumption and Limitation

The assessment of key vulnerabilities involves substantial scientific uncertainties as well as value judgments.

The models involved range from stand-alone carbon cycle and climate models to comprehensive integrated assessment frameworks describing emissions, technologies, mitigation, climate change and impacts. Some frameworks incorporate approximations of vulnerability but none contains a well-established representation of adaptation processes in the global context (IPCC, Third Assessment Report, 2007).

There are significant gaps in knowledge with regard to impacts, the potential and nature of adaptation, and vulnerabilities of human and natural systems.

Report: Livelihoods Vulnerability Index (LVI – IPCC)

Hahn, M.B., et al., The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. Global Environmental Change 19 (2009) 74–88, www.elsevier.com/locate/gloenvcha

Assessment Methodology

The LVI consists of seven major components under the three IPCC defined broad categories of Exposure, Sensitivity and Adaptive Capacity. Each of these components has several indicators under them chosen on the basis of literature review and the practicality of collecting the needed data through household survey. The LVI uses a balanced weighted average approach where each indicator contributes equally to the overall index even though each major component is comprised of a different number of indicators. The value for each indicator is first standardized as an index using the Human Development index formula. The standardized values for the indicators were combined then to get the value of each major component. Subsequently, values of the components under an IPCC defined category were combined to get the value for that category. Once the values of the 3 categories were calculated, they were combined to get the vulnerability index using the formula:

$$Livelihood\ Vulnerability\ Index\ = (Exposure\ - Adaptive\ Capacity) \times Sensitivity$$

The Scaling of the LVI was done from -1 to +1 indicating low to high vulnerability.

Application

Geographical scope i.e. spatial resolution –

Two district of Mozambique - Moma and Mabote

Study area i.e. national, regional, local or sectoral approach –

Study of livelihood for the Moma and Mabote districts, where agriculture is the prime livelihood, followed by livestock rearing, farm fishing and collection of natural resources to sell in the market are the prime source of income

Data collection method i.e. primary and or secondary sources –

Primary (household survey) and secondary sources.

Outcome/ outputs achieved

LVI provides a useful tool for development planners to evaluate livelihood vulnerability to climate change impacts in the communities. By substituting the value of the indicators, the LVI and LVI–IPCC could be used to assess the impact of a program or policy. The LVI approach could be used to compare vulnerability among communities within a district. Similarly, the LVI might be used to project future vulnerability under simple climate change scenarios (such as a 1^{0}C increase in temperature). Formulas for calculating the LVI and LVI–IPCC were designed to be straightforward in order to reach a diverse set of users.

Assumption and Limitation

Limitations of the overall LVI approach include oversimplification of complex reality (Vincent, 2007). As sub-components are averaged into one major component score, this approach does not incorporate variance between study populations. Further, assignment of directionality from less to more vulnerable involves normative judgment (Vincent, 2007). Furthermore, as LVI was designed for district level assessment, same cannot be applied with coarse resolution GCMs.

Report: **Climate Change vulnerability mapping for South-East Asia**

Yusuf A. A. and Francisco H., 2009. Climate Change Vulnerability Mapping for Southeast Asia. Economy and Environment Program for Southeast Asia (EEPSEA).

Assessment Methodology

The aim of this exercise was to identify the most vulnerable regions in the light of climate change. A quick assessment was done to assess the current vulnerability in the study area using available past and present data. Following the standard IPCC definition indicators were chosen under exposure, sensitivity and adaptive capacity. Climate related hazards were used to determine the exposure levels. Sensitivity of the region was assessed on the basis of human sensitivity (population densities) and ecological sensitivity (% of protected areas). However, while calculating final sensitivity values higher weightage was given to human sensitivity. Socio economic factors, technology and infrastructure together comprised the adaptive capacity index. The overall vulnerability index was calculated by combining the above three factors. The values of data were standardized using UNDP Human Development Index formula.

Outcome/ outputs achieved

The study identifies provinces/districts in Southeast Asian countries (namely, Thailand, Vietnam, Laos, Cambodia, Indonesia, Malaysia, and the Philippines) most vulnerable to climate change risks and requires urgent policy focus. Since the study provides a very broad perspective of vulnerability in Southeast Asian countries, it is useful for policy-makers and donors in better targeting financial resources towards adaptation measures undertaken in the focus countries.

Application

Geographical scope i.e. spatial resolution –

Regional vulnerability assessment

Study area i.e. national, regional, local or sectoral approach –

Sub-national areas/ units of Southeast Asian countries (Thailand, Vietnam, Laos, Cambodia, Indonesia, Malaysia, and Philippines)

Data collection method i.e. primary and or secondary sources –

Gathered data at province and district levels from various sources

Assumption and Limitation

The main limitation highlighted by the study is the inability to factor in projections of climate change and socio-economic conditions for the future years.

Report: Vulnerability Assessment for Madhya Pradesh and West Bengal, GiZ, New Delhi (Executing Agency – INRM)

Assessment Methodology

The study is focused on generating district level Composite Vulnerability Index (CVI) for Madhya Pradesh. Vulnerability to climate change in Madhya Pradesh has been derived using integrated vulnerability assessment approach. Accordingly socio-economic, environmental, agriculture, water resource, health, climate and forest indicators of vulnerability are employed and classified into adaptive capacity, sensitivity, and exposure. To analyze the data, multivariate statistical method of Principal Component Analysis (PCA) is performed to obtain the component scores. These are used as weight for the indicators before arriving at the indices. The selected indicators explained the differences in vulnerability between districts with good agreement. Districts are ranked based on the composite indices. Further, this index is developed for the current climatic conditions and for future projected climatic conditions, using PRECIS simulated weather parameters for IPCC SRES A1B. Furthermore, cluster analysis is performed on the indices to group the districts according to their degree of vulnerability using Ward Method of Agglomeration. The districts are grouped into low (1), moderate (2), high (3) and very high (4) categories of vulnerability. The outputs are shown spatially using maps.

CVI has been created by standardising indicators across the range of data for districts of MP, not across a normative range with theoretical high and low values of the indicators. Therefore districts which are at the bottom end of the range with "low" scores nearing zero have the highest relative vulnerability.

Outcome/ outputs achieved

The analysis of the pattern of vulnerability of districts in Madhya Pradesh to climate change has shown that generally the north, east, south east and south western districts are more vulnerable to climate change. To help the decision to prioritise the development activities in any chosen district by identifying the sector which makes that district vulnerable makers, attempt is made to present the drill down version of the CVI (Composite Vulnerability Index). The drill down is performed sectorally and Sectoral index for Social (SI), Economic (ECI) individually and combined as Socio-economic Index (SEI), Climate (CLI), Water (WRI), Agriculture (AGI), Forest (FVI), Health (HLI) and these five combined as Environment Index (ENI) have been derived, using the relevant sector/sub-sector for arriving at the individual indices. Similar exercise was carried out for the state of West Bengal.

Application

Geographical scope i.e. spatial resolution –

For the State of Madhya Pradesh and West Bengal

Study area i.e. national, regional, local or sectoral approach –

Both State level (CVI) and Sectoral based indices were produced

Data collection method i.e. primary and or secondary sources –

Based on secondary source of data

Assumption and Limitation

CVI as one overall figure is good for easy comparison for a non-specialist or policy-makers; but there is a trade-off between the component sub-indices when they are viewed in aggregated form.

Report: Climate change vulnerability profiles for North East India, KfW German Development Bank (Executing Agency – IISc)

Assessment Methodology

In this study, an assessment of the overall implications of climate change and vulnerability in the North East for three major sectors, agriculture, water and forest, has been carried out to identify the vulnerable sectors and regions objective is to understand the sector-wise vulnerabilities at the district level so that the targeted policies by development agencies can be designed to improve the most vulnerable sectors.

In the case of the North East, district wise vulnerability profiles are developed in all the eight states, Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. This is a first of its kind study conducted in North East India whereby the local scale of vulnerability assessment is utilized. The coverage of all the 79 districts of all the 8 states is also unique to this study.

The main objectives of the study are to introduce a quantitative approach for assessing the vulnerability of the three key sectors of agriculture, water and forest. This is done by developing a vulnerability index (ranging from 0 to 5) for each of these sectors. Climate change vulnerability profiles are developed at the district level for agriculture, water and forest sectors for the North East region of India for the current and projected future climates. An index-based approach was used where a set of indicators that represent key sectors of vulnerability (agriculture, forest, water) is selected using the statistical technique principal component analysis. The impacts of climate change on key sectors as represented by the changes in the indicators were derived from impact assessment models. These impacted indicators were utilized for the calculation of the future vulnerability to climate change.

Application

Geographical scope i.e. spatial resolution –

Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura.

Study area i.e. national, regional, local or sectoral approach –

For three major sectors of agriculture, water and forest of the States

Data collection method i.e. primary and or secondary sources –

Results indicate that majority of the districts in North East India are subject to climate induced vulnerability currently and in the near future.

Outcome/ outputs achieved

Results indicate that majority of the districts in North East India are subject to climate induced vulnerability currently and in the near future. The report produced vulnerability index for each sector and district level projection.

Assumption and Limitation

In the absence of knowledge on relative importance of different indicators, equal weights were assumed for all the indicators.

Report: Coping with global change vulnerability and adaptation in Indian agriculture, TERI

O'Brien et al., 2004. Mapping vulnerability to multiple stressors: climate change and globalization in India. Global Environmental Change 14, 303 -313.

Assessment Methodology

Unlike the conventional studies which assess vulnerability to climate change in isolation from other stressors this study maps the vulnerability to two stressors at the district level for the country of India. The approach basically is to develop a national vulnerability profile for climate change and a separate national vulnerability profile for an additional stressor followed by superimposing the two profiles to identify the districts in India that are 'double exposed'. Case studies were conducted in selected districts. For assessing the vulnerability to climate change the three major components of exposure, sensitivity and adaptive capacity were considered with few crucial indicators under each of them. For the exposure and sensitivity components a climate sensitivity index was constructed based on past 30 years data followed by the incorporation of projection results from HadRM2 model, a regionally downscaled GCM. For measuring the adaptive capacity, significant biophysical, socio-economic, and technological factors that influence agricultural production were taken. To get the final climate change vulnerability map these three indices were combined. The map represents current vulnerability to future climate change across districts. The vulnerability to globalization considered the structural changes due to trade liberalization. In this case also indicators were taken under the same three components. Finally, The climate and globalization vulnerability maps were combined to identify areas that are vulnerable to both stressors.

Outcome/ outputs achieved

The project identifies vulnerable areas and social groups, and assesses the nature of vulnerability for all districts of India and undertakes village level case studies focusing on the social and economic implications of double exposure to inland and coastal agricultural climate change impacts. The study resulted in better knowledge regarding the vulnerable areas in India, an exploration of how some villages have coped with these issues, and a discussion of the impacts that public policy has had on the vulnerability in the villages studied.

Application

Geographical scope i.e. spatial resolution –

Overall India and five villages across the country as Case Study

Study area i.e. national, regional, local or sectoral approach –

Agricultural vulnerability to two stressors: climate change and economic globalization

Data collection method i.e. primary and or secondary sources –

Data was gathered at two levels. A macro-scale analysis at the district level maps a vulnerability profile for India, showing areas vulnerable to both climate change and economic changes. At the village level, case studies focus on the social and economic implications of double exposure for inland and coastal agricultural areas

Assumption and Limitation

Report: **Framework for Community- Based Climate Vulnerability and Capacity Assessment in Mountain Areas, ICIMOD**

Assessment Methodology

The study has designed an analytical framework and methodology for assessing environmental and socioeconomic changes affecting the livelihoods of rural, natural resource dependent communities living in mountainous environments by applying a gender perspective and paying attention to marginalised social groups (e.g., based on caste or ethnicity). Mainly qualitative methods were used for collecting and analysing data as being community-based assessment. The study considers impacts driven by both climate change (biophysical), and also non-climatic factors such as - environmental, economic, social, demographic, technological, and political factors, that may have beneficial and/or adverse effects on the exposure, sensitivity, and adaptive capacity of communities. The approach also considers the community's inherent capacity to adapt (Füssel and Klein 2006). The framework also provides interview guidelines for focus group discussions and household surveys.

The framework has been tested by ICIMOD in three districts of Uttarakhand namely Tehri Garhwal, Bageshwar, and Almora and the outcome of this case study has been presented as Exhibit 6 in this report.

Outcome/ outputs achieved

- Identified impact of climate change on the conditions of mountain people, and their perception of change, underlying causes of vulnerability and the most vulnerable communities and groups within a community
- Identified existing traditional and innovative coping and adaptation strategies and evaluated whether these strategies are adequate today and for the future in view of actual and expected climatic change
- Recommends how to reduce vulnerability and enhance the adaptive capacity and resilience of mountain communities including relevant institutional mechanisms

Application

Geographical scope i.e. spatial resolution –

Hindu Kush-Himalayan region

Study area i.e. national, regional, local or sectoral approach –

Community based approach

Data collection method i.e. primary and or secondary sources –

Primary and Secondary data sources (literature reviews)

Primary data were collected at the community and household level applying different research methods and tools including participatory rural appraisal (PRA), in-depth household interviews, and focus group discussions (FGDs).

Assumption and Limitation

Requirement of data triangulation, in particular, the perceptions and observations of people on climate change with existing scientific data on climate change (rainfall and temperature patterns, and so forth).

Qualitative analysis and lacks quantification of vulnerability

Restricted to Livelihood vulnerability assessment

Report: **Uttarakhand Action Plan for Climate Change, Government of Uttarakhand**

Assessment Methodology

The report gives an overall implication of climate change on the State of Uttarakhand based on independent studies examining various (and often discrete) aspects of Uttarakhand's vulnerability to climate change. For vulnerability assessment the report has referenced to the findings reported by –

- WWF India's study of the Ganga Basin17 (and includes Uttarakhand),
- The Interim report of the Uttarakhand Centre on Climate Change18 (UCCC), Kumaon University, and
- International Centre for Integrated Mountain Development (ICIMOD) – International Fund for Agricultural Development (IFAD) study

It gives emphasis on the fact that the State is endowed with different physiography – both hills and plains, hence different assessment approach to be applied for detail vulnerability assessment proposed in future. For the purpose of providing an overarching climate response framework at the State Government level, the report has developed flexible sector specific response strategies and actions, while keeping in mind the overall vision of the State. The sectors included are - Agriculture, Irrigation, Forest and Biodiveristy, Livestock and Animal Husbandary, Disaster Management, Human health, Urban Development, Water Resources, Tourism, Energy, Roads, Industries, and Transport.

The report also takes note of the people perception on climate change at the State level through various participatory discussion medium (consultation held during March – April 2012)

Application

Geographical scope i.e. spatial resolution –

At State Level, for the State of Uttarakhand

Study area i.e. national, regional, local or sectoral approach –

Sectoral approach

Data collection method i.e. primary and or secondary sources –

Integrates inputs from various studies and literatures

Outcome/ outputs achieved

Through the UAPCC, the Government of Uttarakhand commits itself to fostering inclusive, sustainable, and climate resilient growth and development of the State. This vision will be achieved through (a) charting a low carbon growth strategy and climate resilient development model; (b) integration of climate concerns into all aspects of development policy and implementation, and (c) ensuring complementarity with and contributing to the national agenda on climate change. These will be supported by the strategies and actions outlined in this UAPCC, and by all other necessary actions by the State Government for the achievement of the vision.

Sectoral budgets based on broad aspects of climate change impacts and vulnerability has been drafted as part of this report.

Assumption and Limitation

Detailed and qualitative assessment of vulnerability to climate change requires to be carried out for the State

Report: Facing the Facts: Ganga Basin's Vulnerability to Climate Change

Mohan, Divya and Sinha, Shirish, 2011. Facing the Facts: Ganga Basin's Vulnerability to Climate Change, WWF- India, retrieved from www.wwfindia.org

Assessment Methodology

This report examines various factors contributing to exposure, sensitivity, adaptive capacity, and vulnerability index. The assessment of vulnerability involves four steps moving from indicators to profiles and eventually to the final vulnerability index. The basic approach for the macro level vulnerability assessment has been in the form of comparative analysis of vulnerability index values for all the districts of Uttar Pradesh and Uttarakhand to identify the most vulnerable areas. The methodology for assessing the vulnerability has been broadly based on its definition which takes it as being a function of three broad factors of exposure, sensitivity and adaptive capacity. The multi-disciplinary indicators covering diverse dimensions of climate, population, ecosystem and socio-economic conditions have been used to analyze vulnerability in this region. The method for assessing the vulnerability of the two states has been selected after reviewing varied methodologies and LVI–IPCC (Livelihoods Vulnerability Index) methodology was found to be most appropriate and replicable and applied after making necessary modifications.

Outcome/ outputs achieved

The output of the study helps in determining critical sectors which might be more vulnerable to climate change. The study indicates the districts of Almora and Garhwal in the State as the least vulnerable despite their high exposure to climate variability and vulnerability. These districts hold some of the most diverse ecosystems of the Indian Himalayas, which are quite sensitive to climate variability. The districts of Rudraprayag and Champawat emerge as moderately vulnerable due to their high sensitivity and their low adaptive capacity. The Uttarkashi district and the Udham Singh Nagar district have very high vulnerability index. This is primarily due to high exposure index. In the case of Udham Singh Nagar district, the dependence on irrigation (surface and groundwater) is very high and this has resulted in high sensitivity values. On the other hand along with high exposure, lack of infrastructure development and high biomass dependency has resulted in low adaptive capacity values for the Uttarkashi district, making it highly vulnerable.

Application

Geographical scope i.e. spatial resolution –

For the State of Uttar Pradesh and Uttarakhand

Study area i.e. national, regional, local or sectoral approach –

83 districts of Uttar Pradesh and Uttarakhand

Data collection method i.e. primary and or secondary sources –

Based on secondary data sources

Assumption and Limitation

- This analysis has been done at a district level due to constraints in data availability at block and village level.
- The methodology gives equal weightage to all the indicators. However, some variables might have more effect in determining vulnerability.
- The data used for climate analysis has been interpolated for the districts using the 1°X1° grid–wise data from India Meteorological Department (IMD) for the year 1995 to 2005 due to unavailability of district level data for the climate parameters.
- As the data for Ganga Basin is classified due to trans-boundary water sharing issues thus limited data were available for surface water flows.

Report: **Vulnerability and Capacity Index (VCI)**

Mustafa D., Ahmed, S., E. Saroch and The Risk to Resilience Study Team, (2008): Pinning down Vulnerability: From Narratives to Numbers, From Risk to Resilience Working Paper No. 2, eds. Moench, M., Caspari, E. & A. Pokheral, ISET, ISET– Nepal and Provention, Kathmandu, Nepal, 28 pp.

Assessment Methodology

This methodology is to assess the vulnerability in disaster and extreme climate risk regions. The VCI comprises of three dimensions of vulnerability – material (income, education), institutional (infrastructure, social capital) and attitudinal (sense of empowerment) with eleven critical drivers of vulnerability under them; and is applicable for measuring differential vulnerability at the household and community level in both rural and urban areas.

The VCI covers the differential dimensions of vulnerability among different social groups and also the households within such groups. The overall weightage distribution for the three categories is 35, 50 and 15% which has been assigned by literature review and expert consultation. The internal weights for the indicators within the dimensions are assigned differently for the household and community level assessments as well as for the rural and urban areas. The values of material, institutional and attitudinal vulnerabilities were combined to get the overall vulnerability of the target group and to make the comparisons with the other target groups for assessing who is more vulnerable.

Outcome/ outputs achieved

The application of this methodology resulted in development of a vulnerability and capacities index which provides a measure of the current factors that drives vulnerability in terms of material, institutional and attitudinal aspects. This can help the policy makers in designing appropriate packages/ programs for reducing the vulnerabilities of the targeted community/ households/ region.

Application

Geographical scope i.e. spatial resolution –

Households in Aalamchak village and Sonatikar village in Eastern Uttar Pradesh; and in coastal villages in Gujrat. Community VCI –Villages in Gujrat (India) and Rawalpindi (Pakistan)

Study area i.e. national, regional, local or sectoral approach –

Vulnerability of communities towards risks and hazards.

Data collection method i.e. primary and or secondary sources –

Household and Community level study using Primary data collection based on Household Survey or focus group discussions.

Assumption and Limitation

The application of methodology would require the use of data entry software like CS Pro and use of statistical packages like SPSS and STATA. The information gathered using PRRA technique will require content analysis using N Vivo/ Atlas Ti software.

Report: Vulnerability Assessment of Freshwater resources

Babel. M.S. and Wahid. S. M. (2008) Freshwater under threat–South Asia. Vulnerability Assessment of Freshwater Resources to Environmental Change. UNEP, South Asia. 29 pp.

Assessment Methodology

The analysis in this study is based on the premise that the vulnerability assessment of a river basin must have a precise understanding of the four major components of the water resource system which are i) total water resources ii) water resources development and use iii) Ecological Health; and, iv) management. Each of these components had indicators under them. A composite vulnerability index was calculated based on these four components. In order to quantify the vulnerability index, the indicators for each component were determined and quantified. The value of vulnerability ranges from 0 to 1.0, with 1.0 indicating the most vulnerable situation. To give the final VI value in a range from 0 to 1.0, the following rules were applied in assigning the weights: (a) the total of weights given to each indicator should equal 1.0; and (b) the total of weights given to all components should equal 1.0. To avoid bias equal weights were assigned among indicator in the same component, as well as among different components.

Outcome/ outputs achieved

Application

Geographical scope i.e. spatial resolution –

Ganges-Brahmaputra – Meghna River Basin, Helmand River Basin and Indus River Basin

Study area i.e. national, regional, local or sectoral approach –

Sectoral approach – Fresh water resources

Data collection method i.e. primary and or secondary sources –

Basin level study using secondary data.

Assumption and Limitation

Report: Protecting Health from Climate Change, Vulnerability and Adaptation Assessment, World Health Organization

Assessment Methodology

The publication from WHO elaborates the Driving Force, Pressure, State, Exposure, Effect, Action (DPSEEA) Framework, designed to provide a hierarchical model to describe the actions of various causes that act, more or less directly, on health outcomes from environmental or related behavioral conditions. It describes the various levels of actions that can be taken to reduce health impacts (Corvalan et al., 2000). The driving forces refer to the key factors that generate the environmental processes involved, such as population growth and economic development. These driving forces result in pressures on the environment. In response, the state of the environment is altered, with changes that may be complex and wide-ranging. These changes in the state of the environment may operate at markedly different geographical scales, from

Application

Geographical scope i.e. spatial resolution –

A guideline document followed by sample assessment

Study area i.e. national, regional, local or sectoral approach –

Sectoral approach – Human health from climate change impacts local to international. Risks to health may occur when people are exposed to these environmental hazards, which can then lead to health effects; these hazards may vary in type, intensity and magnitude.

Outcome/ outputs achieved

Case study of the Hindu Kush–Himalaya regions - A joint WHO/WMO/UNEP/UNDP qualitative assessment was conducted in the Hindu Kush–Himalaya regions (Ebi et al., 2007). Expert judgement was used to determine the extent to which climate-sensitive diseases could be a concern in populations in mountainous and non-mountainous regions of six countries.

Country	Afghanistan	Bangladesh	Bhutan	China	Nepal	India
Heatwaves	M-P	P	–	P	P	P
Flood deaths/morbidity						
Glacial lake floods	M-P	–	M-P	M-P	M-P	M-P
Flash floods	M-P	P	M-P	M-P	M-P	M-P
Riverine floods	P	P	–	P	P	P
Vector-borne disease	P	P	P	P	P	P
Malaria	P	P	P	P	M-P	P
Japanese encephalitis	–	P	–	P	P	P
Kala-azar	P	–	–	–	P	P
Dengue	–	P	P	P	–	P
Waterborne diseases	M-P	P	M-P	M-P	M-P	M-P
Water scarcity, quality	M-P	P	P	M-P	M-P	M-P
Drought-related food insecurity	M-P	P	–	M-P	–	M-P

M-P health determinant or outcome occurs in mountainous and non-mountainous (i.e. plains) areas;
P health determinant or outcome occurs only in non-mountainous areas;
– health determinant or outcome is not present in the country (WHO/SEARO, 2006).

Data collection method – Integrates inputs from various studies and literatures

Assumption and Limitation

Because data limitations can make quantitative assessments difficult, this guidance focuses on qualitative approaches.

Report: **Hydropower Vulnerability and Climate Change - A Framework for Modeling the Future of Global Hydroelectric Resources**

Ben Blackshear, Tom Crocker, Emma Drucker, John Filoon, Jak Knelman, Michaela Skiles (Fall 2011), Middlebury College Environmental Studies Senior Seminar

Assessment Methodology

The framework considers simple interactions between various characteristics of hydropower facility with climate variability that would impact the availability of water resource – the prime raw material for hydro-power production. The characteristics of a hydro-power facility has been defined in terms of – type of flow - (run-off the river, reservoir based and or pumped storage); reservoir size (small, large); and

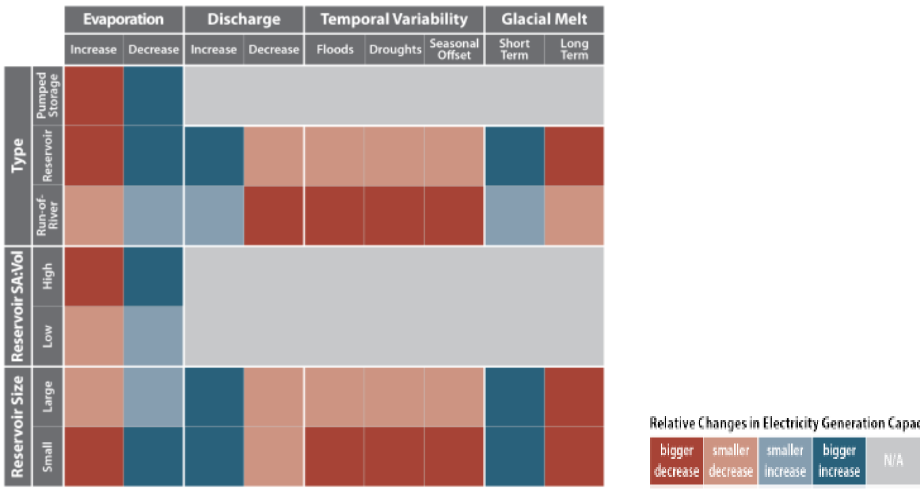
Application

Geographical scope i.e. spatial resolution –

Provides global examples

reservoir capacity in terms of volume. The climate variability has been considered in terms of - rate of evaporation (increase/ decrease); rate of discharge (increase/ decrease); temporal variability of water (due to floods, droughts, seasonal offset) and glacial melt (in short term and long term basis).

The framework produces a simple matrix presented below.



Study area i.e. national, regional, local or sectoral approach –

Global and sectoral approach

Data collection method i.e. primary and or secondary sources –

Integrates inputs from various studies and literatures

Outcome/ outputs achieved

Excerpts from the study identifying climate change impacts and implications for hydropower in Asian Region. Deglaciation in the Himalaya will also cause rapid growth of glacial lakes, which will increase the likelihood of glacial lake outburst floods. These devastating and often unexpected floods could wreak havoc on hydroelectric infrastructure. The deglaciation pattern will deliver water to the rivers in sporadic bursts. Highly variable river flow is not optimal for hydropower, so even though deglaciation will increase the flows at certain periods of time, its variability and unpredictability make hydropower more vulnerable on rivers like the Indus and Ganges which receive over 40 percent of their volume from Himalayan glaciers. While a small select number of glaciers are expanding, the vast majority are rapidly melting. Some smaller rivers are fed exclusively by glacial melt, and could dry up in as few as 50 years. This naturally would affect downstream hydropower.

Assumption and Limitation

Based on literature review. No qualitative and or quantitative approach has been defined.

4. THE REVIEW SUMMARY

4.1 Vulnerability to Climate Change

Most of the literature reviewed for this report has adopted the IPCC definition of Vulnerability [refer to the box for IPCC definition]. It therefore suggests a common agreement that vulnerability of a system is a function of *exposure* to one or more climate-related stressors, *sensitivity* to the effects of the exposure, and the *adaptive capacity* available to prepare for, respond to and recover from those effects. A vulnerability assessment therefore essentially integrates sub-assessments of each of the components of vulnerability: exposure, sensitivity, and adaptive capacity.

VULNERABILITY *(DEF.)* -

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and climate extremes."

Based on the literature reviews, it can also be reasonably concluded that the vulnerability assessments generally focus on two purposes:

- determine what sectors or regions may be most vulnerable - as all studies have either selected a region (spatial resolution – national, regional, state, village or community) or a sector (agriculture, livelihood, forest, energy, tourism) and study area, therefore highlighting vulnerability of the given study area
- what adaptive capacity should be developed to cope with climate change - as outcome of all vulnerability studies identifies the climate change aspect to weakness for which either the system and or the community is vulnerable and therefore, adaptive capacity to transform weakness to strength;

Therefore, a vulnerability assessment can be expected to provide information needed to help make the State/ sector/ community climate-resilient. For instance, results of a vulnerability assessment can help determine which parts of the hilly road network in Uttarakhand may be most vulnerable to projected increases in flash flood, and therefore which routes may minimize the exposure to this hazard. Or a vulnerability assessment can indicate whether particular sub-populations such as women, children, and the elderly require special attention as part of a State/ community program to enhance resiliency.

The results of a vulnerability assessment for the State of Uttarakhand can be used in a variety of ways including:

- Raising awareness of the threats of climate change;
- Determining whether climate change may affect an existing or planned policy, plan, or project;
- Identifying the areas or sectors where adaptation actions are most needed; or,
- Informing the design of new adaptation actions to reduce vulnerability.

Thus, following questions should be considered as the basis for discussion during stakeholder consultation (as next Task to this study – Task C) with an objective to derive and define the goal and the scope of the Vulnerability Assessment, that would be eventually carried out in the next phase (i.e. Phase II).

GUIDING QUESTIONS FOR DESIGNING THE ASSESSMENT

Key considerations to designing the assessment include:

- What are the objectives of the assessment and what level of detail is needed to meet these objectives?
- Who will use results of the assessment for decision-making?
- What information, technical expertise, and other resources are needed?

4.2 Determine Information and Resource Needs

The objectives of the assessment and resources available will dictate the type of information required. This section provides an overview of information and resources applied by different studies that have been reviewed.

4.2.1 Spatial Resolution and extent of the study

Utilizing the right level of detail (i.e., resolution, geographic extent) is important to ensure cost-effective and efficient vulnerability assessments. If the level of detail is not consistent with assessment objectives, the results may not be useful for decision-making, and may overrun budgets. If the objective is to only understand whether there are significant vulnerabilities, then a project screening in the form of a rapid, qualitative assessment may be adequate. For example the study on 'Climate Change vulnerability mapping for South-East Asia', identifies the most vulnerable regions in the light of climate change through a quick assessment and suggest useful for policy-makers and donors in better targeting financial resources towards adaptation measures undertaken in the focus countries. On the other hand, for highly capital intensive infrastructure projects with long lifetimes, such as transportation or hydropower projects, a quantitative and detailed vulnerability assessment may be needed, requiring more granular dataset.

The scope of a vulnerability assessment can vary by geographic coverage (e.g. regional, national, municipal), temporal scale (e.g., 30 yrs, 50 yrs, 100 yrs), and sector coverage (e.g., cross-sectoral, a single sector, or one aspect of a sector). The temporal scale of an assessment should be consistent with the timescale of the decision(s) the assessment will inform. For example, agricultural extension agents are typically asked to assist with decisions on the timescale of weeks to seasons to a few years. For them, a centennial-scale climate assessment is less relevant. In contrast, transportation and urban planners often consider the impacts of their plans over many decades and may require an assessment of impacts over the mid- or end- century.

In some cases, it will be essential to understand the spatial differences in vulnerability. For example, the vulnerability of roads to flash flood is highly dependent on their distance from the course of the mountain river and their elevation. In contrast, a screening-level assessment focused on characterizing the vulnerability of older adults to heat stress may not require any spatial information.

4.2.2 Information Sources

From the review of UAPCC and annual reports by Directorate of Economics and Statistics, Government of Uttarakhand it can be reasonably concluded that some information and data for the assessment will be readily available, but in many cases such as in the sector of health, tourism and energy there will be data gaps or limitations that are important to acknowledge when designing the assessment and reporting assessment results. Where existing data are insufficient to inform the assessment, additional modeling or analyses may be required, suggest IPCC third assessment report.

Based on the review exercise a list of indicators and their associated utility been applied by the studies under review has been collated. The list also identifies the current sources of information available from both publically accessible documents and information provided by different government agencies of the State of Uttarakhand who are capturing such data. For detail on identified indicators, refer to Appendix 1 to this report. In cases where data source has not been identified, it is treated to be a data gap at the present.

4.3 Assessing Exposure

Exposure refers to the nature and degree to which inputs are exposed to significant climatic variations. Conclusions of the various studies suggest that while addressing to the context of exposure following questions should be answered:

GUIDING QUESTIONS FOR ASSESSING EXPOSURE

Key considerations for assessing exposure include the following:

- What are the specific climate stressors to which inputs are exposed?
- What are important non-climate stressors?
- Are there potentially important interactions between climate and non-climate stressors?
- What type of climate information is needed to assess exposure?
- What information is available on non-climate stressors?

4.3.1 Climate related Stressors

As per review of IPCC Assessment Reports, climate stress may arise from natural climate variations from one season or one year to the next or from climate change that persists for a decade to centuries. Direct climate stressors are changes in (long-term) meteorological conditions, including temperature, precipitation, and wind, that are a direct result of human changes to the global atmosphere. Consideration of climate stressors should take into account observations of past variability and change as well as model projections of future conditions. It is also important to consider climatic extremes as well as changes in the averages since climate extremes and their variation over time generally pose more of a threat than changes in average conditions.

4.3.2 Non-climate related Stressors

In some cases, non-climate stressors (e.g., deforestation, overpopulation, or migration) are more problematic than climate-related stressors. For example, the study by ICIMOD on Migration of labour due to climate change (community perception) at Uttarakhand, identifies that hill agriculture has never been very productive in Uttarakhand, and migration has been an integral feature of the hill society. It is felt that in the last decade the further decline in agricultural productivity – for which change in climatic conditions appears to be one of the causes – has been quite detrimental to the interests of the hill farmers and has contributed to outmigration. In some locations flooding may be increasing largely as a result of land use change rather than climate change, requiring more attention to land use management than climate stressors.

Examples of non-climate stressors include:

- **Economic:** Rising prices, Inflation, Economic shocks;
- **Social:** Increasing crime, Population displacement, Population growth, increased urbanization;
- **Physical:** Aging pipelines, poorly maintained sewers, substandard buildings;
- **Political:** Poor governance, Corruption; and,
- **Environmental:** Overconsumption of natural resources, Deforestation, Reduced biodiversity, Pollution

4.3.3 Method of Assessing Exposure

The methods used for assessing exposure will depend on the objective, the type and availability of information being gathered, and resource and time constraints. Most of the studies reviewed suggest participatory discussion with the concerned stakeholders to understand the limits of exposure from past incidence and community perception. This brings in a real lifetime approach to the study and includes peoples' judgment & traditional knowledge into decision making. However, a study of this nature relies to a certain extent on people's subjective perceptions. Several limitations are, therefore, inherent and could affect the validity of the conclusions. Therefore, conclusion from the feedback of the people should also be supported by scientific and theoretical approach, such as in the sector of infrastructure and health.

Some studies such as Climate Vulnerability and Capacity Analysis (CARE) and Community-Based Risk Screening Tool - Adaptation & Livelihoods (CRiSTAL) suggest quantitative exposure mapping as a powerful visual tool for assessing exposure. This method combines map-based locations of inputs and expected hazards. Geographic Information System (GIS) is the primary tool used for these analyses. Limitations to GIS-based analysis include the lack of quantitative data in some places, and constrained assessment budgets with which to conduct the analysis. Refer to Exhibit 5 illustrating Map of climate vulnerability in south Asia produced by CARE based on quantitative indicators and represented using a high – low ranking system[6].

4.4 Assessing Sensitivity

Sensitivity is the degree to which an input is affected, either adversely or beneficially, by climate stressors. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal

[6] http://www.careclimatechange.org/files/reports/CARE_Human_Implications.pdf

flooding due to sea-level rise) (IPCC). Most of the studies have borrowed the concept and suggestive indicators on sensitivity assessment from IPCC. A case study on ‘Mapping vulnerability to multiple stressors: climate change and globalization (TERI) has applied sensitivity components to derive climate sensitivity index based on past 30 years data followed by the incorporation of projection results from HadRM2 model, a regionally downscaled GCM.

The study titled ‘Facing the Facts: Ganga Basin's Vulnerability to Climate Change’, identifies indicators such as change in reserved forest cover, land use pattern for Kharif & Rabi cropping, and groundwater extraction to derive ecosystem sensitivity to climate change, and indicators such as net sown area to total land, yield of all crops, irrigation pattern, ratio of agricultural workers to derive agricultural sensitivity profile of the study areas.

Many studies have also assigned weightage to different components to address the level of sensitivity expressed in terms of severe vulnerability, moderate vulnerability and light vulnerability scales, example, Vulnerability assessment and Enhancing the Adaptive Capacity to Climate Change in Semi –Arid Regions of India.

GUIDING QUESTIONS FOR ASSESSING SENSITIVITY

Key considerations for assessing sensitivity include:

- How are the inputs (exposed elements) affected by historical and current climate variability and change?
- Will the inputs be affected by future climate variability or change?
- What factors influence the sensitivity of the inputs to climate variability and change?
- Are there differences in the sensitivity of inputs in particular sectors of interest?

In the next Task to this study, the above questions should be referred to for discussion, enabling to bring forth the indicators to address sensitivity of the exposed elements as well as the scale at which they are exposed (low, medium, high and or in short-term, medium term and or in long term basis).

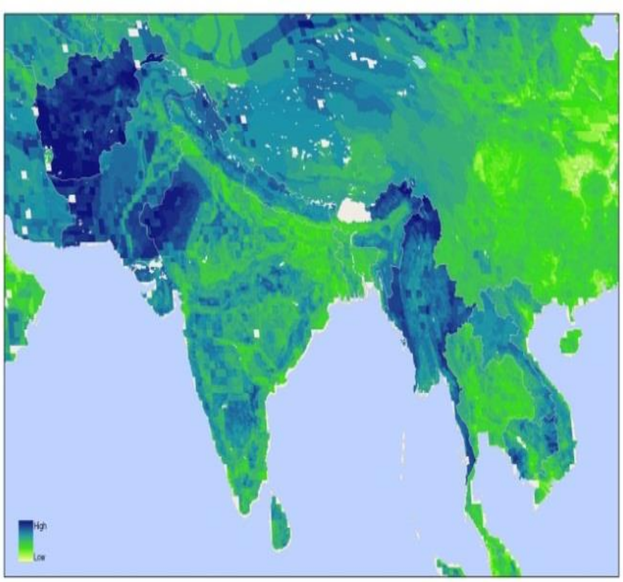


Exhibit 5: Map of climate vulnerability in south Asia produced by CARE based on quantitative indicators and represented using a high – low ranking system

4.5 Assessing Adaptive Capacity

Adaptive capacity, which is the ability of an input to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC). Adaptive capacity is largely determined by available resources and the ability to take advantage of opportunities that may occur because of climatic changes and to take action to cope with climate-related stressors. Inputs with high adaptive capacity are less vulnerable to climate variability and change and are better able to deal with or accommodate climate stressors with minimum disruption or additional cost.

The information gained through reviewing various literatures suggests few broad dimension of adaptive capacity of a given socio-economic system. They are:

- **Social -** Social dimensions of adaptive capacity include things such as social networks, agreements, relationships, and support systems. People with access to appropriate, accurate, and timely information will have greater potential to make better-informed decisions, such as early warning systems.
- **Human -** Human adaptive capacity can include things such as access to education, health services, and similar resources. Those who are more educated are better equipped to use information and financial resources wisely, and are generally better able to respond to climate and non-climate stressors.
- **Financial -** The more financial capital (e.g., access to savings, loans, and insurance) individuals or a community has, the more options people or systems have to respond to climate stressors (Mendelsohn et al. 2006).
- **Institutional -** Those inputs with high institutional capacity have a greater ability to integrate into decision-making and effectively prepare for, respond to, and rebuild after climate-related impacts occur (expert view from INRM)
- **Ecosystem -** Several ecological factors can influence the adaptive capacity of ecosystems
- **Structural -** Certain structural elements can also contribute to adaptive capacity.

Exhibit 6 - A Case Study result of Vulnerability and Capacity Assessment carried out by ICIMOD at three districts of Uttarakhand namely Tehri Garhwal, Bageshwar, and Almora, where the communities are already reacting to the perceived changes in climate.

Coping and adaptation mechanisms implemented by the communities			
Communities' perception of change	**Potential future risks**	**Experienced impacts on livelihood systems**	**Coping and adaptation**
Decrease in rainfall and unpredictable onset of monsoon	Growing food and livelihood insecurity	Overall decline in agricultural productivity	Replacement of rice with finger millet; purchasing rice; barter; improvising with new (cash) crops; delayed sowing
Longer dry spells; in some places drought like conditions	Scarcity of water for drinking and agriculture; increase in health problems; increased workload for women and children; children staying away from school	Drying up of springs; less flow in springs and streams	Irrigation systems opened on a rotational basis; traditional water sharing system in Almora

Coping and adaptation mechanisms implemented by the communities			
Communities' perception of change	**Potential future risks**	**Experienced impacts on livelihood systems**	**Coping and adaptation**
	Crop failure		Delayed sowing time in irrigated fields at the far end of channels
Higher temperatures linked with decreased water availability	Risk of malnutrition; increased drudgery	Lack of fodder; in some places lack of water for animals	Sell off dairy animals; shift to smaller livestock, particularly goats (maladaptation); barter fodder for manure
	Dependence on cash income; food insecurity	Land becoming less productive	Less land area under cultivation; buying food
Warmer winters and significantly less snowfall	Increased food and livelihood insecurity	Increased incidence of pests and diseases, e.g. white grub 'kurmula' attacking roots	Installation of kurmula traps; increased use of insecticides and pesticides; use of ash and salt
	Degradation of orchards; income insecurity	Double flowering of Malta orange and apple trees	No coping strategy

4.6 Determining Vulnerability

A vulnerability assessment should consider that climate change would affect different people in different ways, a concept known as differentiated social vulnerability. Differentiated social vulnerability is often due to underlying social, cultural, and economic factors influencing sensitivity or adaptive capacity[7].

A single sector vulnerability assessment will need to take into consideration potential cascading impacts on other sectors in order to identify related systemic vulnerabilities and/or adaptation strategies. Changes in the timing of seasonal glacial melt, for example, may impact water availability, with implications for agricultural production, sanitation services, and energy production, among others (ICIMOD).

GUIDING QUESTIONS FOR DETERMINING VULNERABILITY

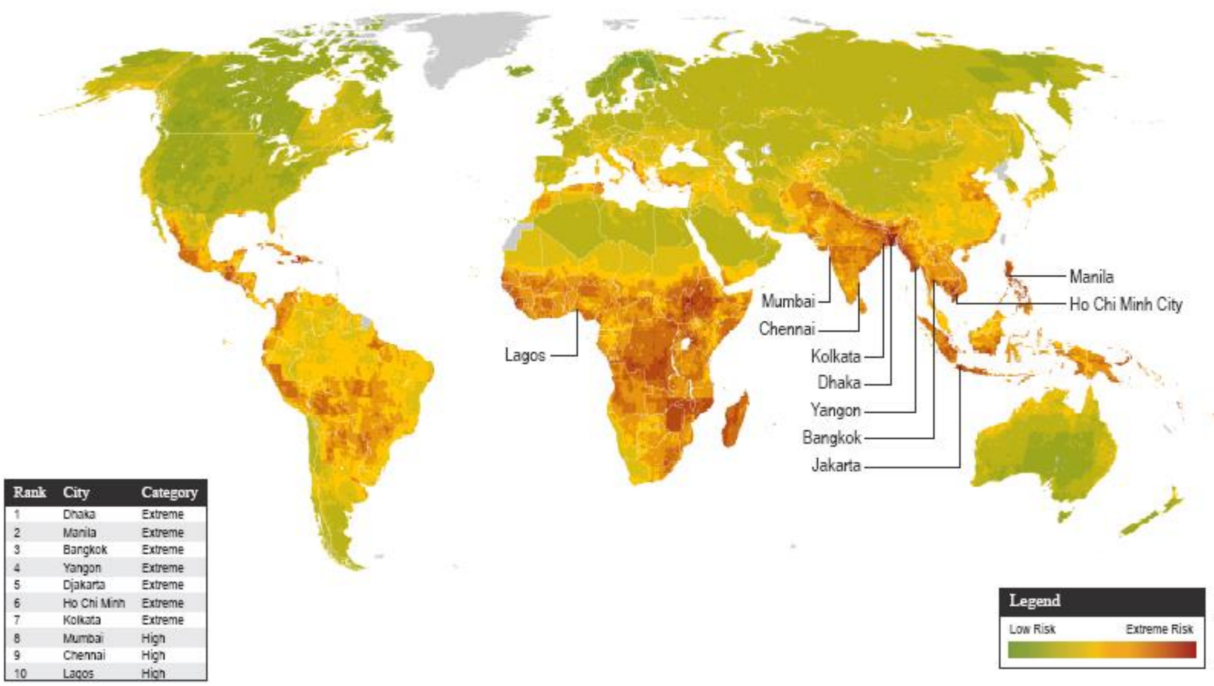
- What qualitative and quantitative methods and tools are available for determining vulnerability?
- What are some of the advantages and disadvantages of the different methods/tools?
- How do different social groups affected by the development initiative differ in their vulnerability?
- Are there other factors that could cause vulnerability to vary?

[7] For more information about differentiated vulnerabilities see the Annex on Disadvantaged Populations: A Guide to Identifying and Addressing Vulnerability to Climate Change.

4.6.1 Vulnerability Ranking

Many vulnerability assessments identify the most vulnerable systems through a ranking or prioritization scheme. The types of ranking systems include categorical (e.g., high/medium/low), or numerical rankings of vulnerability creating a new index. Although a number of vulnerability indices have been developed by the climate community, there is no clear consensus about their use because of issues associated with the selection; care should be taken when selecting vulnerability indices to ensure their appropriate use. Exhibit 7 illustrates Climate Change Vulnerability Index (CCVI) for Indian cities, released by global risks advisory firm Maplecroft in the category of Low to Extreme Risk.

Exhibit 7 - Climate Change Vulnerability Index (CCVI) for Indian cities



Rank	City	Category
1	Dhaka	Extreme
2	Manila	Extreme
3	Bangkok	Extreme
4	Yangon	Extreme
5	Djakarta	Extreme
6	Ho Chi Minh	Extreme
7	Kolkata	Extreme
8	Mumbai	High
9	Chennai	High
10	Lagos	High

4.6.2 Vulnerability Indices

A vulnerability index typically involves an equation that measures vulnerability based on a quantitative analysis of indicators, ranging from simple equation as Exhibit 8 to as complex as Exhibit 9.

Exhibit 8 – Livelihood Vulnerability Index equation - LVI - IPCC

$$Livelihood\ Vulnerability\ Index\ = (Exposure\ - Adaptive\ Capacity) \times Sensitivity$$

The Scaling of the LVI was done from -1 to +1 indicating low to high vulnerability.

Exhibit 9 – Vulnerability Index equation - Mapping South African Farming Sector Vulnerability to Climate Change and Variability

$$V_j = \sum_{i=1}^{k} [b_i \ (a_{ji} - x_i)] / S_i$$

Where:

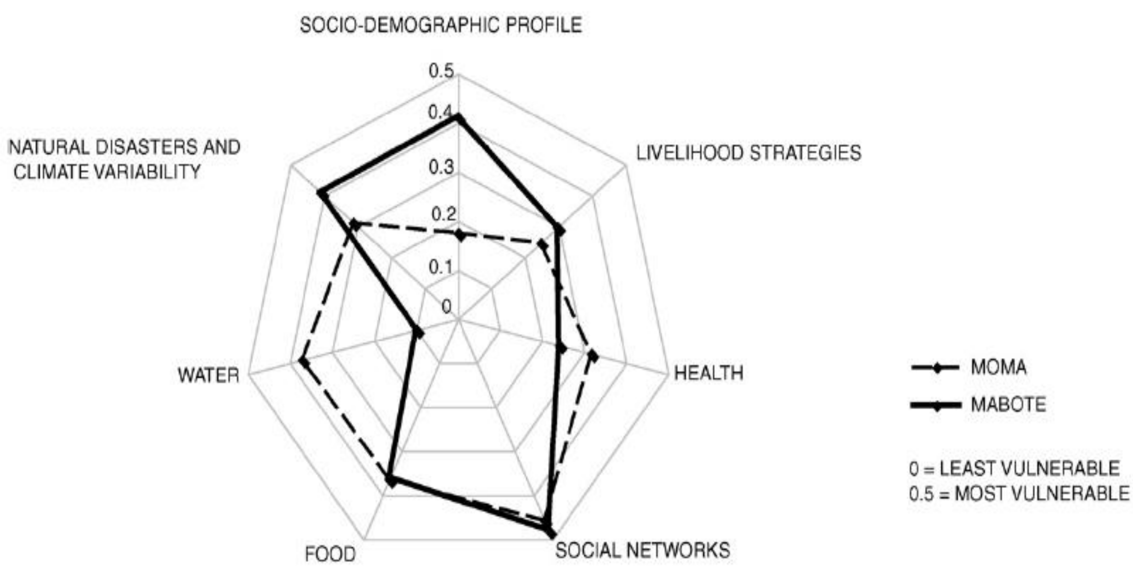
- v is the vulnerability index,
- b is the weight from component analysis,
- a is the indicator value,
- x is the mean indicator value, and
- S is the standard deviation of the indicators.

A prioritization system is particularly useful when an assessment is intended to identify the most vulnerable systems and/or if resources are limited. Priorities can be identified by employing a screening process, whereby the results of the assessment only identify those systems that are highly exposed and sensitive, and have low adaptive capacity. It is also possible to identify or test prioritizations through stakeholder engagement. Overall, it is important for a prioritization process to reflect the needs of decision-makers.

Vulnerability Profile

A vulnerability profile is a way to summarize the vulnerability of different exposure elements in a written summary or represented visually such as pentagrams or radar charts. In a radar plot, the dimensions of vulnerability are represented by the spokes of the plot. An indicator with a high score (higher vulnerability) is plotted further away from the center (see Exhibit 10).

Exhibit 10 - Vulnerability spider diagram of the major components of the Livelihood Vulnerability Index (LVI) for Moma and Mabote Districts, Mozambique



5. CONCLUSION

The science of vulnerability and assessment methods is not new. Progress towards a comprehensive, empirical understanding of vulnerability inputs and processes, has grown in breadth and depth since IPCC coined the key definitions. In addition to this growing understanding of the drivers and dynamics of climate change impacts, it is realized that there is huge difference in "theoretical" construct of an assessment framework that is practically implementable and brings forth useful outcome that can actually be fed into decision making process.

While there are a myriad of approaches to understanding vulnerability, assessing vulnerability and conducting empirically-based assessments, producing vulnerability indices/ indexes is a complex subject and includes many dynamism. The dynamic inter-relationships between inputs of exposure, sensitivity and adaptive capacity demands need for evidence-based science to support policy decisions. Thus, the development of a robust vulnerability framework, providing insight to both bio-physical parameters and socio-demographic characteristics of a system/ area/ community is of utmost importance. This literature review provides a baseline from which a comprehensive understanding of vulnerability assessment can be rooted. While it is not comprehensive inventory of all peer reviewed literature on the subject, it does include the seminal works within the field of vulnerability assessment relevant for the State of Uttarakhand and presents the main theories, concepts (IPCC) and applications related to identifying, quantifying, analyzing, and displaying vulnerability to climate change impacts.

In the next task (Task – C – Stakeholder Consultation) the team will use this baseline to further define a methodology in consultation with stakeholders taking into account the constraints and limitations.

Appendix 1

List of Indicators (Exposure/ Vulnerability/ Capacity) Identified by various study for Vulnerability Assessment				
Sector	**Indicators**	**Unit**	**Source**	**Reports**
Social	Density of Population	Persons/Sq Km	Census of India	TERI, Vulnerability in Agriculture
Social	Sex-ratio	Number of females/1000 males	Census of India	WWF report
Social	Literacy Rate	Percentage	Census of India	TERI, Vulnerability in Agriculture, WWF report
Social	Proportion of Child Population In The Age Group 0-6	Percentage	Census of India	WWF report
Social	Decadal Population Growth	Percentage	Census of India (determined based on two time series)	WWF report
Social	Proportion of elderly population aged 65 and above	Percentage	Census of India	
Social	Percentage of population with disability	Percentage	Directorate of Economics and Statistics	
Social	Percentage of People Below Poverty Line	Percentage	Ministry of Social Justice 2003-2004 data	WWF report
Social	Percentage of Households With Access To Safe Drinking Water	Percentage	Census of India	WWF report
Social	Percentage of Households With Access To Sanitation Facilities	Percentage	Census of India	
Social	Percentage of Households With Access To Electricity	Percentage	Planning Atlas, State Planning Board, GoUk	WWF report
Social	Number of Slum Dwellers Per Slum	Number of Persons		

Sector	Indicators	Unit	Source	Reports
Social	Percentage of Households owning Radio, Transistor, Television and Telephones	Percentage	GoUk, Departmemt of Communication and Technology	
Social	Percentage Share of Marginal Workers	Percentage	Census of India	
Social	Road density	km of paved road per 1000 sq. km of land area	Directorate of Economics and Statistics GoUk	WWF report
Social	Population Serverd per Health Centre (Community, Primary and Sub Health Centres)	Number of Persons	State HDR	WWF report
Social	Number of bed per health center per geographic area	Bed/100 person	State HDR	WWF report
Social	Number of Primary, Middle, High and Higher Secondary Educational Institutions Per Lakh of Population	Number/Lakh of population	State HDR	WWF report
Social	Level of urbanization	Percentage	Directorate of Economics and Statistics GoUk	TERI report
Social	Percentage of Schedule Tribes population	Percentage	Directorate of Economics and Statistics GoUk	ICIMOD CBA Study
Social	Percentage of Schedule Caste population	Percentage	Directorate of Economics and Statistics GoUk	
Social	Percentage of households having a permanent housing structure	Percentage	Directorate of Economics and Statistics GoUk	
Economic	Per Capita Income At Current Prices	Rupees	Economic Survey of Uk, 2010-11	
Economic	Net District Domestic Product At Current Prices	In Lakh Rs	Economic Survey of Uk, 2010-11	
Economic	Scheduled commercial banks per lakhs of population	Number	Planning Atlas, State Planning Board, GoUk	
Economic	Agricultural credit societies per lakhs of population	Number	Planning Atlas, State Planning Board, GoUk	

Sector	Indicators	Unit	Source	Reports
Economic	Loan disbursed by agricultural credit societies per cultivator	Rupees	Planning Atlas, State Planning Board, GoUk	
Agriculture	District under influence of topography (plains/ hills)	Location/ percentage	GoUk	UAPCC
Agriculture	Net Swon Area to total area	Percentage	Directorate of Economics and Statistics	UAPCC, TERI,
Agriculture	Percentage of Net Irrigated Area To Geographical Area By Ground Water	Percentage	Directorate of Economics and Statistics	
Agriculture	Percentage of Net Irrigated Area To Geographical Area By Surface Water	Percentage	Directorate of Economics and Statistics	TERI, Vulnerability in Agriculture
Agriculture	Percetage of area under rain-fed cultivation	Percentage	Directorate of Economics and Statistics	UAPCC
Agriculture	Fertilizer Consumption	Kg/ha/yr	Directorate of Economics and Statistics	UAPCC
Agriculture	Yield of All Crops	Kg/ha	Department of Agriculture, GoUk	UAPCC
Agriculture	Percentage of Land Holdings below 1 Hectare	Percentage	Directorate of Economics and Statistics	UAPCC
Agriculture	Percentage Share of Agricultural And Cultivators Main Workers	Percentage	Census of India	TERI, Vulnerability in Agriculture
Agriculture	Percentage of Bio-Farming villages in total villages	Percentage	Department of Agriculture, GoUk	UAPCC
Agriculture	Electrified pumpsets per thousand hectares of gross cropped area	Numbers	Planning Atlas, State Planning Department	
Agriculture	Crop diversity (number of crops grown)	Numbers	Department of Agriculture, GoUk	UAPCC
Agriculture	Cropping intensity	Times	Department of Agriculture, GoUk	UAPCC
Agriculture	Soil Quality (soil moisture retention capacity)	vol/ vol		TERI

Sector	Indicators	Unit	Source	Reports
Agriculture	Crop Water Stress(Evapo-transpiration/Potential Evapo-transpiration)	mm	IIT Delhi, MoEF (NATCOM), Central Ground Water Board, Ministry of Water Resources, Government, of India.	Ganga Basin, VA, WWF, TERI
Livestock	Livestock Population	Numbers per household/ Numbers per capita	Administrative Reports of Department of Animal Husbandry, GoUk	UAPCC
Livestock	Poultry Population	kg /capita/ yr	Administrative Reports of Department of Animal Husbandry, GoUk	UAPCC
Livestock	Milk production per capita	gms/day	Administrative Reports of Department of Animal Husbandry, GoUk	UAPCC
Livestock	Egg Production per capita	Numbers per capita/ yr	Administrative Reports of Department of Animal Husbandry, GoUk	UAPCC
Livestock	Fish production per capita	kg /capita/ yr	Administrative Reports of Department of Animal Husbandry, GoUk	UAPCC
Forest and Biodiversity	Percentage of High Density Forest area to geographical area	Percentage	Forest Survey of India, Forest Research Institute of Dehradun	
Forest and Biodiversity	Percentage of Medium Density Forest area to geographical area	Percentage	Forest Survey of India, Forest Research Institute of Dehradun	
Forest and Biodiversity	Percentage of Low Density Forest area to geographical area	Percentage	Forest Survey of India, Forest Research Institute of Dehradun	
Forest and Biodiversity	Area under the control of Government of the total forest area	Percentage	GoUk	UAPCC
Forest and Biodiversity	% of land under agro-forestry	Percentage	GoUk	UAPCC

Sector	Indicators	Unit	Source	Reports
Forest and Biodiversity	Number of endangered species (flora)	Numbers	GoUk	UAPCC
Forest and Biodiversity	Number of endangered species (fauna)	Numbers	GoUk	UAPCC
Forest and Biodiversity	Incidence of Forest Fires	Numbers in time series	GoUk, Forest Research Institute of Dehradun	UAPCC
Forest and Biodiversity	Pest outburst (bark temperature)			CIFOR
Forest and Biodiversity	Number of JFM Communities	Numbers	Forest Department, GoUk	
Forest and Biodiversity	Non Timber Forest Produce Diversity(no of varieties)	Numbers	Forest Department, GoUk	TERI
Forest and Biodiversity	Female work Participation Rate	Number	Forest Department, GoUk	UAPCC
Forest and Biodiversity	Percentage of wasteland to geographical area	Percentage	Commissioner Land records	
Forest and Biodiversity	Altitudunal and latitudinal shift of species			Managing Forest for Climate Change, FAO, 2010
Forest and Biodiversity	Surface Water Availability in Forest Areas			Managing Forest for Climate Change, FAO, 2010
Forest and Biodiversity	Extreame events (glacial lake outburst, floods)			Managing Forest for Climate Change, FAO, 2010
Water Resource	Surface Water Availability	mm	IIT Delhi, MoEF (NATCOM), Central Ground Water Board, Ministry of Water Resources, Government, of India.	Ganga Basin, VA, WWF
Water Resource	Ground Water recharge/Availability	mm	IIT Delhi, MoEF (NATCOM), Central Ground Water Board, Ministry of Water Resources, Government, of India.	Ganga Basin, VA, WWF

Sector	Indicators	Unit	Source	Reports
Water Resource	Ground Water quality problem			
Energy	Evaporation lossess from reservoirs	mm/ m2/day		USA, Energy vulnearbility
Tourism	Loss or degradation of natural scenic beauty			
Climate	Cool nights- days when minimum temperature < 10th Percentile	Percentage	Analysis of PRECIS climate data (IITM, Pune)	
Climate	Warm nights- days when minimum temperature > 90th Percentile	Percentage	Analysis of PRECIS climate data (IITM, Pune)	
Climate	Cool Days - Cool nights- days when maximum temperature < 10th Percentile	Percentage	Analysis of PRECIS climate data (IITM, Pune)	
Climate	Warm Days - Cool nights- days when maximum temperature > 90th Percentile	Percentage	Analysis of PRECIS climate data (IITM, Pune)	
Climate	Frost Days (Annual count when TN(daily minimum)<0ºC)	Number of Days	Analysis of PRECIS climate data (IITM, Pune)	
Climate	Warm Spell Duration Indicator (Annual count of days with at least 6 consecutive days when maximum temperature>90th percentile)	Number of Days	Analysis of PRECIS climate data (IITM, Pune)	
Climate	Average annual rainfall	mm	Analysis of PRECIS climate data (IITM, Pune)	
Climate	No. of Rainy Days	Number of Days	Analysis of PRECIS climate data (IITM, Pune)	
Climate	Extremely Wet Days-Annual total rainfall when rainfall>99th percentile	mm	Analysis of PRECIS climate data (IITM, Pune)	
Climate	Consecutive Dry Days-maximum number of Consecutive Days With Rainfall Less Than 1 mm	Number of Days	Analysis of PRECIS climate data (IITM, Pune)	
Climate	Frequency of Drought	Number of weeks	IIT Delhi, MoEF (NATCOM)	
Climate	Flood discharge	cumecs	IIT Delhi, MoEF (NATCOM)	

Sector	Indicators	Unit	Source	Reports
Climate	Percentage of People Having Diarrhoea	Percentage	Department of Health & Family Welfare, Government of Uttarakhand	
Climate	Index of Malaria	Number of reported cases/Population		
	Number of days that exceed the temperature humidity index threshold			

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