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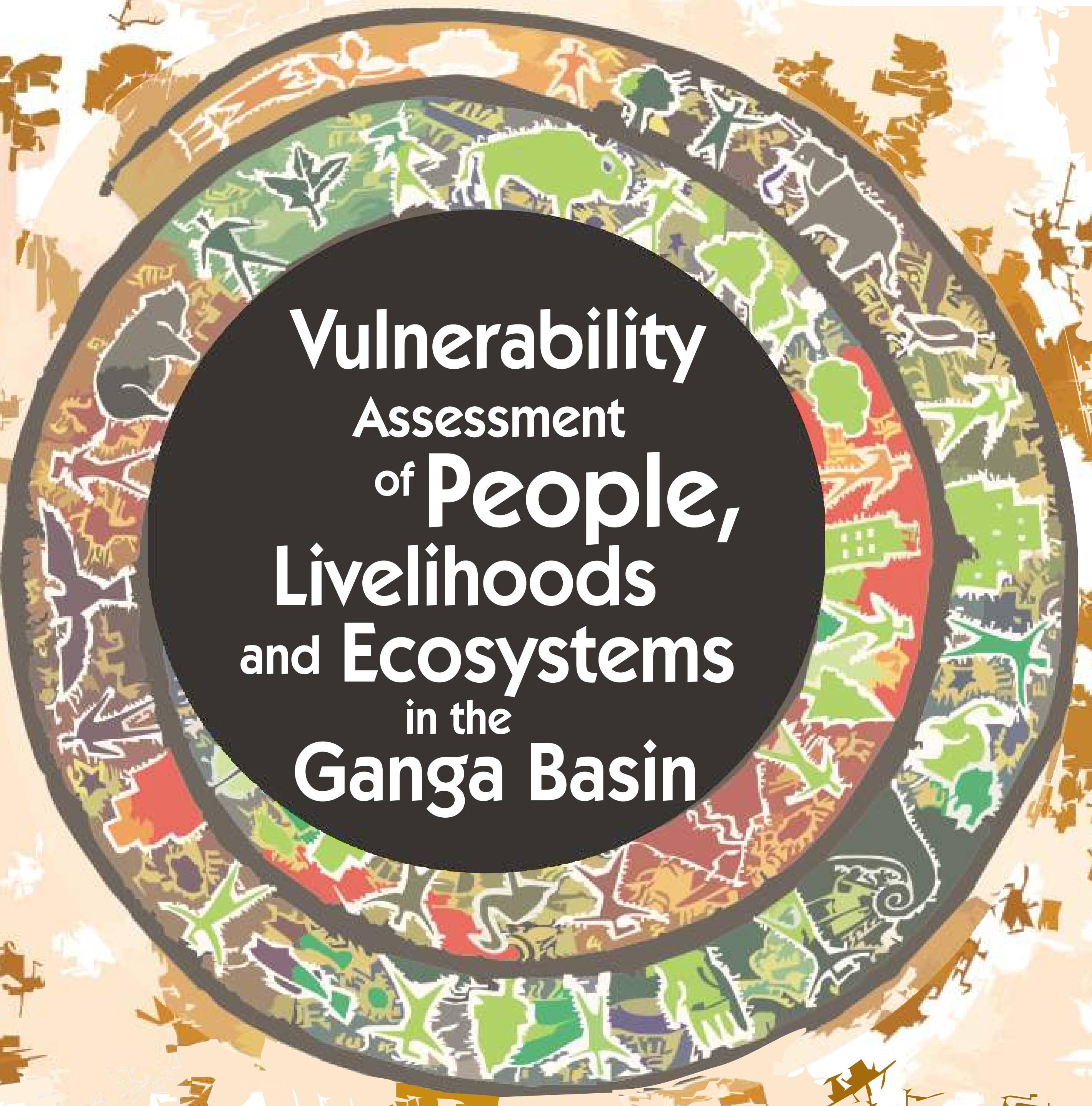

Vulnerability Assessment of People, Livelihoods and Ecosystems in the Ganga Basin

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1. BACKGROUND

Climate Adaptation is an integral component of WWF-India's Living Ganga Programme under the HSBC Climate Partnership. The Living Ganga programme aims to develop and implement strategies for sustainable energy and water resource development within the Ganga Basin, given climate change implications.

The objective of the Climate Adaptation component is to assess the vulnerability of people, livelihoods and ecosystems with the purpose of identifying relevant adaptation response mechanisms, in a critical stretch of the Ganga Basin extending from Gangotri to Kanpur. This summary document presents the analysis of a macro level vulnerability assessment, based on secondary data, and has been used to identify highly vulnerable districts for further assessment and implementation of pilot adaptation projects.

2. VULNERABILITY ASSESSMENT

Vulnerability implies the susceptibility to damage or injury due to any negative impact. In the perspective of climate change, vulnerability simply refers to the probability of being negatively affected by the variability in climate, including extreme climate events. Due to the intricate interactions between diverse components of the natural system along with human interventions, assessing vulnerability becomes a complicated job. Nevertheless, Vulnerability Assessment is significant as it is an important method in developing policies and adaptation plans for specific vulnerable groups and areas. It thereby forms the basis for establishing response mechanisms towards climate change risk reduction.

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability to climate change as a function of three factors:

i) the types and magnitude of **exposure** to climate change impacts,
ii) the **sensitivity** of the target system to a given amount of exposure, and
iii) the coping or **adaptive capacity** of the target system.

Exposure reflects factors external to the system of interest, such as changes in climate variability including extreme weather events or the rate of shifts in mean climate conditions. Sensitivity and adaptive capacity reflect internal qualities, resilience and coping characteristics of the system of interest. The adaptive capacity of a community depends on a combination of economic, social and technological factors such as extent of infrastructure development and distribution of resources. Depending on the system and regional differentials, these factors are quite dynamic and vary considerably. In some cases high levels of exposure are observed but they might be negated by high adaptive capacity thus resulting in lower vulnerability values. Developing countries owing to their comparatively lower adaptive capacity are considered to be inherently more vulnerable to climate change.

IPCC Definitions of some key terms [1]:

Vulnerability
Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Sensitivity
Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change. 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 flooding due to sea-level rise).

Adaptive Capacity
The ability of a system to adjust to climate change (including climate variability and weather extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

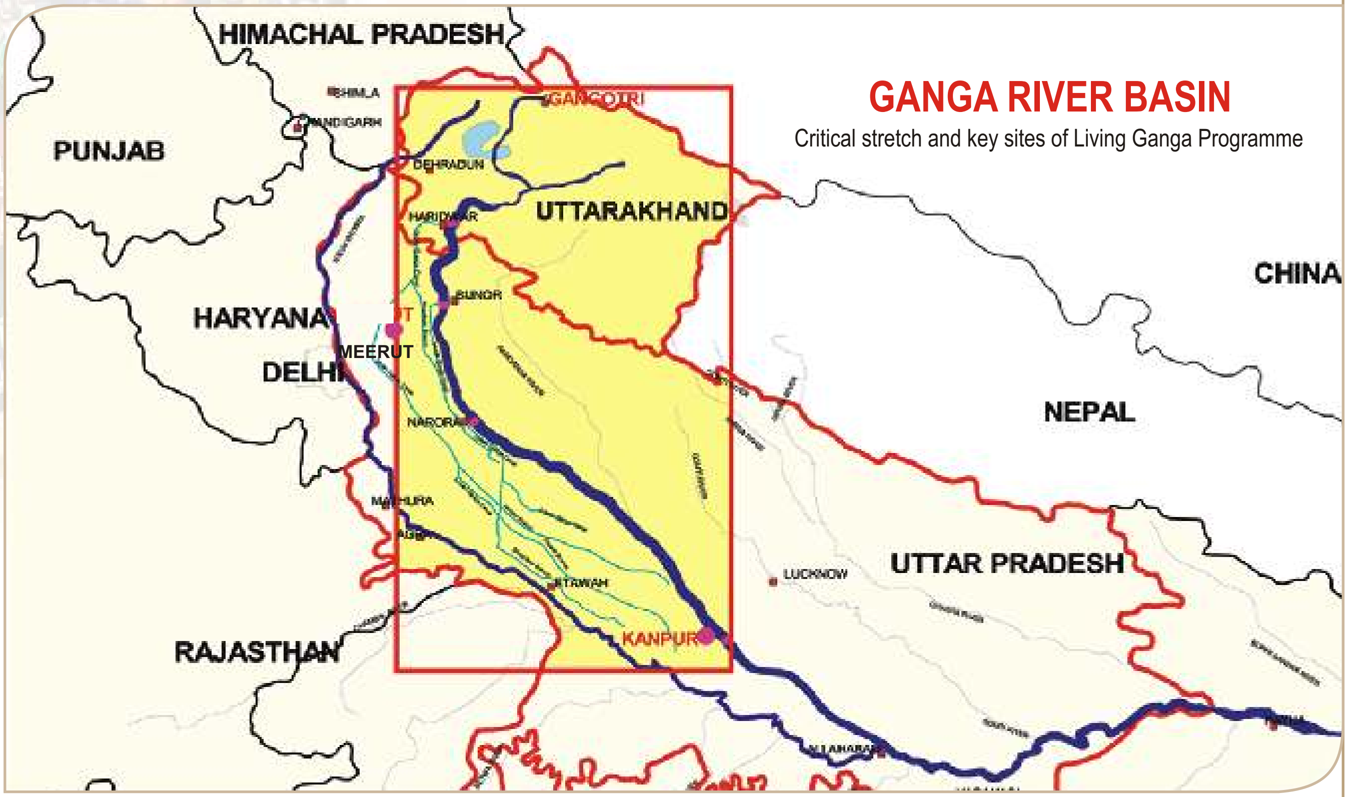
Assessment of vulnerability to climate change mainly involves research into the exposure, sensitivity and adaptive capacity levels of a system in the presence of a specific impact, for example, rising frequency of floods. Vulnerability is a dynamic concept, as exposure to climate change and the capacity to cope with those impacts shifts across temporal and spatial scales. The governing factors of vulnerability assessment studies mainly include scale of assessment; the kind of impact or hazard being considered; and the target group or system being assessed.

3. STUDY AREA

The states of Uttar Pradesh and Uttarakhand have been chosen as the study area within the Ganga basin. The Ganga river basin is one of the most densely populated and fertile basins in the the world. The basin supports about 300 million people over an area of approximately 800,00 sq. km of which some 100 million are directly dependent on the river and its tributaries.

The basic approach for the macro level study has been to compare the vulnerability index values for all the districts of these two states and identify the most vulnerable districts. The results of this study are expected to act as inputs for a detailed vulnerability assessment and build adaptation pilots.

[1] **Source:** IPCC, 2007; Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry. M.L., et al., Eds., Cambridge University Press, Cambridge, UK, 976 pp.



4. METHODOLOGY

Assessing vulnerability to climate change has several approaches and various methodologies have been used for such studies across the world. A review of these methodologies indicates that the scale of assessment is an important determinant of the kind of data collection required. Usually for micro level studies primary data is collected, and for macro level studies an analysis of broader scale indicators is done using secondary data.

After a detailed study of existing methods, LVI-IPCC (Livelihoods Vulnerability Index) methodology was found to be most appropriate and was applied in this study after suitable modification. This methodology has been used in the case of 'The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change - A case study in Mozambique'[2]

The methodology places multiple indicators under the broad umbrella of three factors which define vulnerability – exposure, sensitivity and adaptive capacity. Table 1 shows the indicators and the broad structure chosen for this study.

[2]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 Environ. Change (2009), doi:10.1016/j.gloenvcha.2008.11.002

Table 1 - Indicators for Vulnerability Assessment

Component	Input		Output
	Profile	Indicators	
	Climate	Average Temperature Rainfall	1.Climate Profile
Exposure	Demographics	Sex Ratio Population in the age group 0-6 Decadal Population Growth Below Poverty Line (BPL) Population	2. Demographic profile
Sensitivity	Ecosystem	Change in forest cover Land use pattern (*Kharif* & *Rabi)* Groundwater extraction	3. Ecosystem Profile
	Agriculture	Crop Production Land Capability Irrigation pattern Ratio of agricultural workers	4. Agriculture profile
Adaptive Capacity	Socio–Economic structure	Livestock population density Literacy rate Access to basic amenities (Drinking water, electricity, *pucca* houses) Biomass Dependency Infrastructure (Educational, Health, Banking and Communication facilities)	5. Socio-Economic Profile

The assessment of vulnerability involves four steps moving from indicators to profiles and ultimately to the final vulnerability index. The data for the indicators was normalized to bring consistency using the Human Development Index formula. For each profile a value was obtained by combining the data for the indicators under it. Based on the combination of the normalized values for each indicator the five outputs (***Climate, Demographic, Agriculture, Ecosystem and Socio-economic Profiles)*** were obtained. The profile values in turn were used as inputs for calculating the values for the three components: **Exposure, Sensitivity** and **Adaptive Capacity**. The vulnerability index for the region has been calculated by combining the values of these components. Box 1 summarizes the methodology which has been used for calculating the vulnerability index. The analysis presented in this report is based on the available secondary data and accordingly the results obtained are only for the purpose of getting insights on Vulnerability rather than drawing any strong conclusions on changes in the respective climate and non-climatic stressors.

Box 1 : Steps to calculate the vulnerability index

The steps can be broadly summarized as:

Step 1: Indicators

- Values for all the indicators are to be standardized for all the districts.
- Indicator Index **(Ix)** = $\frac{I_d - I(min)}{I(max) - I(min)}$

Where, **Ix** = Standardized value for the indicator

I_d = Value for the Indicator I for a particular district, d.

I (min) = Minimum Value for the indicator across all the districts

I (max) = Maximum Value for the indicator across all the districts

Step 2: Profiles

- Indicator Index Values are combined to get the values for the profiles
- Profile **(P)** = $\frac{\sum_{i=1}^{n} \text{Indicator Index}_i}{n}$

where, **n** – no. of indicators in the profile

Indicator Index **i** – Index of the i th indicator.

Step 3: Components

- Values of the profiles under a component are to be combined to get the value for that component.
- Component **(C)** = $\frac{\sum_{i=1}^{n} W_{Pi} P_i}{\sum_{i=1}^{n} W_{Pi}}$

where, **W_{Pi}** is the weightage of the Profile **i**

- Weightage of the profile will depend on the no. of indicators under it such that ***within a profile each indicator has equal weightage***.

Step 4: Vulnerability Index

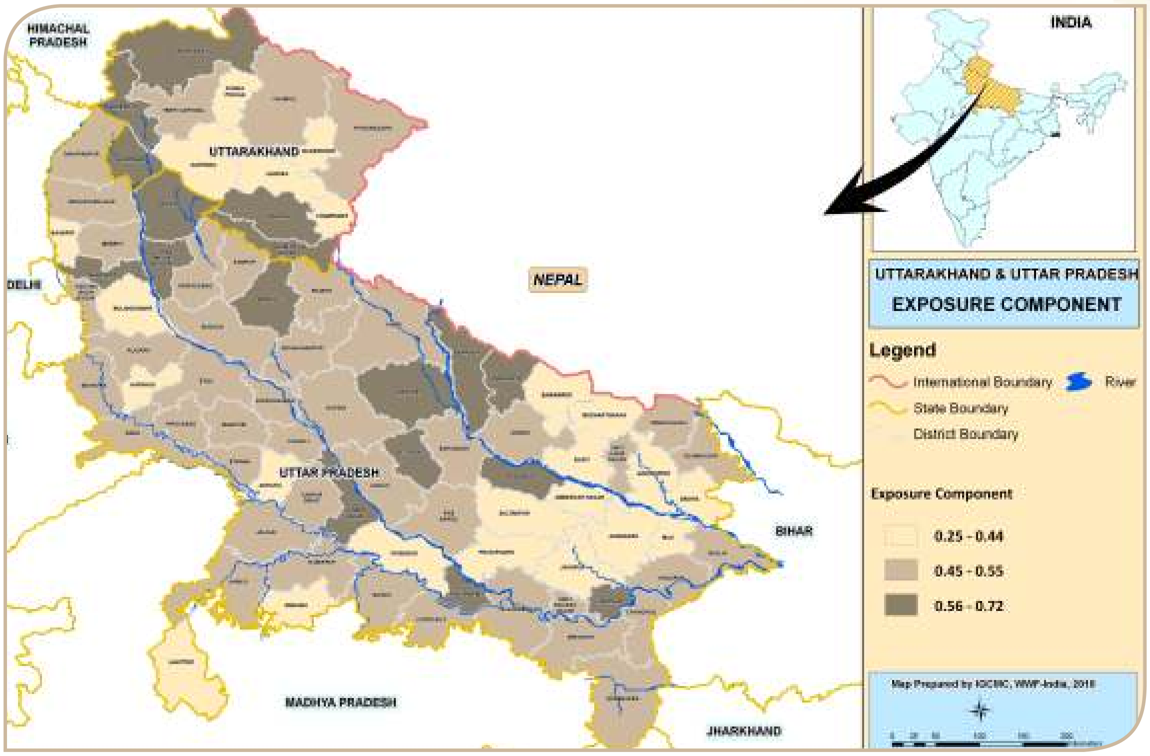
- The combination of the values of the three components will give the vulnerability Index.
- Vulnerability Index = (Exposure – Adaptive Capacity) x Sensitivity
- Scaling is done from -1 to +1 indicating low to high vulnerability.

5. VULNERABILITY ASSESSMENT - AN ANALYSIS

5.1 EXPOSURE

Exposure

The exposure component encompasses two broad elements – aspects of the system of interest that are likely to be affected by climate change and the changes in the climate itself. This statement forms the rationale of having two profiles–Climate and Demographic-under this component. The Demographic profile includes trends of population growth, gender inequality, population



below the age of six, and the Below Poverty Line (BPL) population. This profile shows what is at risk in view of exposure to climate change. The climate profile takes into account the change in the climate parameters. For the purpose of analysis the values were divided into three categories – low, medium and high.

The final values for the exposure levels of the districts show that almost 50 % of the districts are moderately exposed. In case of Uttarakhand these include the hilly districts of Tehri Garhwal and Pithoragarh whereas in Uttar Pradesh this category of districts are mainly placed in the central region . A combination of moderate variation in climate and medium values of demographic profile are the probable causes for these districts being moderately exposed. About 20 % of the districts in the study area are found to be highly exposed to changes in the climate. Remarkably, many of these districts such as Dehradun, Haridwar, Ghaziabad, Lucknow and Kanpur Nagar are the predominant urban districts of Uttarakhand and Uttar Pradesh. Higher values of demographic profile due to rapid population growth, lower sex ratio, and high density of population below the age of six are the prime reasons of these districts being highly exposed. Some other districts have experienced higher levels of change in temperature and precipitation. These include the districts of Uttarkashi, Bijnor, Bareilly, Faizabad and Jyotiba Phule Nagar. The districts which are found to be less exposed to climate change are primarily found to be located in the Eastern parts of UP as well as Uttarakhand. Higher sex ratio along with relatively lower level of urbanization and population growth are the pushing factors for the districts such as Rudraprayag, Garhwal, Bageshwar, Almora, along with Azamgarh, Mau, Deoria and Gorakhpur in Eastern UP being classified under this category. However, being placed in this category doesn't imply that these districts are not vulnerable to climate change; it just indicates their relative vulnerability when compared with other districts.

Climate Profile Analysis

The climate profile analyzes the changes in two important indicators of climate- temperature and rainfall. The yearly average calculated using daily gridded (1°X1°) temperature and rainfall data obtained from India Meteorological Department has been used for this analysis. The moving average method has been used to capture the year-to-year changes from 1995 to 2005 in the two parameters. A t-test, carried out to test the significance of the change in the temperature and amount of rainfall over the period 1995-2005, found the results to be statistically significant for a majority of the districts. It can be said that for UP and Uttarakhand, the average rainfall and temperature over our analysis period corresponds to the overall trend. For the deviations, it can be said that those districts are influenced by local changes. However, the changes that occur in respect to shifts in time for the rainfall across the districts are statistically valid.

The average yearly temperature data for the districts of Uttar Pradesh shows that majority of the districts have observed an increasing trend. Greater increase has been observed in Western UP as compared to the rest of the state. All the districts of Uttarakhand except Champawat have also shown a rising temperature trend with more increase in the Garhwal region as compared to the Kumaon region. Also, the decadal average temperature trend shows that regions at higher altitudes observed a greater rise in temperature.

The data for rainfall does not highlight any significant changes. However, there are some trends of minor, non-statistically significant declines. In case of Uttarakhand, rainfall showed a declining trend over the last 10 years (1995-2005), with a greater decline observed in the Garhwal region as compared to the Kumaon region.

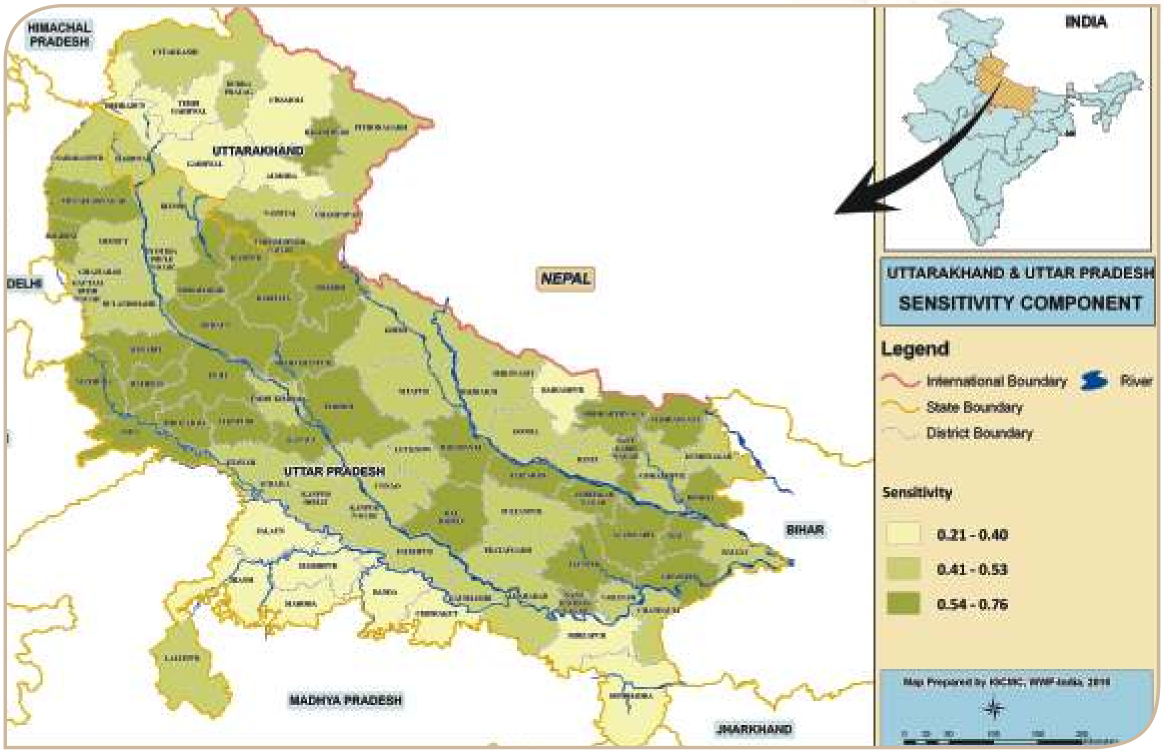
Demographic Profile Analysis

The combined demographic profile values obtained are found to be skewed and most of the districts of UP and Uttarakhand have low to medium values. Further analysis reveals a consistent trend of lower sex–ratio, and greater population growth in Western parts of UP. In case of sex-ratio, reversed normalized values have been used so that low sex-ratio implies high exposure levels. Almost half of the total districts, mainly in Eastern UP, have high (>0.80) reverse normalized values for this variable. This innately means that the gender distribution is not good in these districts and they have low sex-ratio values. Population growth has been highest in the urban districts over the last ten years. In other places there is a mixed trend with not much growth in the Bundelkhand region.

The data for below poverty line (BPL) households significantly ranges from 8.6 to 74% in the case of UP. The districts of Bahraich, Hardoi and Kaushambhi in UP have more than 70% of BPL households. In case of Uttarakhand although there is not much variation in data, the comparative analysis shows that the highest value is for Dehradun followed by Almora and Chamoli.

5.2 SENSITIVITY

Sensitivity reflects the degree of response to a given shift in climate. As a result, the biophysical effects of climate change are broadly grouped under the sensitivity component. These include the changes in the natural ecosystems as well as managed systems such as agriculture. Changes in forest



cover, land use pattern and groundwater extraction (in this case, only for UP) have been chosen as the variables of the Ecosystem Profile. The Agriculture Profile include changes in crop production, percentage of irrigated area, land utilization and percentage of agricultural workers out of the total workforce. Variations in the ecosystem and agriculture profile together govern the sensitivity levels of the districts.

As evident from the *Sensitivity map* above, almost the entire state of UP is in the medium to high sensitivity category. Western UP in particular has a maximum number of districts in the highly sensitive category. Higher groundwater extraction and excessive dependence on irrigation are governing factors for the elevated sensitivity values of these districts. Due to this rising pressure on surface and groundwater resources, the ecosystem and agriculture system in this basin are likely to be more sensitive to the shifts in temperature and precipitation patterns. The state of Uttarakhand is divided mainly into low and medium sensitivity categories primarily because the groundwater indicator could not be included in the analysis due to unavailability of data.

Ecosystem Profile

A comparison of the ecosystem profile values shows that Sonbhadra, Mirzapur and Chandauli on the Eastern border of UP and Balrampur in Western UP have the lowest values mainly because of smaller values for forest cover as well as groundwater extraction. The highest values for the ecosystem profile thus indicating comparatively greater sensitivity is for the districts of Western UP mainly Shahjahanpur, Mainpuri, Hathras and Budaun which lie in the critical area. In case of Uttarakhand most of the districts have low values with only two exceptions – Rudraprayag and Udham Singh Nagar.

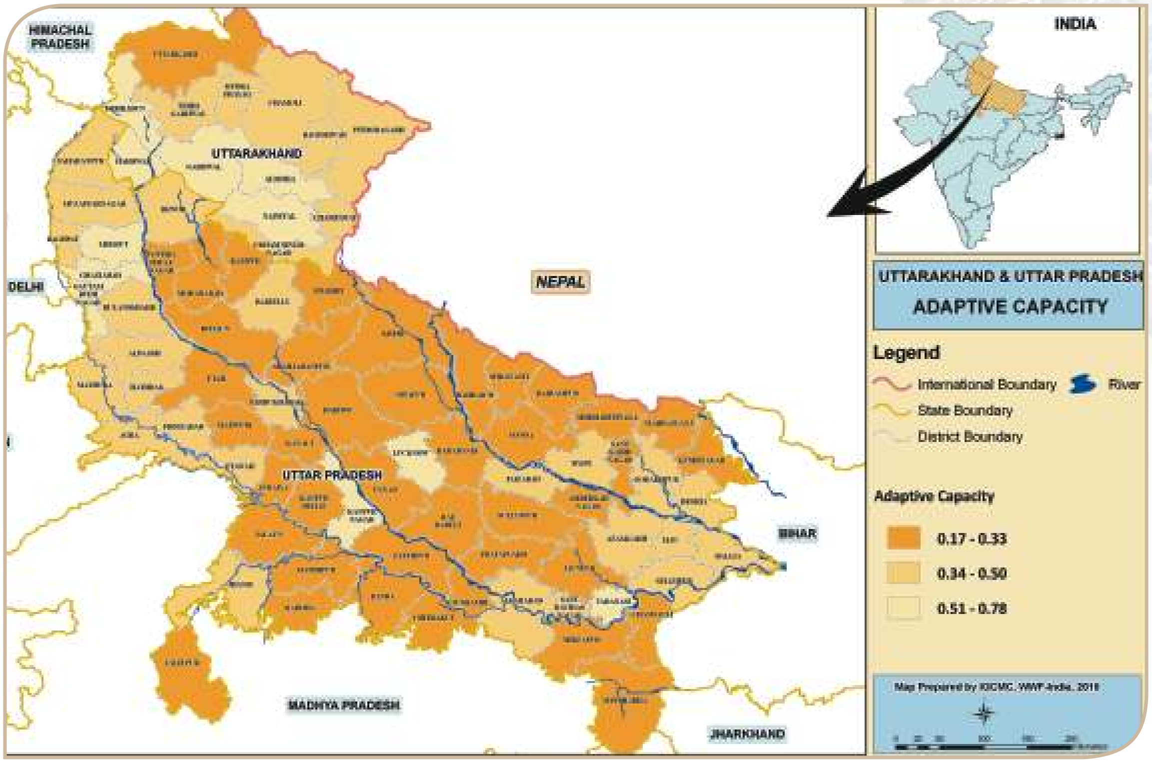
Further analysis of the forest cover data shows that there has been a change in the range of -1 to +2 % in the districts of UP and Uttarakhand. In most of the districts there has been a decrease in land area under *rabi* crops, the maximum being for Jhansi. On the other hand, an increase of land area under *rabi* crops has been seen for Mainpuri, Lalitpur and Shahjahanpur. Likewise, in Uttarakhand there has been a decrease in land area under *rabi* crops in all the districts except Pithoragarh, Rudraprayag and Udham Singh Nagar. The land area under *kharif* crops has mostly decreased in the districts of Eastern UP and Bundelkhand region whereas there has been minor increase on the Western side of the state. In Uttarakhand, marginal decrease of land area under *kharif* crops is seen in almost all districts except Rudraprayag, Udham Singh Nagar and Uttarkashi where there has been a substantial increase.

There is a large variation in the data for groundwater extraction. Budaun is the most over-exploited area with more than 100% stage of groundwater development followed by Hathras, Moradabad and Saharanpur in Western UP which lie in the critical category (>90 % extraction). Most of the districts of Western UP lie in the semi- critical category where the extraction lies between 70 to 90 %. An assessment of the variable at block level shows that most of the over- exploited blocks are located in Agra, Budaun, Baghpat, Hathras, J. P. Nagar, Moradabad and Saharanpur of Western UP. Uttarakhand is largely a hilly state and has a mixed hydrological set up consisting of the Gangetic alluvial plain and the Himalayan mountain belt. For this reason the GW data is available only for 4 districts and thus this variable was not taken for Uttarakhand. The limited data available shows that Haridwar is the most over–exploited district for groundwater extraction.

Agriculture Profile

The aggregate of all the variables for the agricultural profile places most of the districts of UP predominantly in the high category. On the contrary, almost all the districts of Uttarakhand lie in the low to medium category. The outcomes obtained for UP are primarily because of greater reliance of the agriculture system on irrigation and engagement of a large fraction of the working force in agriculture.

Very high percentage (>90%) of agricultural land is irrigated in almost the entire state of UP. Given current trends, the water demand in this region is likely to rise in the near future, placing more pressures on the limited water resources. On the other hand, in case of Uttarakhand a very low percentage of area is irrigated out of the net sown area mainly because of the hilly terrain. Yet, these areas can also be considered sensitive as any changes in rainfall will have a direct impact on cropping patterns. Udham Singh Nagar, Dehradun, Haridwar and Nainital are the only districts having a high proportion (50 to 90%) of area under irrigation.



The other indicator which has been found to be predominant in this profile is the ratio of agricultural workers to the rest of the working population. Though the values show a wide range, a large number of districts have substantial populations (approximately three times more than other workers) engaged in agriculture. In districts such as Shrawasti, Balrampur, and Siddharth Nagar the ratio is very high with the agricultural workers almost 6-8 times higher in proportion to the other workers. This shows that there is a significantly large population having high dependence on agriculture for livelihoods, which is a climate sensitive sector.

5.3 ADAPTIVE CAPACITY

Adaptive capacity denotes the capacity to cope up with the changes and adapt to changing conditions. It is dependent on several socio- economic factors such as infrastructure development, access to key resources and literacy levels. Health, educational facilities and road density are examples of indicators for infrastructure development. Similarly, access to safe drinking water, lighting and *pucca* (permanent) houses indicate the extent of access to resource which people have in a region. Literacy rates and female work participation also determine the level of development of people. Together these indicators are determinants of the socio-economic profile and consequently, of the adaptive capacity of the districts.

The final component values show that most of the districts have very low adaptive capacity as the level of infrastructure development and access to basic amenities is substantially low *[See Adaptive*

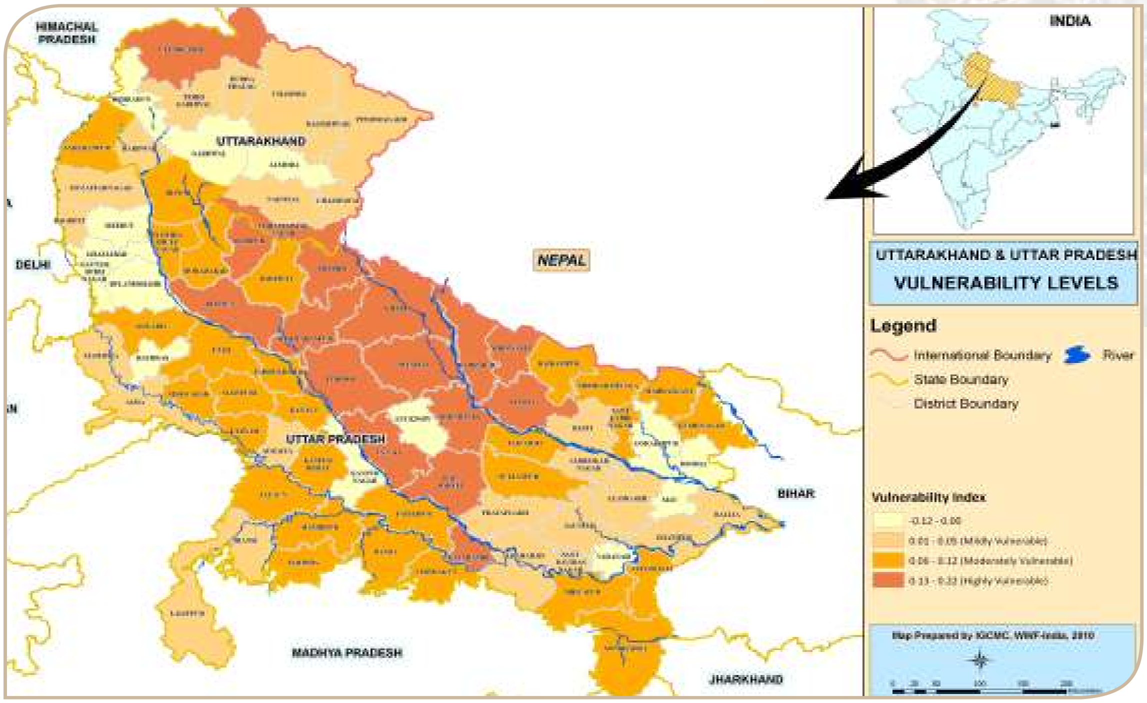
Capacity map]. Higher adaptive capacity values are seen only in the main urban districts such as Dehradun, Meerut, Gautam Budh Nagar, Ghaziabad and Lucknow. A majority of the districts are very low in regard to provision of basic necessities of living especially in Eastern UP and Bundelkhand region as well as the hilly districts of Uttarakhand. Even in terms of infrastructure development such as education and health facilities these districts rank very low as compared to the few urban districts of the state, showing discrepancy in development levels. These districts are also highly dependent on biomass (firewood, crop residue and cowdung cake) as a large proportion of the households (60 - 90 %) use it as fuel for cooking purposes. The figure reflects the high dependence on natural resources for energy requirements.

For the variable of female work participation, larger values have been found for few districts concentrated in Eastern UP. Some of them are also clustered in and around Bundelkhand region. On the other hand, districts having lowest values are mainly located in Western UP.

These variations in infrastructure and access to basic amenities show a general trend that the urban districts have better access to services and resources. The Bundelkhand region scores among the lowest values for these indicators. This mainly implies that this area severely lacks infrastructure development and in case of any changes in the climate these areas might not be able to cope with the severity. These areas need more attention for the general upliftment and for making them better adapted to climate change.

6. CONCLUSION

The final vulnerability index for the districts has been calculated by combining all the three components of exposure, sensitivity and adaptive capacity. The values lie between -1 and +1. Lesser the value, lower is the vulnerability of the district. The final values have been divided into four classes. The districts having negative values (below 0) form one class of districts which are least vulnerable (denoted in white). Many of these districts are the more urbanized districts of these two states. Owing to higher adaptive capacity these districts fall under this category. Most of the districts along the river Ganga are highly or moderately vulnerable. This is because their exposure and sensitivity levels are very high whereas the adaptive capacity levels are very low. There has been more climatic variability due to uncertain precipitation pattern and increasing temperature over the last decade. The sex ratio is low and a large population is below poverty line. These together have resulted in high exposure values. The pressure on the ecosystem is more in these districts with more land utilization, higher groundwater extraction and larger area under irrigation, which has made them more sensitive to any form of impacts in the context of climate variability. Lower levels of development in the form of infrastructure and low levels of access to resources as well as assets have resulted in lower coping capacity of the people in these districts which makes them more vulnerable to any form of impacts occurring due to climate change.



Final Vulnerability Index Map

Way Forward

The analysis presented above provides a broad indication of current level of vulnerability of the districts clearly bringing out the changes that these districts are undergoing both as a result of climate stressors as well as non-climate stressors. Drawing on the above analysis, following are the first level of policy measures that need to be addressed:

- Integrating climate vulnerability and risks into the current development policies in the two states.
- Assess future risks to the development objective in the critical sectors such as water and agriculture as they have significant bearing on people and their livelihoods.
- Formulate an adaptation policy bringing out both "reactive" (based on what is known) as well as "pro-active" (taking into account future challenges) policy response to sustain the ecosystems as well as livelihoods.

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The HSBC Climate Partnership is a five-year US$100 million programme on climate change to inspire action by individuals, governments and businesses worldwide. Formed in 2007 the partnership brings together HSBC, The Climate Group, Earthwatch Institute, Smithsonian Tropical Research Institute and WWF to tackle the urgent threat of climate change on people, water, forests and cities.

Under the HSBC Climate Partnership, in India, WWF is working to reduce the impacts of climate change on people and livelihoods by promoting action in the Ganga river basin, which will lead to the development of a framework for sustainable water and energy management in critical parts of the Ganga Basin. For more information, please visit:

http://www.hsbc.com/1/2/climatepartnership

Living Ganga Programme (2007-2011)

The Living Ganga Programme aims to develop and implement strategies for sustainable energy and water resource management within the Ganga basin, in the face of climate change. Specifically, the programme will work on key sites and a critical strech of the river of approximately 800 kilometres from Gangotri in Uttarakhand to Kanpur in Uttar Pradesh. The programme brings together components of climate adaptation, vulnerability assessment, environmental flows and water allocation coupled with pollution abatement and co-management of water flow and energy. The programme aims to establish partnership with the key stakeholders with a focus on river restoration, community education and engagement, business and government involvement, and bio-diversity conservation. The programme consists of seven cross cutting components:

- **Sustainable Water Management**
- **Climate Adaptation**
- **Pollution Abatement**
- **Water-Energy Co-management**
- **Sustainable Hydropower**
- **Biodiversity Conservation**
- **Communications and Business Engagement**

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