TIFAC (GoI) - Sponsored Project on: Integrating Hydrology, Climate Change and IWRM with Livelihood Issues:

Development of Methodology and a DSS for Water-Scarce Bundelkhand Region in India

Vulnerability Assessment for UR River Watershed, Tikamgarh District

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ABSTRACT

Existing studies in the context of assessing vulnerability to climate variability and change describe, rather inadequately, interconnections occurring within the climate-human-environment interaction space. Besides, studies documenting stakeholders' perceptions regarding climate-change induced vulnerabilities are limited in terms of providing indicators for decision-making. This paper aims at creating a livelihood vulnerability index for climate variability and change, capturing inter-connected interactions based on peoples' perceptions while providing indicators for evidence based decision-making. A quantitative IPCC vulnerability framework, based on district and block level secondary data and a semi-quantitative fuzzy cognitive mapping (FCM) approach, has been deployed to capture peoples' perceptions of climate induced perturbations and adaptations. This complementary approach helps quantify stakeholders' perspectives while capturing inter-connected interactions in order to estimate livelihood vulnerability to climate variability and change of poor agro-pastoralists in the Ur river watershed, which is a tributary of the river Dhasan, Tikamgarh District, in Madhya Pradesh. Combining the FCM approach with IPCC vulnerability framework warrants an understanding of assets sensitive to climate variability and change, along with those serving as adaptive capacities. The findings of this study confirm that financial and natural assets are most susceptible to harm while organisational and financial assets provide resilience against climate variability and change. The results suggest that livelihood vulnerability of agro-pastoralists lie in the range of being 'vulnerable' to climate variability and change while varying across three seasons - summer, winter, and monsoon. Specific assessments on climate change provide the necessary evidences for planning, adaptation and mitigation against climate change. These assessments will particularly help to design adaptation strategies for weaker and vulnerable sections of the society and will move the planning processes towards climate resilience.

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1. INTRODUCTION

The semi-arid Bundelkhand region of Central India, with six districts in Madhya Pradesh and seven in Uttar Pradesh, suffers from significant development deficits and challenges of poverty and is one of the most backward regions of our country. It is highly perturbed with variable climatic conditions intensified by erratic precipitation trends, high evapo-transpiration losses, high run-off rates and poor water retention capacity of the soil and large areas of barren and uncultivable land. Drought conditions are frequent in the region, leading to unstable socio-economic conditions. Varying weather conditions influence crop productivity in summers as well as winters. Monsoon is a critical determinant of the sowing time, which has been varying drastically in the past few years, causing huge losses to the native farmers. Therefore, the development challenge of regions such as Bundelkhand, together with uncertainties posed by climate change impacts, becomes a strong rationale for focusing on climate adaptation interventions in this region. The economy of Bundelkhand is predominantly agrarian; and, agriculture, livestock rearing and seasonal outmigration provide more than 90 percent of the rural income in the Bundelkhand region. Climate change sensitivities in Bundelkhand are majorly aggravated by the water stress in the region. Irrigation heavily relies on the availability of water through the rainfall which increases the climate change sensitivities. Loss of traditional water management practices and insufficient water-harvesting infrastructures have further added to the stress in the region. The ever-growing population and a parallel increase in the demand for natural resources have left agricultural and water resources in the region susceptible to increasing climate change risks, affecting livelihoods of local communities.

In order to assess the livelihood related vulnerabilities and derive the strategies and solution for mitigating the impacts of climate change, a vulnerability assessment was conducted in proposed watershed area (Ur River Watershed). This area falls in the Tikaggarh disctrict of Bundelkhand region.

2. Ur RIVER WATERSHED – AN OVERVIEW

The study area as shown in Figure - 1, slide 4 represents the typical topography and geology of the region. The total geographical area of the Ur River watershed is 993.42 sq. Km (99342.20 ha). The maximum length of the watershed is about 119 km from North to South with an average width of about 80 km. The mainland extends between latitudes 24°35’0” N and 25°05’0” N and between 78°50’0” E and 79°10’0” E longitudes and has an elevation of 400 m above the mean sea level.

Table 5: Block wise area falling in Ur watershed

Block Name	Area of Block falling in watershed (sq km)	% area of watershed
Jatara	326.94	32.91
Palera	77.86	7.83
Baldeogarh	272.65	27.44
Tikamgarh	315.97	31.80
Total	**993.42**	

The entire soil in the area is composed of vertisols and inceptisols, which belongs to highly alkaline. The Ur River flows in the South to North-East direction. The Ur river watershed area falls under four development blocks of Tikamgarh district (Jatara, Palera, Baldeogarh and Tikamgarh). The total area falling under each block is given in Table -1 the Jatara block cover the maximum area i.e. 32.91% while Palera block cover the minimum area 7.83%. The study area comprises 197 villages. The total population of the 197 villages are 3.84 lakhs which is 27% of the district population. Schedule Cast & Schedule Tribe population in the study area is 21% and 5% of the total population of the area.

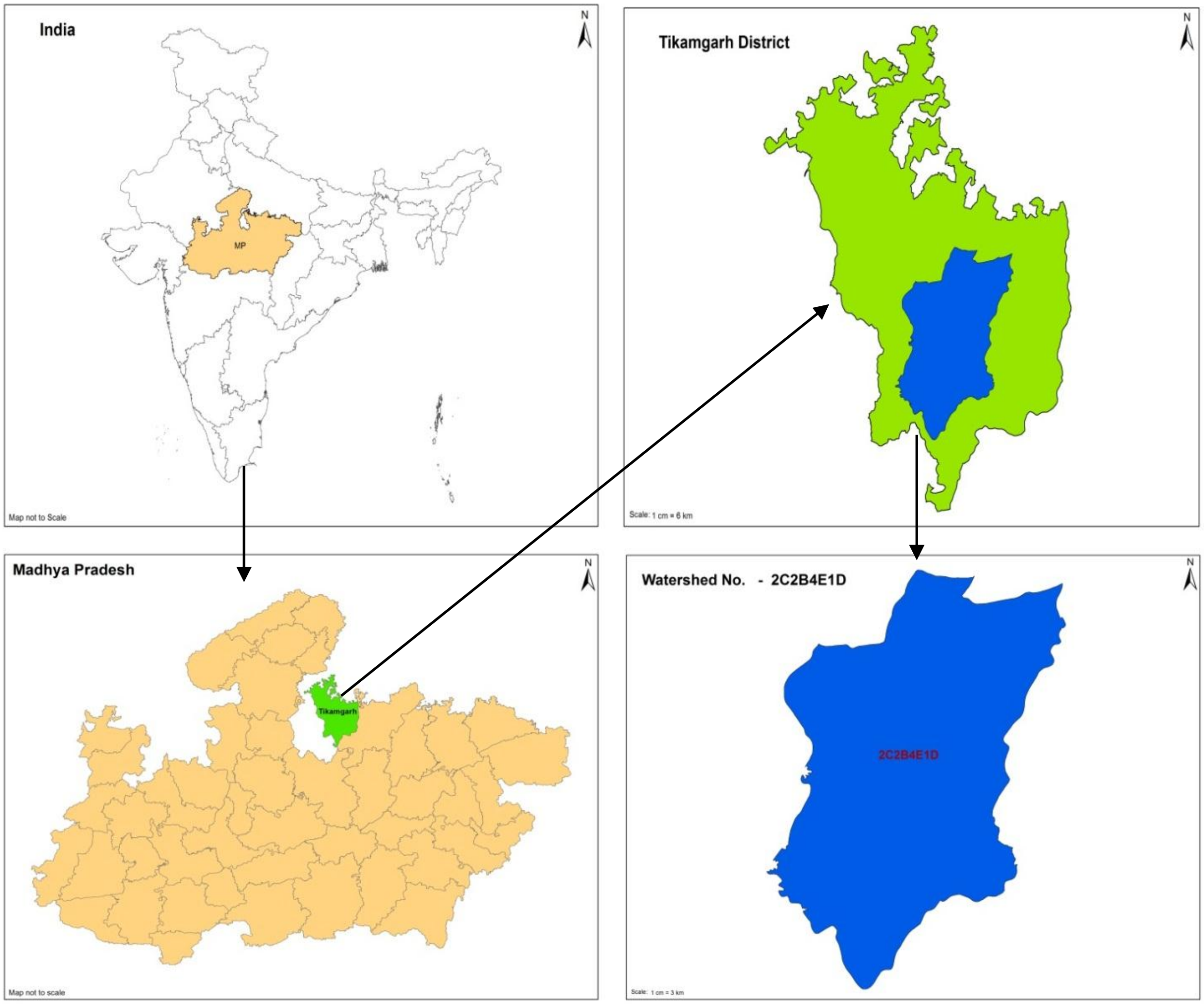

Figure 2: Location Map, Data Source: MPCOST

Average literacy rate is 51% out of which 60% is male and 40% is female which is lower than the average literacy rate of Tikamgarh district which is 61.43% and Madhya Pradesh which is 63.94%. Population density is 388 persons per sq km. Working population is 42.16% out of this male worker are 49.67% and female workers are 33.86%. Within total worker main cultivator population is 33.67%. Main cultivated worker males are 38.73% and females are 25.47%. The major part of working population is engaged in agriculture and allied activities. Land use profile of the Ur river watershed area depict that the out of total 99342.20 ha of land dense forest is only 4.59% while scrub forest is 13.20% and for agriculture area double crop is 23.19%, Rabi crop is 24.85%, Kharif crop is 10.55%. Barren Rocky land is 1.12% and Built up area is 2.01 %. Follow land is 7.01% and river and water bodies are covering 3.47% of the total area.

Table 6: Land use profile of Ur river watershed

Land use Class	Total Area (ha)	% of total area (ha)
Barren Rocky	1117.09	1.12
Built-up	1997.80	2.01
Dense Forest	4556.79	4.59
Double Crop	23040.52	23.19
Fallow Land	6965.05	7.01
Kharif Crop	10477.04	10.55
Land with or without Scrub	9937.90	10.00
Rabi Crop	24684.60	24.85
Rivers & Water Bodies	3447.36	3.47
Scrub Forest	13118.05	13.20
Total	**99342.20**	

It was clearly evident that the agricultural activities cover around 58.59% of the total area. It is clearly evident from the data that the main source of livelihood is agriculture and any pressure on the agriculture will increase the vulnerabilities of the communities.

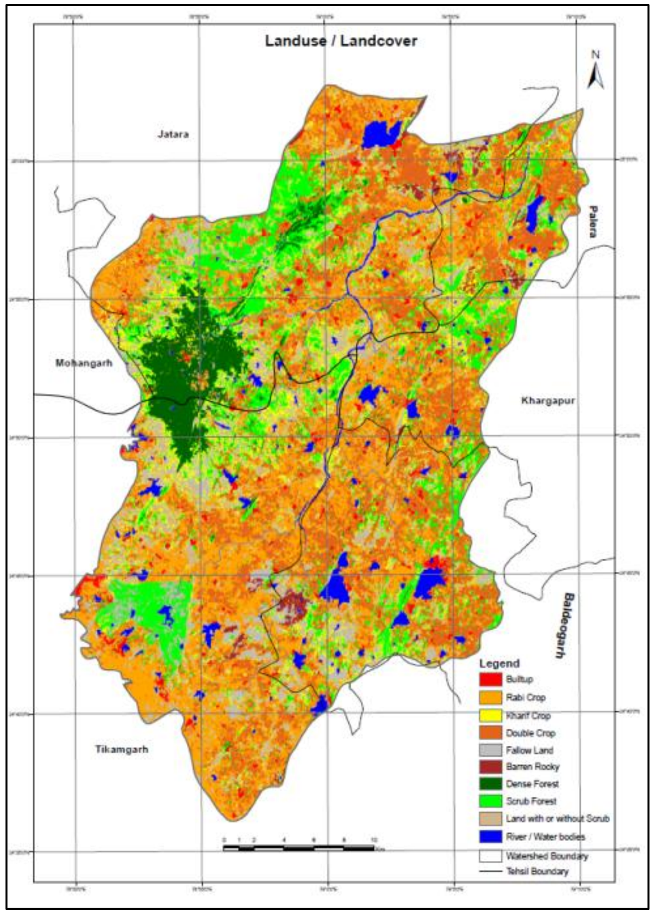

Figure 3: Land Use Map; Source: MPCOST

3. OVERALL APPROACH & METHODOLOGY

The vulnerability assessment was done using the IPCC Livelihood Vulnerability Index (LVI) framework in conjunction with FCM. For the analysis, district and block level secondary data has been utilised and additionally, validated through workshops, brainstorming sessions, in-depth interviews, observing onsite conditions and FGDs. Through LVI, block level vulnerabilities was assessed, after which detailed community vulnerability mapping was done in Ur river watershed using Fuzzy Cognitive Mapping (FCM).

3.1 IPCC Framework Approach

Several researchers have put forward various methodologies to assess the vulnerabilities to climate change. One such methodology is the vulnerability assessment using **Livelihood Vulnerability Index** given by Hahn et al, 2009. The LVI methodology comprehensively evaluates the livelihood risks of vulnerable communities posed by climate change. The methodology was tailored (using climatic data and secondary information, verified by primary consultations, to meet the local rapid assessment needs of the current study. It measures the socio-economic vulnerabilities of a region using IPCC's three contributing factors to vulnerability - **exposure, sensitivity and adaptive capacity**.

Exposure is the magnitude and duration of climate related exposure, such as drought temperature variability or change in precipitation.

Sensitivity is the degree to which a system can be affected, negatively or positively, by a change in climate. This includes the change in mean climate and the frequency and magnitude of extremes. The effect may be direct or indirect.

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

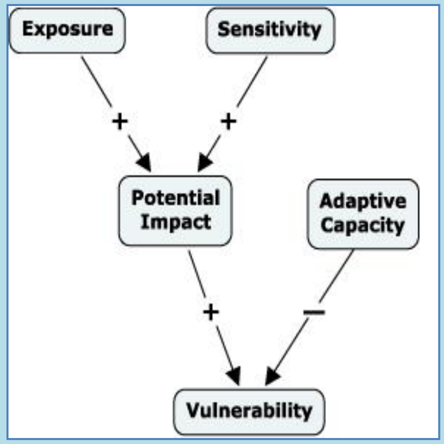

Figure 3: IPCC Framework for Assessment vulnerability

The reason for selection of this methodology is that it presents a framework for grouping and aggregating indicators at the district level, which can be critical for development and adaptation planning. In addition, the sub-components and weighing measures of index can be adjusted in relevance to the local community needs of Ur river Watershed area. This provides an added advantage over other methodologies where these components are more or less fixed. Lastly, it is a socio-economic vulnerability index in which socio-economic indicators are standardized; therefore, it is designed to provide development organizations, policy makers, and public health practitioners with a practical tool to understand demographic, social, and health factors contributing to climate vulnerability at the district or community level. It is a flexible tool so that the researchers and planners can tailor the framework to meet the needs of unique geographic areas (Hahn et al, 2009) such as that of Ur river Watershed. Thus, variation and applicability are its biggest advantages.

The vulnerability profile for Ur River Watershed was calculated using climatic data for the region and secondary information obtained from the district statistical handbooks. The results were further verified by primary data collection. The climate data was used to understand the variability of climate and the long term trend of parameters. For the purpose of conducting vulnerability assessment, indices were computed for all four blocks of Tikamgarh district and were used to derive vulnerability contributing factors - **Exposure (E), Sensitivity (S), and Adaptive capacity (A)**. Each contributing factor was determined using proxy indicators listed in the table below. The LVI uses a balanced weighted average approach where each sub-component contributes equally to the overall index even though each major component is comprised of a different number of sub-components.

Table 7: Major Components and sub-components comprising livelihood vulnerability index

Contributing Factors	Components	Weightage (Wpi)	Sub-Components
Exposure (E)	Climate	3	Temperature Variability
			Annual Average Rainfall
			Average no of drought events in past 10 years
Sensitivity	Ecosystem	3	Percentage Forest Cover

Contributing Factors	Components	Weightage (Wpi)	Sub-Components
(S)			Area of Wasteland
			Net Annual Groundwater Availability
	Agriculture	8	Irrigation Intensity
			Sex Ratio
			Cropping Intensity
			Per Capita Food Grain Production
			Livestock Population Per Hectare of Net sown Area
			Number of Cultivators
			Number of Small Famers (0-2 hectares landholding)
			Number of Agricultural Workers
Adaptive Capacity (A)	Socio-economic	10	Total Literacy Rate
			Number of Agriculture Credit Societies Per Lakh Cultivators
			Number of Health Care Centres Per Thousand Persons
			Percentage of Rural to the Total population
			Number of Hand Pumps Per Thousand Persons
			Per Capita Rural Electricity Consumption
			Number of Electrified Pump Sets Per Thousand Hectares of Gross Cropped Area
			Average Daily Employment in Working Registered Factories Per Lakh Persons
			Total Number of APL Families
			Number of Agricultural Machineries

Selection of Indicators for Measuring Vulnerability Index:

A holistic set of indicators have been selected in order to represent the contributing factors for vulnerability i.e. exposure, sensitivity and adaptive capacity. Vulnerability is a function of these three aspects with respect to climate change. These indicators are representative of the livelihood and socio- economic vulnerabilities in the Ur river watershed area.

<u>Exposure</u>

- **Climate**

This factor includes current climate variability in the region, indicating temperature and rainfall variability. Higher inter-annual rainfall variability indicates a higher probability of unanticipated quantum of rainfall in a given year. This could mean flooding, drought, or simply below/above average rainfall that impacts agriculture. Also, rainfall is crucial in water recharge and in rain-fed cultivation systems. Additionally, temperature variability exposes the region by affecting crop productivity (due to uncertainties), increased evapo-transpiration losses and decrease in the soil moisture.

Sensitivity

- **Demographics**

Sex Ratio: Low sex ratio further increases the sensitivity of women towards climate change due to increased cultural and social pressures, additionally increasing their high vulnerability to climate change.

Above poverty level population: Above poverty level families have resources to sustain because of which they will be more adapted to climatic stress indicators. Blocks with higher numbers of APL families will have foremost adaptive capacity and lower sensitivity.

- **Ecosystem**

Percentage of forest cover: Forest resources are highly sensitive to the impacts of climate change. Climatic uncertainties in future may affect the composition and distribution of forest resources. This will disturb the delicate balance of bio-geochemical cycle, making the forests prone to degradation. This will also affect the forest productivity. Lastly, this may result in habitat shifting of fauna in the region.

Area of wasteland: Wasteland in the region increases the sensitivity due to the loss in land fertility, thus decreasing the land area fit for farming or grazing in the region. The area of wasteland increases with the changing soil moisture conditions. Climate change is thus likely to affect the situation of wasteland in the semi-arid geography.

Net Annual Groundwater availability: The variability in rainfall may affect recharging of groundwater in the region. This may also result in over-extraction of groundwater resources. There is a high reliance on groundwater in the region, for irrigation, drinking water and other purposes. The situation is aggravated by the low percolation rate and sudden extreme drought conditions.

- **Agriculture**

Irrigation intensity: Climate variability and impacts such as drought will affect the water resources (e.g. water in wells, dug wells, ponds) available for agriculture. The vulnerability of irrigation sources makes irrigation highly sensitive to climate change.

Cropping intensity: It refers to raising a number of crops from the same field during one agricultural year. This indicates the pressure on the same amount of land for farming. Cropping is directly related to the irrigation facilities available, thus indirectly making it sensitive to climate change

Per Capita Food Grain Production: This is the amount of food grain produced per hectare. This indicates the pressure on the same amount of land for farming.

Livestock population per hectare of net area sown: Livestock, an adaptation option, has itself become highly prone to uncertainties of climate change. Adverse impacts of climate change in this area (such as increasing extreme temperatures, increased frequency of droughts, scarcity of water resources, and poor availability of fodder) have severely affected the livestock population. In semi-arid geography, livestock is the main alternative source of livelihood. Their sensitivities may increase due to the occurrence of new unidentified diseases, heat strokes and low productivity.

Number of Cultivators: This indicator is selected to calculate the vulnerability related to occupational characteristics of people and all these variables are converted into per hectare of net sown area.

Number of Agricultural Workers: This indicates the dependency on agriculture as a major source of livelihood, which is one sector that is highly sensitive to climate change.

Number of small scale farmers: Small and marginal farmers are more sensitive to climate variability because they tend to have less resources/means to respond to external pressures. This area with relatively higher numbers of small farmers will be more sensitive to climate variability.

Adaptive Capacity

- **Demographics**

Percentage of Rural to the Total population: More than 70 percent of rural labour force is engaged in the agricultural sector and is therefore highly dependent on agriculture for its subsistence and income. Agriculture is one of the most sensitive sectors to variable climatic conditions. Therefore, rural population percentage acts as a proxy for the degree to which the study area population relies on agriculture for their livelihood, which correlates with climate change sensitivity.

- **Socio-economic Status**

Literacy rate: Literacy rate acts as a proxy for the general level of human capital (i.e. education) in a district. This indicates the level of awareness people might have. Higher the level of access and information to the people, higher is the adaptive capacity.

Number of health care centres: Health care facilities increase the adaptive capacity by providing infrastructures to respond to the health impacts of climate variability.

Number of hand pumps: The availability of hand pumps indicates access to groundwater resources, or an additional source of water for the community. Having access to this type of water resource increases the adaptive capacity to drought and related climate stressors, assesses water resource of a particular area, provides easy access to drinking water, and reduces vulnerability.

Per capita rural electrification: This may not indicate a tangible relationship, but the availability of electrification depicts it to be a more developed district or block, which will have a higher adaptive capacity to climate variability. It also indicates the mechanization adopted for better crop productivity.

Number of electrified pump sets per thousand hectares of grossed cropped area: The availability of electrified pumps indicates access to agricultural water resources, an additional source of water for the cultivator. Having access to this type of water resource increases the adaptive capacity to drought and related climate stressors.

Average Daily employment in working registered factories per lakh population: Area with registered factories is assumed to be more developed. This facility increases the adaptive capacity also.

Agriculture machinery: Agricultural machinery serves as a proxy for the state of agricultural development in any block. Blocks with more agricultural machinery are assumed to be more developed. A more developed agricultural sector will have a higher adaptive capacity to climate variability. It also indicates the mechanization adopted in farming practices for ease and better crop productivity.

The steps to calculate the Livelihood Vulnerability Index are:

Step 1: Indicators

Values for all the indicators are to be standardized for all the blocks

$$\text{Indicator Index } (\mathbf{Ix}) = \frac{\mathbf{I_b - I\ (min)}}{\mathbf{I\ (max) - I\ (min)}}$$

Where, Ix = Standardized value for the indicator

I_b = Value for the Indicator I for a particular blocks.

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

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

Step 2: Profiles

Indicator Index Values are combined to get the values for the profiles

$$\text{Profile } (\mathbf{P}) = \frac{\mathbf{\Sigma_{i=1} \text{ Indicator Index}_1}}{\mathbf{n}}$$

Where, **n** - number 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

$$\text{Component } (\mathbf{C}) = \frac{\mathbf{\Sigma^n_{i=1} W_{Pi}\ Pi}}{\mathbf{\Sigma_{i=1} W_{Pi}}}$$

Where W_{Pi} is the weightage of the Profile i

Weightage of the profile will depend on the number of indicators under it such that ***within a profile, each indicator has equal weightage***

Step 4: Livelihood Vulnerability Index

The combination of the values of the three components will give the vulnerability index.

Livelihood Vulnerability Index = (Exposure – Adaptive Capacity) x Sensitivity

Scaling is done from -1 to +1 indicating low to high vulnerability. This is done for each area and then they are ranked in a decreasing order of vulnerability.

Livelihood Vulnerability Index (LVI) methodology was used to prioritize the vulnerability of the study area using the secondary information/data. Assessing the vulnerability of the community and verify the result of the LVI approach a detailed perception based vulnerability assessment was done using the Fuzzy Cognitive Mapping (FCM). The FCM approach is undertaken through village level FGDs conducted with the community. This approach is based on awareness and perceptions of community level stakeholder, where participants are facilitated to identify the impact of selected climate variability parameters on livelihoods and assets as defined by the sustainable livelihood framework of DFID. Participants are made to map these interconnections on a chart and assign weightages on the basis of their relative positive or negative impacts. The process is facilitated through the use of a questionnaire that seeks information from stakeholders on their vulnerability and exposure to climate change impacts, coping mechanisms and adaptive capacities and measures that would improve their adaptive capacity. Although the tool allows for conversion of these perceptions based maps to quantitative estimations of climate vulnerability, for the purpose of this study the same has not been attempted. Instead, the scope of the exercise has been limited to the mapping of community perceptions. The variations between the findings arrived at through the two approaches are indicative of the gaps with respect to community understanding of the interconnections between climate perturbations and livelihoods and assets. This allows for appropriate awareness building and sensitisation interventions for the community to be designed and applied as part of the adaptation strategy.

3.2 Fuzzy Cognitive Mapping (FCM) Approach

The Fuzzy Cognitive Mapping (FCM) is a powerful tool in environmental decision-making and management, attempts to capture the functioning of a complex system based on people's understanding and their belief systems. FCMs comprise a set of nodes representing variables connected through links denoted by arrows (fig is in annexure). Each variable represents characteristics of a system while interconnections between the variables depict the dynamics of the system (Papageorgiou and Kontogianni 2012). The variables could be physical, measurable entities and qualitative, aggregate or abstract ideas including ethical, political or aesthetic issues. Relationships between these variables are labelled with positive or negative polarities. These polarities describe the arrangement of the system, with the positive sign indicating a direct relationship and the negative sign an inverse one. Weights delineating the strength between variables have been assigned values ranging between 0 and 1. FCM depicts interconnected relationships between variables and explains complex interactions occurring within a dynamic system. The FCM approach in this study has been deployed to understand the effects of various climate-related perturbations on social, economic, and ecological systems along with adaptations that provide resilience against shocks. FCMs are useful tools for modelling complex relationships between variables. FCMs enable the analysis of both direct and indirect feedback, aiding the exploration of dynamic vulnerabilities induced by climate variability and change, yielding semi-quantitative results.

Process of conducting FCM[1]:

Obtaining cognitive maps from communities

Marginal agro-pastoral communities, most affected by climate variability and change, were selected for the study. The construction of an FCM was demonstrated to community participants citing an example of extreme heat waves and their direct and indirect impacts along with coping mechanisms providing resilience. Thereafter, following questions were asked of the participants:

i. **What climatic changes have you observed in the past six years during the various seasons of a year?**

Answers to this question helped us understand the community's perception of changes occurring during summers and winters in terms of temperatures along with precipitation patterns over the past six years, while allowing us to capture our central variables. Most perception-based studies resort to a 6–20year recall window for analysing climate variability and change. For this study, a six-year recall window was chosen to capture community's perceptions of climate perturbations and adaptations to climate variability.

Farmers with cattle and land holdings of less than 0.3 ha were selected as community participants. A near consensus on temperature changes observed during summers and winters was achieved and precipitation patterns were established by the participants. Afterwards, in order to avoid the influence of certain members, the participants were divided into homogenous 4-5 member groups based on land holding and gender. Each group was provided large sheets of paper; each of the three climate variables was placed as a central variable on a separate sheet. Groups were asked to draw causal relationships concerning direct and indirect climate-related perturbations on livelihoods with each central variable based on the following open-ended questions:

ii. **How have your livelihoods been affected due to perceived changes in summer and winter temperatures and rainfall patterns in the last six years?**

iii. **What are the consequential impacts arising from direct impacts due to changes in climate?**

The participant groups listed variables affected by each central climate variable. The groups were then asked to explain the relationships between the variables. These variables were placed around the central variable and links/ interconnections were established between them. Arrows were drawn to indicate the directionality of relationships.

iv. **What are the coping mechanisms used to respond to these impacts?**

After the climate-related perturbations were captured, the groups identified coping strategies and adaptations.

v. **Do these coping strategies increase the sensitivity of already occurring climate perturbations?**

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[1] Livelihood vulnerability assessment to climate variability and change using fuzzy cognitive mapping approach Pramod K Singh & Abhishek Nair

The groups identified coping mechanisms and adaptation practices and added them to their list of variables. Members of various groups then placed the new variables on the map before linking their relationships in the context of reducing impacts and/or increasing sensitivities.

Once the cognitive maps of climate-induced perturbations and coping mechanisms had been drawn up and causal relationships established between variables, relative weights were assigned to these links. These weights were assigned by group participants, based on their understanding of the influence of one variable over another. Weights were assigned values ranging between 0 and 10, with 10 representing the highest influence and 0 no influence; this was later scaled down to 0–1 by the researchers. Positive and negative polarities between the links were provided by the researchers as groups found it difficult to assign signs. A positive sign depicted positive causal relations and a negative sign an inverse relation. In order to reduce biases, including the influence of certain members, the maps were refined with the help of community participants and experts.

Transforming cognitive maps into a social cognitive map

Each Fuzzy Cognitive Map (FCM) may be mathematically represented through adjacency matrices as A (D) = $[a_{ij}]$ where variable v_i is listed in the vertical axis and the variables v_j in the horizontal axis to form a square matrix. When a connection exists, a value between −1 and 1 is coded into the square matrix. Each individual cognitive map is coded into an augmented matrix that includes all variables of the individual cognitive maps. Then all the individual maps are added with the help of matrix addition and normalised to create a social cognitive map in the range of −1 and +1.

Determining adequacy of samples

Monte Carlo simulation technique with STATA was deployed to determine sample size through accumulation curves. The average accumulation curve is the total number of maps versus the number of new variables added per map that depicts the adequacy of the sample size, based on the way accumulation curve saturates. The average accumulation curve stabilised at32 maps. FCMs were created with different groups until the representative population was sampled sufficiently. A total of 38 cognitive maps were obtained during the primary survey.

Simplifying/ condensing cognitive maps

The method employed for condensation was qualitative aggregation, enabling the category-wise combination of variables represented by a larger encompassing variable. Condensation entails combining variables with similar characteristics and/ or attributes into a larger category in line with the sustainable livelihood framework.

Visualising condensed social cognitive map

FCMs are graphically represented through cognitive interpretive diagrams (CIDs) for the easy depiction of interconnected interactions occurring within the climate-human-environment system. The size of each node (bubble/ shape) in the CID represents the centrality or the importance of that particular variable in the entire structure of the cognitive map, which means that larger the node size the greater its importance. FCM aids the visualisation of interrelated variables affecting one another while representing the feedback.

Combining Sustainable Livelihood (SL) framework with FCM approach

Climate variability and change adds complexity to livelihood vulnerability analysis. Several studies have incorporated the SL approach for assessing vulnerability. The SL framework helps identify the sensitivity of assets, entitlements, and critical assets for coping with and adapting to risks while linking livelihood strategies to opportunities and constraints of the broader institutional and bio-physical environment. The SL framework proposed by the Department for International Development (1999) looks at five types of assets. Another asset—the organisational asset—was incorporated rendering the sustainable livelihood framework more comprehensive. The variables (climate-related perturbations and coping mechanisms) captured by the cognitive maps were categorised under various assets of the SL framework.

Constructing the livelihood vulnerability index to climate variability and change

Vulnerability includes exposure and sensitivity to perturbations or external stress and adaptive capacity. Exposure is the nature and degree to which a system is exposed to significant climatic variations and sensitivity. It is the degree to which a system is affected directly or indirectly, either adversely or beneficially, by climate-related stimuli, directly and/or indirectly. Adaptive capacity is defined here as the ability of a system to manage sensitivity to climatic influences.

As discussed in approach this tool allows for translation of these perceptions based maps to quantitative estimations of climate vulnerability. Instead, the scope of the exercise has been limited to the mapping of community perceptions only.

4. RESULTS

The vulnerability assessment done using secondary data, using the LVI approach, brings out the following vulnerability ranking for the four blocks of Ur river watershed. Vulnerability profile ranges from -1 to +1 depicting low to high vulnerability. It is clear from the calculated LVI that Tikamgarh part is the most vulnerable area of watershed.

Table 8: Climate impacts and vulnerability

Blocks	Exposure	Sensitivity	Adaptive Capacity	LVI	Zone
Tikamgarh	2.20	0.35	0.45	0.625	1
Baldevgarh	0.40	0.52	0.44	-0.006	4
Jatara	0.30	0.70	0.63	-0.183	3
Palera	0.53	0.40	0.38	0.063	2

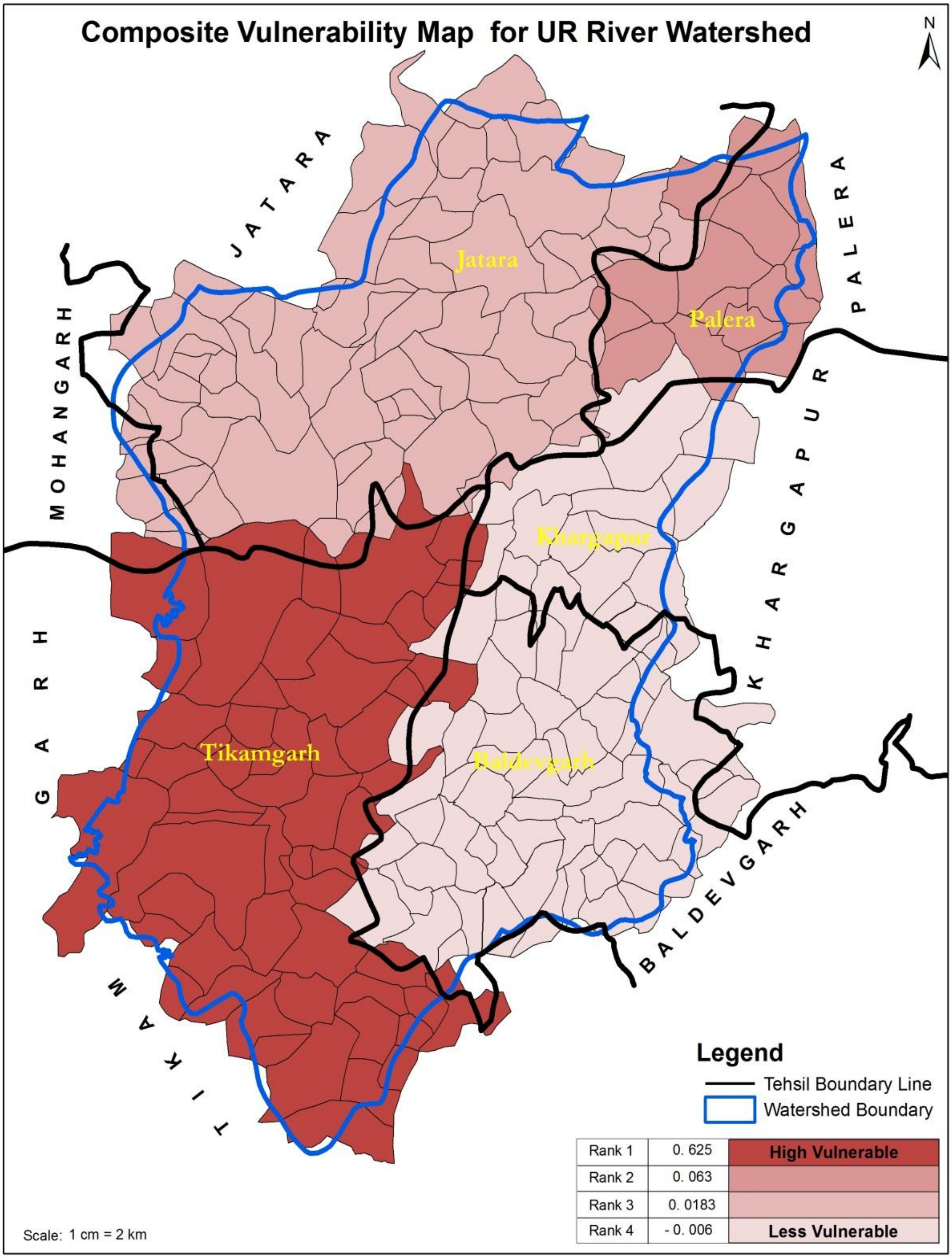


Figure 4: UR River Watershed Vulnerability Map

4.1. Analysis of Climate Change Vulnerabilities in the Ur river Watershed area

Climatic Exposure

The Climate of Ur River Watershed actually encompasses Tikamgarh district, characterized by hot summers and general dryness except during the southwest monsoon season. The year may be divided into four seasons. The cold season, December to February, is followed by the hot season from March to about the middle of June. The period from the middle of June to September is the southwest monsoon. October and November form the post-monsoon or transition period. The normal annual rainfall of Tikamgarh district is 1057.1 mm.

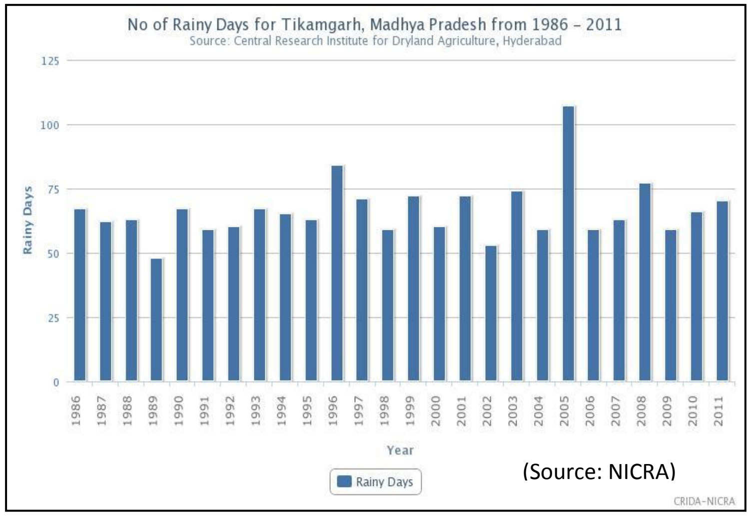


Figure 5: Number of Rainy Days for Tikamgarh District

Tikamgarh District receives the maximum rainfall during southwest monsoon period i.e. June to September. About 90.3% of the annual rainfall is received during the monsoon season. Only 9.7% of the annual rainfall takes place between Octobers to May period. Thus, surplus water for groundwater recharge is available only during the southwest monsoon period. The normal maximum temperature received during the month of May is 41.8° C and the minimum temperature during the month of January is 7.0°C. The normal annual mean maximum and minimum temperatures of Tikamgarh district are 32.4°C and 17.5°C respectively.

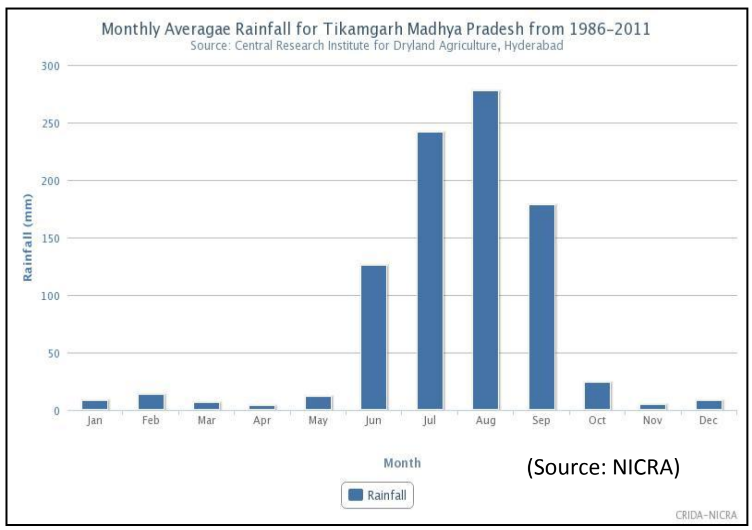


Figure 6: Monthly Average Rainfall for Tikamgarh Madhya Pradesh (1986 to 2011)

During the southwest monsoon season, the relative humidity generally exceeds 87% (during the August). During the rest of the year, it is much drier. The driest part of the year is the summer season, when relative humidity is less than 35%. In fact, May is the driest month of the year. The data reveals that the exposure is higher during summers and winters due to increasing temperatures. The exposure component of decreased rainfall is lower than the increased temperatures in the study area, which exists in a semi-arid region. The perception of perturbations arising out of increased summer and winter temperatures and decreased rainfall (during the rainfall months) is relatively high according to last 5 years. Adaptation practices are high during rainfall months, which are crucial to agro-pastoralists in terms of sustaining livelihoods. The smallest decline in rainfall is said to cause relatively large perturbations.

Through analysis of the two approaches (IPCC and FCM), it has been observed that communities have witnessed increasing temperatures and decreasing rainfall directly affecting agriculture, fodder, land, water, and forest resources. Based on field exercises for FCM approach, it has been observed that degrading land and water resources have affected forests and agriculture, leading to reduced fuel wood and fodder availability, while limiting water resource management strategies (Annex 2: Figs. 8, 9 and 10).

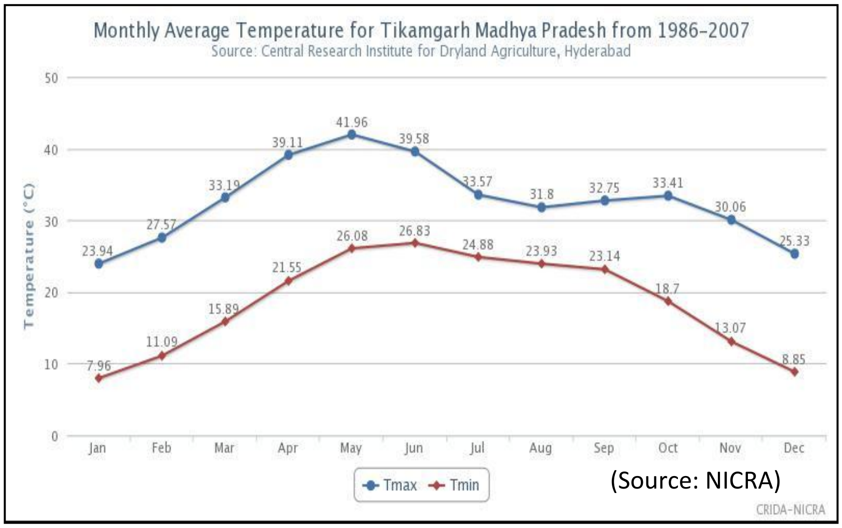


Figure 7: Monthly Average Temperature for Tikamgarh District

- **Agriculture**

In all, 67 percent of the total workers of Ur river watershed have engaged in agriculture and allied activities. The scarcity of water, along with the poor soil quality, adds to the vulnerability. **Zone 1 (Tikamgarh Block) is having high vulnerability because land productivity or agricultural yield is affected** by the poor water retention ability of the soil, weather fluctuations and large amount of wasteland. It has been experienced that the onset of monsoons has shifted from end of June to end of July – August. This has caused a delay in the sowing time of the seeds, which affects the growth and harvest of the crop due to differential temperature conditions which the crop has to tolerate. Also, due to sudden downpour, the crops also face water-logging conditions which decay the growth. Like this year, considering the delayed monsoons and low rainfall, the farmers sowed Til (sesame) but the delayed heavy rains affected the crop to such an extent that the crop on field started to decay.

Small scale farmers and landless farmers are also prevalent in villages. These farmers do not have any fixed source of income and often migrate when weather conditions disrupt economic activities in the region. To further add to the socio-economic vulnerabilities, large numbers of people face problems due to lack of information, low levels of awareness about welfare schemes and poor information capacities to cope with high risk situations.

- **Livestock:** In this area, Livestock Rearing is a common livelihood option practiced by the communities. People have moved beyond the cattle and are taking up poultry and goat-rearing as more economically viable options. But, the growing unavailability of grazing pastures has added on to the trouble in livestock rearing. Except few communities such as the Yadav colony in zone 2 (Baldevgarh block) and zone 4 which are chiefly dependent on cattle because of the availability of few forests and larger dams, other zones have shown a declining trend in continuing with this option due to lack of resources to keep the cattle healthy. Through FCM, it has been cleared that factors like declining water and fodder availability, coupled with increasing temperatures, have been causing deterioration in term of livestock health and milk produce, leading to adverse effects on human health (Figs. 8, 9 and 10). Lack of fodder availability and water has reduced the interest of local communities in livestock-rearing, which has further lowered their adaptive capacities. In addition to the quantitative assessments of Ur river watershed, primary consultations with communities reveal micro-level climate change vulnerabilities at the household level.

- **Forest:** Population growth, increase in cultivable land, anthropogenic pressures and climatic changes have all in all affected the quality of the forest in the region. Deforestation has also become rampant which has lead to gradual environmental degradation. Based on the Resource Atlas of Tikamgarh, much of the dense forest is along the stretch of Prai, Kirtwrai and some other smaller streams join together in Jatara. Lesser stretches of dense forests are seen in Palera, Baldevgarh and Tikamgarh tehsil also, mostly in the vicinity of significant rivers and nallas. Due to the declining forest cover, the land is increasingly becoming barren due to the increased rate of erosion. This also has lowered the water holding capacity of the soil. Per capita forest cover has also reduced in Zone 1 (Tikamgarh Block) because of rapid urbanization of this area. The losses in the agricultural produce, due to the variable climate, made people depend more on forest for other livelihood options. Mahua, Tendu leaf, Chironji and other NTFPs are being taken from the forest. Mahua fruit, in particular, is used for alcohol production and is considered a good source of livelihood for the local communities. Mainly fuel wood is sourced from the nearby forests. Zone 4 (Jatara) is really enriched with different large forests (eg: Panayarakhera) for that reason Bidi making provides livelihood to a large number of poor families in the region.

  Also, this watershed shows a high percentage of small land holding size, with an average of just 0.46 hectares. Marginal land holdings (of a size less than two hectares) form the bulk of cultivation and account for 47.7% of all holdings and command only 12.8% of the total land area. This shows that climate-sensitive agriculture sector has become a gamble for farmers with small land holding size that solely depend on small agricultural lands and raise just a single crop in an entire year.

- **Water: Water is the most important parameter for sustainable agriculture. Most of the agricultural area in the** watershed **is irrigated by tube wells and dug wells. Groundwater is the main source of irrigation in the area.** As rainfall distribution pattern changes with the changing climate, groundwater resources are also under threat. Along with geological conditions, climatic variables also impose a grave threat to the resources. It is essential that water management practices are adopted in the region for water security reasons.

  Most part of the Tikamgarh district is covered with an impermeable rocky layer, found at quite shallow depths. Factors like decrease in the rainfall period , higher rain intensity leading to high run off, high evapo-transpiration due to rise in temperature, have culminated to contribute to water stress in the region. Another most important factor is that the topography of the watershed is undulating and comprises of very high hills along the ridge line, with the elevation varying between 200 m to 400 m above the mean sea level (msl). The elevation gradually decreases from the Southern part (Tikamgarh block, Zone 1) of the watershed towards the North (Jatara block, Zone 4). Therefore, the Ur river also flows in a North-eastern direction till its confluence with the Dhasan River. These factors cause **low groundwater recharge, making groundwater availability a major issue of concern.** The recharging of groundwater resources through collection of rain water in traditional ponds is not taking place due to degradation of such ponds in Zone 1 (Tikamgarh block), encroachment of forest lands, cutting of forests and blocking of the catchment areas of watershed regions. The result is that wells that are being used for drinking water and irrigation are not providing enough water to serve the purpose for the whole year. During the survey, it has been observed that the local populace is hugely dependent on groundwater for its household requirements as well as for irrigation purposes. Water for drinking and for other household purposes is fetched from far off sources by the females of the households, adding to their already burdened normal work load.

- **Migration**: An increasing trend of distress migration is observed in the region. Due to the poor environment and economic conditions, the people are migrating out to other regions in search of better income and opportunities for sustenance. Typically, migration is sought as an adaptive response once the other sources have been already tested for support and proved incapable. Rising input costs and frequent incidence of drought are pushing agricultural labourers and small farmers out of agriculture. Mining of minerals and stone-quarrying has emerged as a major non-agricultural activity. From our field surveys, it has been observed that women also accompany men as they migrate to the cities to work as unskilled labours. Migration has increased as around 70-80% migrates to big cities or towns in search of job opportunities. The migrating population ranges from seasonal to permanent. This leads to migration of large rural population to towns and cities. This has adversely affected the agriculture practices in villages.

  Demographically, imbalanced male-female ratio and caste structures are some of the social dynamics which play a great role in varying sensitivities and adaptive capacities of communities. This highlights that they are still largely restricted to manual labour and have diminished adaptive capacities. Similarly, lower caste communities and below poverty line population are also restricted due to the low resource base and limited income and hence exhibit poor adoption to new and advanced adaptation strategies.

4.2 Some of the key findings from primary assessments (FCM Approach) are as follows:

Climate-related impacts as perceived by communities:

In UR River Watershed, recognising the unavoidability of climate variability and change, have observed an increase in summer and winter temperatures and a decline in precipitation. Climate-related direct and indirect perturbations on livelihoods due to increased summer and winter temperatures, declining rainfall, and frequent natural calamities like heat waves and hailstorms affect natural, human, and financial assets. Agriculture in the region is very sensitive due to its higher dependency on rainfall as agriculture in the region is rain-fed. Communities perceived that increasing temperatures and decreasing rainfall have directly affected agriculture production, fodder availability, have degraded land, water, and forests resources, increased pest invasion, and have deteriorated human and livestock health. Increasing temperatures in winter season is also leading to increased pest invasion, which further reduces agriculture production. The most evident impact of increased summer temperature is decline in water availability; groundwater level has decreased over the years as a result of which drinking water has become difficult to extract. Increased frequency of heat waves during summer has further added stress on people's health and reduced their work efficiency. Scarcity of drinking water increases drudgery among women as they have to travel long distance to fetch water. Increased temperatures and decreased rainfall have led to reduction of forest cover and productivity inhibiting the various ecosystem services obtained by the local people. Increasing temperatures, declining rainfall, and degrading forests have all deepened the climatic changes involving heat waves and erratic rainfall, which has a major contribution to deteriorating human health with combined effect of insects and pests, and decline in rainfall, water, agricultural, and fodder produce. With decline in forest cover, wild animals encroach into the agricultural fields in search of food and destroy crops. Another impact of water scarcity is decreased soil quality and soil moisture which also inhibits agricultural productivity. Decreased agricultural productivity has not only affected food availability but also livestock health and number since crop residue serves as fodder. The farmers are now forced to keep fewer cattle then earlier. Factors such as declining water and fodder availability coupled with increasing temperatures are responsible for declining livestock health and milk production, which in turn affects human health. The decline in agriculture and fodder, along with human and livestock health have caused financial reserves of the communities to reduce, this eventually impact education while limiting livelihood diversification opportunities and access to market. Falling health status has affected the work efficiency of people which eventually has resulted in less earning.

Climate change adaptations as perceived by communities:

Organisational assets have facilitated adaptations via setting up watersheds, afforestation, and pastureland development committees. Village-level forest committees facilitate afforestation activities while other groups deal with forest protection to enhance forest ecosystem services leading to improved fuel wood availability. Watershed development committees have brought community members together to facilitate the construction of check-dams, loose boulder check-dams and water supply drains while raising awareness on water conservation strategies. These improvements have indirectly led to improved financial reserves of the communities. Financial assets including access to credit have been enhancing the adaptive capacity of communities across all three seasons. Access to micro-finance has helped communities to cope up during times of need by providing means of credit and helping financial reserves to improve. Market systems also provide alternatives vis-à-vis procurement of food and fodder which has become more frequent due to climate variability and change. Social assets in the form of social cohesion play an important role in reducing the indirect impacts of climate variability and change including human-wildlife conflict, which has been on the rise due to degrading forests. Physical assets including agricultural inputs, water resource management practices, water infrastructure, health care facilities and alternative sources of green energy contribute towards improving water, agriculture, fodder, land, fuel wood, human and livestock health. However, agricultural inputs are perceived as ineffectual vis-à-vis the above-mentioned strategies.

Impact of increased summer temperature and respective adaptations

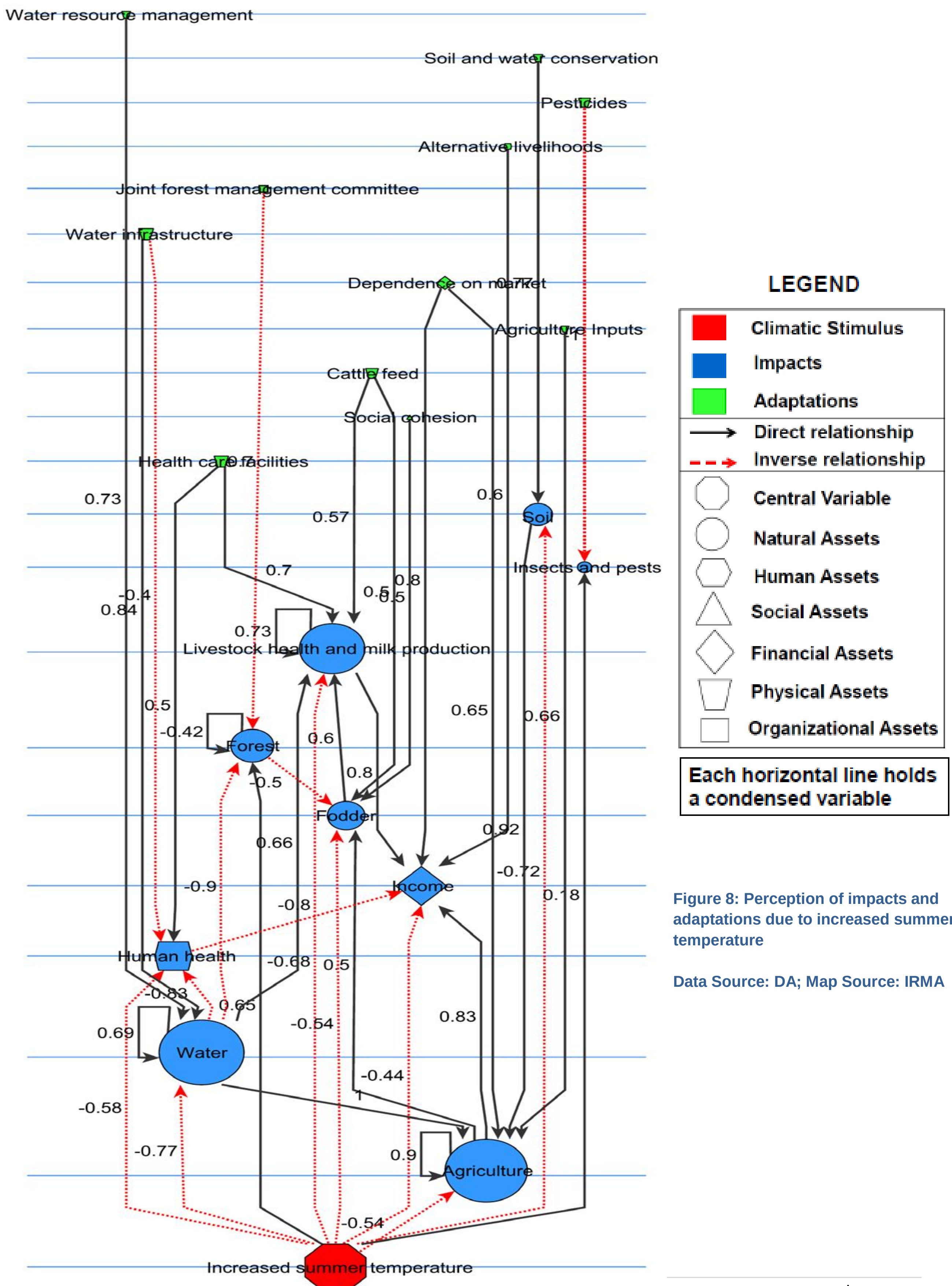


Figure 8: Perception of impacts and adaptations due to increased summer temperature

Data Source: DA; Map Source: IRMA

Impact of decreased rainfall and respective adaptations

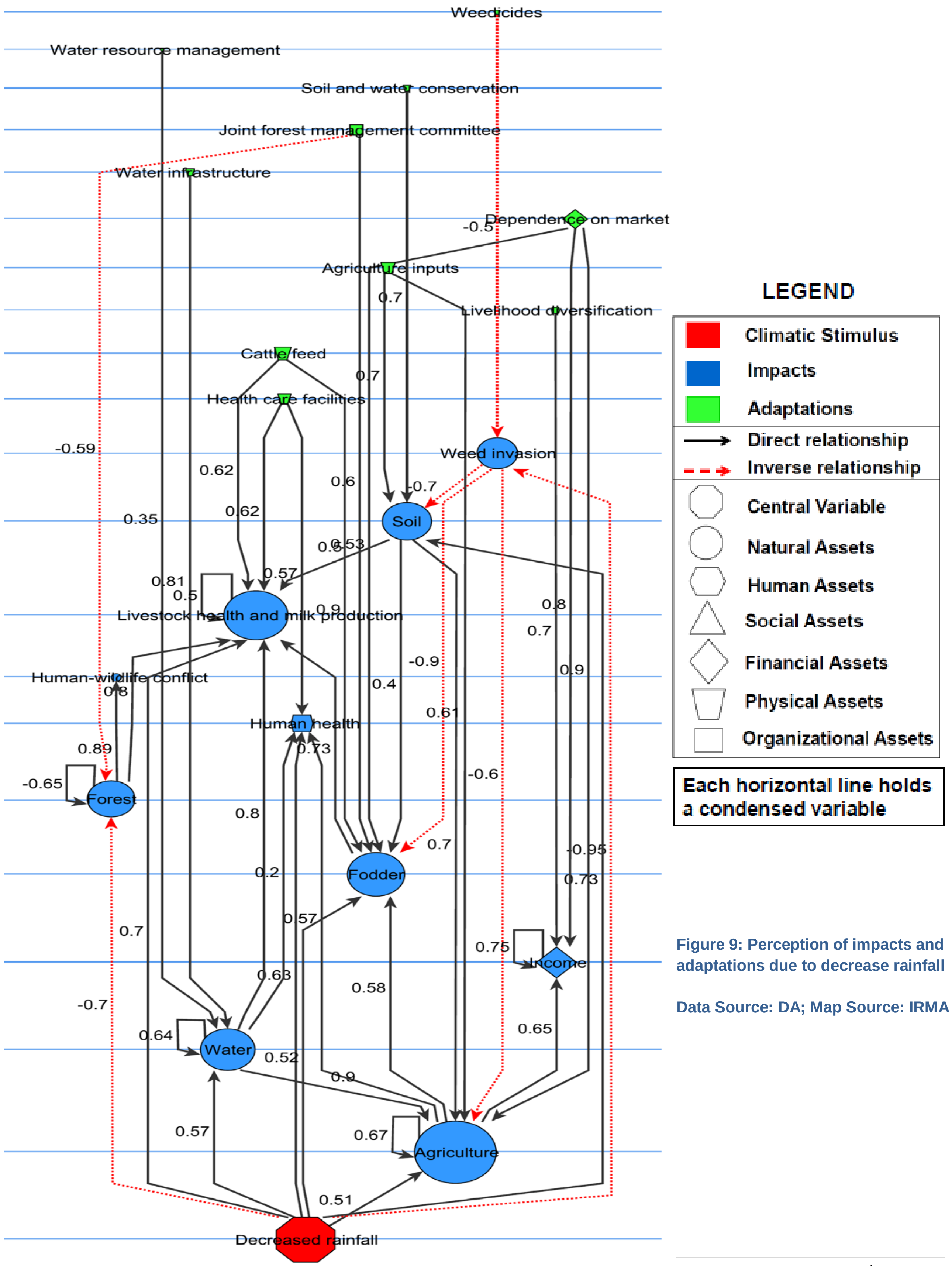
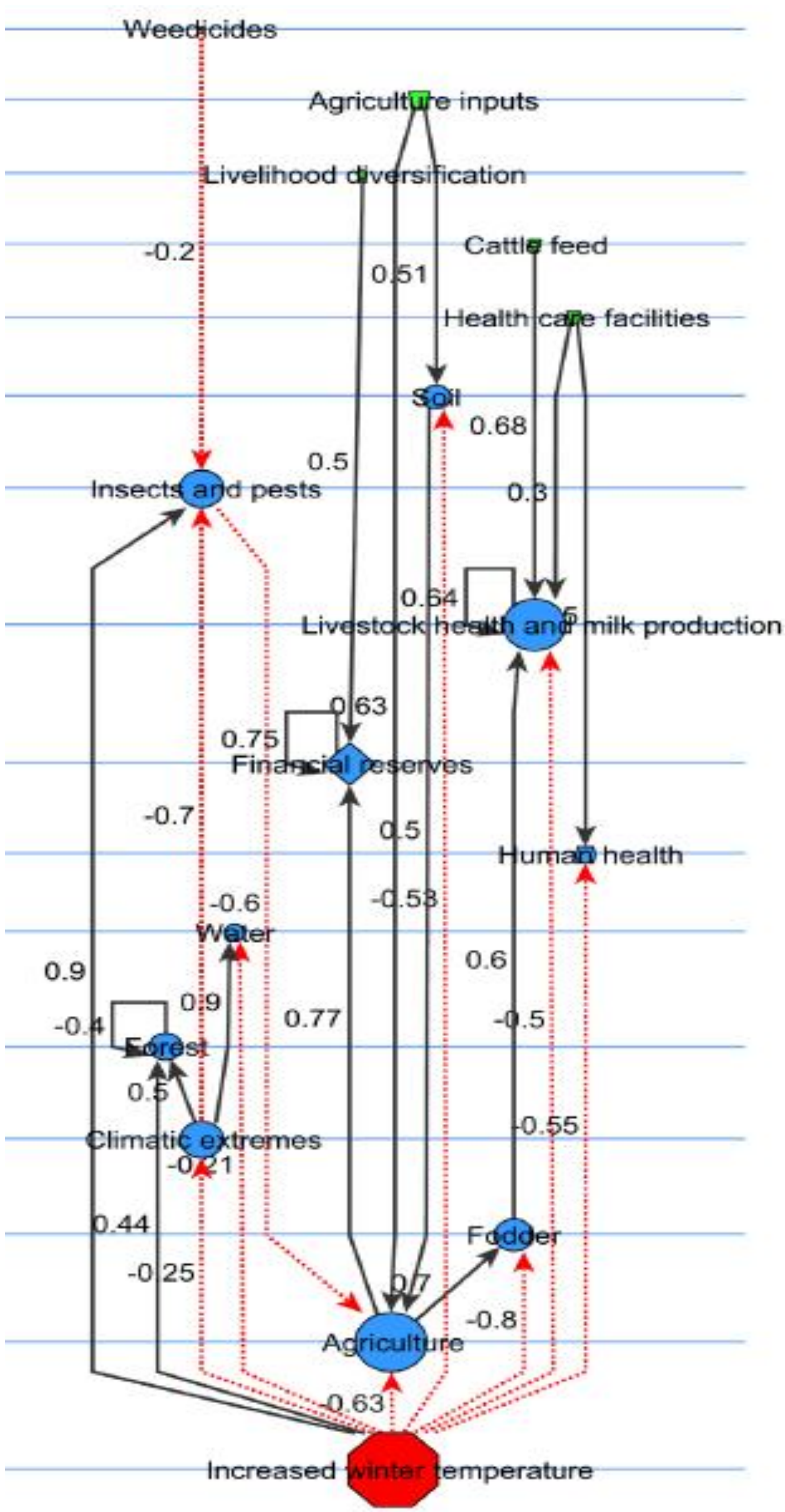


Figure 9: Perception of impacts and adaptations due to decrease rainfall

Data Source: DA; Map Source: IRMA

Impact of increased winter temperature and respective adaptations



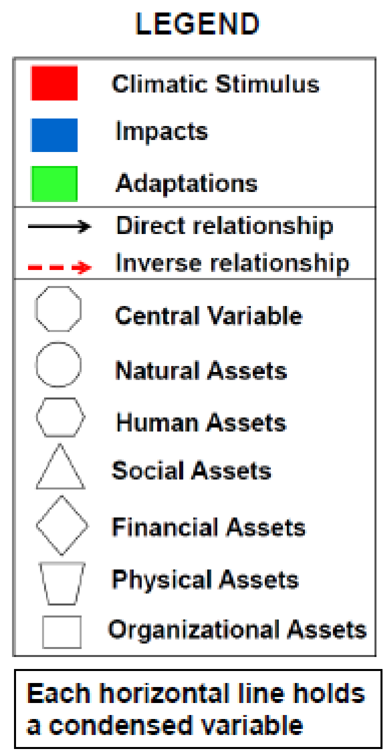


Figure 10: Perception of impacts and adaptations due to increased winter temperature

Data Source: DA; Map Source: IRMA

5. PROPOSED STRATEGIES/SOLUTION FOR UR RIVER WATERSHED

There are several adaptation measures available in the short term and long term perspective which, if incorporated well for the Ur Watershed, can create significant change in the lives and livelihoods of the communities. Currently, there are many existing schemes, policies and practices that have been formulated, implemented and deployed to enhance the livelihoods of rural communities. These actions can be further retrofitted and efficiently implemented to serve the purpose of climate-resilient development. Some of the suggested strategies/solutions based on vulnerability assessment are detailed below.

Suggestive Measures:

Agriculture

- **Usage of improved seeds and varieties like drought tolerant crops and short duration crops:** Can allow crops to better adapt to scarce water situations by shortening the duration of time when water is needed; can also increase cropping intensity by allowing more additional crops to be planted and harvested.
- **Encourage mixed cropping (multi-cropping, intercropping) and crop diversification to reduce risk:** Multi/inter-cropping can reduce the risk of total crop failure and the diversification of crops may increase the overall yield through synergistic effects between each other's.
- **Agro-horticulture and Agro-forestry:** Can help diversify a farmer's crops, increase sustainability, income and productivity of fields through synergistic effects between crops and trees/shrubs as well as increase the natural resource base and/or income through increased production of woody materials.
- **Dry sowing and Line sowing:** Allows for timely planting of crops during dry conditions, which can increase the yield as compared to late sowing by decreasing inter-species competition; uses less seed than the 'broadcasting' sowing technique.
- **Employing different agricultural methods:** Ridge and furrow method allows for water drainage in the case of extreme rainfall; provides better aeration to roots and conserves soil moisture during times of scarce rainfall. Contour cultivation slows the water run-off from hilly slopes, which reduces soil erosion and allows more water to infiltrate the soil.
- **Provision for weather-based crop insurance and fortification of the existing credit scheme linked with insurance:** Weather indexed crop insurance will be better suited to the region as the current insurance is against loss of crops which is complex and not transparent. Also, the number of farmers who are able to avail the facility of insurance schemes is very limited. Efforts are needed to bring a larger number of farmers within the ambit of insurance schemes. *Kisan Credit Card Scheme* was found to have better acceptance among the farmers in the region. The scheme simultaneously insured the farmers against crop loss. Such similar insurance mechanism for the farmers in the region can benefit them in case of crop damage due to weather variability.

- ***Wadi*-little orchards to enhance livelihood security:** It is a tree-based farming model that has helped tribal communities of this region to enhance the food and nutrition security and its focus on integrated farming systems for enhancing income, productivity and livelihood security in a sustainable manner. It has been employed specifically to minimize climatic, biological and marketing risks and provide an opportunity to small and marginal farmers for better management of natural resources and enhance adaptive capacities against climatic risks.
- **System of Rice/Crop Intensification (SRI): Can significantly reduce water and seed requirements for rice while simultaneously increasing the yield significantly.** The System of Rice Intensification, known as SRI, is an agro-ecological methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients.
- The benefits of SRI include 20-100 percent (or more) increased yields, up to a 90 percent reduction in the required seed, and up to 50 percent water savings. SRI principles and practices have been adapted for rain-fed rice as well as for other crops, with yield increases and associated economic benefits. We use 'SCI' as a generic term for all other crops besides rice. For a specific crop, the term is adapted; for example for wheat, System of Wheat Intensification or SWI is used. SRI systems teach us that we can produce more by using less. SRI is a knowledge-based approach, and once farmers have learnt about the new principles, they can become more independent in improving their agriculture. It is fascinating to see the transformation of farmers, who have started working with SRI, becoming so much more confident and entrepreneurial in developing their own innovations.
- **Use of organic fertilizers:** Organic fertilizers like manure, compost and green manures add organic matter to the soil and feed the life that lives within the soil. These are not only cost-effective; they also make the soil rich and ideal for planting. With a good soil, plants will receive the nutrients that they need. Furthermore, organic fertilizers do not upset the balance in the soil as they do not leave behind any artificial compound.

Water:

- **Improved irrigation methods like drip irrigation, sprinkler Irrigation and furrow irrigation:** Can significantly increase water accessibility and fertilizer leakage and water runoff and moisture (both in flood and dry spell); and, it can also reduce labour inputs, water efficiencies or allow large areas of land to be irrigated with relatively little technological inputs.
- **Groundwater recharging structures such as check dams and gabions:** Can help reduce soil erosion and increase water infiltration; and, retained water can be used for crop saving irrigation. Slow rate of infiltration enhance the groundwater level that can be seen in connected well.
- **Farm ponds:** A farm pond is a large hole dug out in the earth, usually square or rectangular in shape, which harvests rainwater and stores it for future use. The pond is surrounded by a small bund, which prevents erosion on the banks of the pond. Such ponds provide irrigation water during dry spells between rainfalls. This increases the yield, the number of crops in one year, and the diversity of crops that can be grown. Bunds can be used to raise vegetables

and fruit trees, thus supplying the farm household with an additional source of income as well as nutritious food. Farmers are able to apply adequate farm inputs and perform farming operations at the appropriate time, thus increasing their productivity and their confidence in farming. These ponds check soil erosion, provide water for domestic purposes and livestock, promote fish rearing, recharge the groundwater, and improve the drainage.

- **Rainwater harvesting:** As the water crisis is becoming severe, there is a need to reform the water management systems so that water could be available to all. Water can be conserved using one such technique called rainwater harvesting, wherein rainwater could be stored and has proven to be an efficient way of conserving water for future needs. It also helps in groundwater recharging through percolation. It will cater to the demands of the people. Rainwater harvesting provides an independent water supply during regional water restrictions and drought conditions. It also helps mitigate the flooding of low-lying areas, and thus reduce the demand on wells which may enable retention of groundwater levels.
- **Weir embankment:** These are the structures around the field that help in retaining the soil moisture, which is exceptionally beneficial in an area of low water availability and in situations like the drought.

Integrated Watershed Management Programme: IWMP provides a good platform for conservation and management of water resources and drought-proofing the semi-arid region of Bundelkhand against the cascading effects of adverse climatic conditions. This programme integrates the Drought Prone Areas Programme (DPAP), Desert Development Programme (DDP) and Integrated Wastelands Development Programme (IWDP) of the Department of Land Resources, with key objectives of drought-risk mitigation, augmentation of land productivity and harnessing the water storage potential of the region. The main objectives of the IWMP are to restore the ecological balance by harnessing, conserving and developing degraded natural resources such as soil, vegetative cover and water. The outcomes are prevention of soil erosion, regeneration of natural vegetation, rain water harvesting and recharging of the ground water table. This enables multi-cropping and the introduction of diverse agro-based activities, which help to provide sustainable livelihoods to the people residing in the watershed area.

Others:

- **Knowledge sharing and communication:** Can help in transfer of knowledge relating to agricultural, water resources, or other adaptation strategies through various channels including workshops, farm visits, plus information and communication technology. The backward regions have always suffered from lack of information, which has quite often termed them susceptible to extreme events. It is important that the knowledge-sharing network of civil society organizations, government authorities and scientific community is strengthened for better communication to benefit the grassroots. Communities can certainly adapt to climate change with validated and relevant information through online software’s like *Sky met*, from where one can easily get information about the weather.
- **Livestock rearing:** Can help reduce agricultural risks and increase the overall income by utilizing marginal lands for grazing and fodder; it can still be susceptible to climatic conditions

that reduce the available grazing lands and fodder. There is a need to improve upon the varieties and breeds of animals.

- **Farmers Adaptation Cluster (FAC):** Farmers Adaptation Cluster is an initiative of Development Alternatives. The initiative commenced with an initial limited sample of 100 small and marginal farmers in Bundelkhand region to explore and adopt, on a pilot basis, measures that would increase the adaptive capacity to drought conditions through the use of sustainable agriculture practices and efficient use of energy and water. Some of these measures included promotion of efficient irrigation, soil conservation methods and agro-forestry, involving demonstration plots and exposure visits of farmers. Although single interventions have limited impacts, putting together different available technical options coupled with institutional strengthening demonstrate significant impacts. Farmers are ready to adopt 'demonstrated beneficial practices' even if these are not formally validated by research /Government institutions.

  Some of the key aspects of FAC include

  - Extension of crop insurance to cover more farmers as the current penetration of the insurance scheme is not adequate.
  - Establishment of “Farmers Adaptation Clubs/Clusters” to bring farmers together to respond to threats of climate change by connecting them to local markets.
  - Enhancing the access to information of farmers by use of innovative platforms such as radio-based Rural Reality Shows and mobile telephony. Access to knowledge and information and cooperative action will enable farmers to enhance productivity, reduce the input costs and bring about a quick change in the strategy when the monsoon variability threatens the Kharif sowing.
  - No cost options such as change in sowing dates have been shown to minimize losses or to actually increase the yields of agricultural crops. Such measures need to be tested at a pilot level for research purposes and then, if found feasible, be scaled up.
  - Increasing the number of information wherein the farmers can attain information about the weather, schemes, agricultural inputs and climate resilient adaptation options viable in Bundelkhand region.

6. CONCLUSION

Some of the short and medium term (2-3 years) measures which may be suggested are:

- Promotion of efficient irrigation, soil conservation methods and agro-forestry, involving demonstration plots and exposure visits of farmers. Although single interventions have limited impacts, putting together different available technical options coupled with institutional strengthening demonstrate significant impacts. Farmers are ready to adopt 'demonstrated beneficial practices' even if these are not formally validated by research /Government institutions.
- Extension of crop insurance to cover more farmers as the current penetration of the insurance scheme is not adequate.
- Establishment of "Farmers Adaptation Clubs/ Clusters" to bring farmers together to respond to the threats of climate change by connecting them to local markets.
- Enhancing the access to information of the farmers by use of innovative platforms such as radio based Rural Reality Shows and mobile telephony. Access to knowledge and information and cooperative action will enable farmers to enhance productivity, reduce input costs and bring about a quick change in strategy when the monsoon variability threatens the kharif sowing.
- As exchange of knowledge is critical to adaptation, there is a need to set up or strengthen the existing knowledge platforms.
- No-cost options such as change in sowing dates have been shown to minimize losses or to actually increase the yields of agricultural crops. Such measures need to be tested at a pilot level for research purposes and then if found feasible, be scaled up.
- Increasing the number of information wherein the farmers can attain information about the weather, schemes, agricultural inputs and climate resilient adaptation options viable in Bundelkhand region.

In the long run, there needs to be a systematic approach to the problem that may consist of:

- Conducting research to identify the best approach to adapt agriculture to climate change by determining the crop mix which would be most resilient to the impacts of climate change in different regions of the state.
- Establishment of a meteorological network in the state to provide customized local information and forecasting services to the farmers that will help in reducing the impacts of climate variability.
- Institutional capacity building will play a crucial role in adapting to climate change by providing appropriate direction and channelization of funds and efforts. Therefore, there is a need of a long term programme for capacity building on key aspects of climate change adaptation.

- The Government of MP needs to review its procurement policy to include/enhance the quota for alternate crops such as sesame for preferential purchase in drought-prone areas.

For decision makers, it has been observed that it is very important for them to understand the relevance of the suggested adaptation options, in case the predictions made by modelling exercises do not happen or happen at a magnitude which is quite less or much more than that predicted. Below is a Robust Matrix, which presents the various adaptation options and how relevant each one of them is in case climate change does not take place, the impacts of climate change are less than that predicted, impacts are as they were predicted and impacts are more than they were predicted to be. The robustness of each one of the adaptation options has been derived from a combination of expert views, consultations and from ground observations directly.

Table 5: Zone wise non-farm and farm-based present livelihood options in Ur River Watershed

	Non-Farm Practices	Farm Practices
Zone 1 – Tikamgarh	NTFP, Livestock, Wood work, Poultry farming, Bamboo – katora making, Dairy	Agricultural Activity (Major - Wheat, soyabean, and urad; Minor- mustard, til) and vegetable farming through tomato, brinjal, pumpkin, coriander and cucumber
Zone 2 – Baldevgarh	Bidi making, Livestock, Poultry farming, Pisciculture, Bamboo-katora making, Dairy	Agricultural Activity (Major - Wheat, soyabean, and urad; Minor- mustard, til and sugarcane) In addition, a few families do vegetable farming and grow tomato, brinjal, bottle gourd, pumpkin, coriander and cucumber
Zone 3 – Palera	Livestock, bamboo - work and Chattai making, Poultry farming, Pisciculture, Pottery making, Bamboo – katora making	Agricultural Activity (Major - Wheat, soyabean, and urad; Minor – sugarcane, mustard, til, sugarcane and paddy) and vegetable farming
Zone 4 – Jatara	Livestock, Bamboo katora and Chattai making, Poultry farming, Pisciculture, Neem seed processing to prepare neem oil, Pottery making, Dairy	Agricultural Activity (Major - wheat, soyabean, and urad; Minor- mustard, til, sugarcane and paddy) In addition, few families do vegetable farming and grow tomato, brinjal, bottle gourd, pumpkin, lady finger, coriander and cucumber

	Zone 1 - Tikamgarh	Zone 2 - Baldevgarh	Zone 3 – Palera	Zone 4 - Jatara
Off farm Practices	Rice hask industry, Seed threshing	Rice hask industry, Seed threshing, Tree Fruits	Tree Fruits, Seed threshing	Agro-forestry, Seed threshing

Annexure 1: Block wise Vulnerability Assessment

Indicators for Vulnerability Assessment at Block Level - Tikamgarh										
Component (C)	**Input**	Scaling can be done from -1 to +1 indicating low to high vulnerability								Output
	Profile (P)	Weightage (Wpi)	Indicators (Ib)	(Ib)	I (min)	I (max)	Indicators Index (Ix)	Profile (P)	Component (C)	Vulnerability Index for Tikamgarh
Exposure	Climate	**3**	Average no of drought events in past 10 years	8	5	10	0.60	**2.17**	**2.20**	**0.62046**
			Average Rainfall (mm) (over the period of (2007-20013)	794.04	500.7	555.04	5.40			
			Average Temperature (oC)	40	35	45	0.50			
Sensitivity (S)	Ecosystem	**3**	per capita forest cover	0.02	0.01	0.15	0.10	**0.45**	**0.35**	
			Ground water table (m)	100	50	150	0.50			
			Wasteland (ha)	21272	14137	23790	0.74			
	Agriculture	**3**	work force in agriculture	46234	41011	66807	0.20	**0.35**		
			Yield/ha	100	50	500	0.11			
			Net irrigated area	32508	25561	35094	0.73			
	Demographics	**1**	rural BPL families	8954	7432	21887	0.11	**0.11**		
Adaptive Capacity (A)	Socio-economic	**7**	no of pump sets/ha agri land	5	2	10	0.38	**0.45**	**0.45**	
			per capita loan	2000	1000	5000	0.25			
			Average Land holding	5	1	8	0.57			
			Livestock population	143315	82983	188136	0.57			
			Number of pukka houses	500	100	1000	0.44			
			Number of health care centers	27	23	37	0.29			
			Number of villages with drinking water access	155	123	171	0.67			

"Assumptions:
1. Weightage of the profile will depend on the no of indicators under it such that within a profile each indicator has equal weightage.
2. Base year 2000-2001
3. For indicator values presented in percentage maximum is considered as 100 and minimum as 0"

Indicators Index (Ix) = [Ib - I (min)] / [I(max) - I (min)]

"Ix = standardized value for the indicator
Ib = value for the indicator for a particular block (b)
I (min) = minimum value for the indicator across all blocks
I (max) = maximum value for the indicator across all blocks"

Profile (P) = (∑ni=1 Ixi) / n

"n= no of indicators in the profileIxi = index of the ith indicator"

"Component (C) = [(∑n i=1 WPiPi) / (∑ni=1 W Pi)]"

Vulnerability Index = (E-A) X Sensitivity

Scaling can be done from -1 to +1 indicating low to high vulnerability

LVI - IPCC (Livelihoods Vulnerability Index) methodology[2]

2 "Reference: 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"

Indicators for Vulnerability Assessment at Block Level - Baldebhgarh										
Component (C)	**Input**	**Scaling can be done from -1 to +1 indicating low to high vulnerability**								**Output**
	Profile (P)	**Weightage (Wpi)**	**Indicators (Ib)**	**(Ib)**	**I (min)**	**I (max)**	**Indicators Index (Ix)**	**Profile (P)**	**Component (C)**	**Vulnerability Index for Baldebhgarh**
Exposure	Climate	**3**	Average no of drought events in past 10 years	8	5	10	0.60	**0.53**	**0.43**	**-0.006**
			Average Rainfall (mm) (over the period of (2002-2007)	591.2	540.7	794.04	0.20			
			Average Temperature (oC)	40	35	45	0.50			
Sensitivity (S)	Ecosystem	**3**	per capita forest cover	0.0174	0.01	0.15	0.05	**0.34**	**0.52**	
			Ground water table (m)	100	50	150	0.50			
			Wasteland (ha)	23640	14137	23790	0.98			
	Agriculture	**3**	work force in agriculture	52986	41011	66807	0.46	**0.60**		
			Yield (crop per unit area of land under cultivation)	100	50	500	0.11			
			Net irrigated area	33044	25561	35094	0.78			
	Demographic	**1**	rural BPL families	18284	7432	21887	0.75	**0.01**		
Adaptive Capacity (A)	Socio-economic	**7**	no of pump sets/ha agri land	5	2	10	0.38	**0.38**	**0.44**	
			per capita loan	2000	1000	5000	0.25			
			Average Land holding	5	2	10	0.38			
			Livestock population	137102	82983	188136	0.51			
			Number of pukka houses	500	100	1000	0.44			
			Number of health care centers	31	23	37	0.57			
			Number of villages with drinking water access	151	123	171	0.58			

"Assumptions:
1. Weightage of the profile will depend on the no of indicators under it such that within a profile each indicator has equal weightage.
2. Base year 2000-2001
3. For indicator values presented in percentage maximum is considered as 100 and minimum as 0"

Indicators Index (Ix) = [Ib - I (min)] / [I(max) - I (min)]
"Ix = standardized value for the indicator

Ib = value for the indicator for a particular block (b)

I (min) = minimum value for the indicator across all blocks
I (max) = maximum value for the indicator across all blocks"

Profile (P) = (∑ni=1 Ixi) / n

"n= no of indicators in the profileIxi = index of the ith indicator"

"Component (C) = [(∑n i=1 WPiPi) / (∑ni=1 W Pi)]"

Vulnerability Index = (E-A) X Sensitivity

Scaling can be done from -1 to +1 indicating low to high vulnerability

LVI - IPCC (Livelihoods Vulnerability Index) methodology[3]

[3] "Reference: 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"

Indicators for Vulnerability Assessment at Block Level - Jatara										
Component (C)	Input	Scaling can be done from -1 to +1 indicating low to high vulnerability								Output
	Profile (P)	Weightage (Wpi)	Indicators (Ib)	(Ib)	I (min)	I (max)	Indicators Index (Ix)	Profile (P)	Component (C)	Vulnerability Index for Jatara
Exposure	Climate	**3**	Average no of drought events in past 10 years	8	5	10	0.60	**0.37**	**0.37**	**-0.183**
			Average Rainfall (mm) (over the period of (2002-2007)	545.4	540.7	794.04	0.02			
			Average Temperature (oC)	40	35	45	0.50			
Sensitivity (S)	Ecosystem	**3**	per capita forest cover	0.05055	0.01	0.15	0.29	**0.60**	**0.70**	
			Ground water table (m)	100	50	150	0.50			
			Wasteland (ha)	23790	14137	23790	1.00			
	Agriculture	**3**	work force in agriculture	66807	41011	66807	1.00	**0.70**		
			Yield (crop per unit area of land under cultivation)	100	50	500	0.11			
			Net irrigated area	35094	25561	35094	1.00			
	Demographic	**1**	rural BPL families	21887	7432	21887	1.00	**1.00**		
Adaptive Capacity (A)	Socio-economic	**7**	no of pump sets/ha agri land	5	2	10	0.38	**0.63**	**0.63**	
			per capita loan	2000	1000	5000	0.25			
			Average Land holding	5	2	10	0.38			
			Livestock population	188136	82983	188136	1.00			
			Number of pukka houses	500	100	1000	0.44			
			Number of health care centres	37	23	37	1.00			
			Number of villages with drinking water access	171	123	171	1.00			

"Assumptions:
1. Weightage of the profile will depend on the no of indicators under it such that within a profile each indicator has equal weightage.
2. Base year 2000-2001
3. For indicator values presented in percentage maximum is considered as 100 and minimum as 0"

Indicators Index (Ix) = [Ib - I (min)] / [I(max) - I (min)]
"Ix = standardized value for the indicator

Ib = value for the indicator for a particular block (b)
I (min) = minimum value for the indicator across all blocks
I (max) = maximum value for the indicator across all blocks"

Profile (P) = (∑ni=1 Ixi) / n

"n= no of indicators in the profileIxi = index of the ith indicator"

"Component (C) = [(∑n i=1 WPiPi) / (∑ni=1 W Pi)]"

Vulnerability Index = (E-A) X Sensitivity

Scaling can be done from -1 to +1 indicating low to high vulnerability

LVI - IPCC (Livelihoods Vulnerability Index) methodology[4]

[4] "Reference: 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"

Indicators for Vulnerability Assessment at Block Level - Palera

Component (C)	Input: Profile (P)	Weightage (Wpi)	Indicators (Ib)	(Ib)	I (min)	I (max)	Indicators Index (Ix)	Profile (P)	Component (C)	Output: Vulnerability Index for Palera
		Scaling can be done from -1 to +1 indicating low to high vulnerability								
Exposure	Climate	**3**	Average no of drought events in past 10 years	8	5	10	0.60	**0.53**	**0.53**	**0.063**
			Average Rainfall (mm) (over the period of (2002-2007)	667.8	540.7	794.04	0.50			
			Average Temperature (oC)	40	35	45	0.50			
Sensitivity (S)	Ecosystem	**3**	per capita forest cover	0.0286	0.01	0.15	0.13	**0.34**	**0.40**	
			Ground water table (m)	100	50	150	0.50			
			Wasteland (ha)	17749	14137	23790	0.37			
	Agriculture	**3**	work force in agriculture	59272	41011	66807	0.71	**0.60**		
			Yield (crop per unit area of land under cultivation)	100	50	500	0.11			
			Net irrigated area	34941	25561	35094	0.98			
	Demographics	**1**	rural BPL families	7576	7432	21887	0.01	**0.01**		
Adaptive Capacity (A)	Socio-economic	**7**	no of pump sets/ha agri land	5	2	10	0.38	**0.38**	**0.38**	
			per capita loan	2000	1000	5000	0.25			
			Average Land holding	5	2	10	0.38			
			Livestock population	153148	82983	188136	0.67			
			Number of pukka houses	500	100	1000	0.44			
			Number of health care centers	27	23	37	0.29			
			Number of villages with drinking water access	135	123	171	0.25			

"Assumptions:
1. Weightage of the profile will depend on the no of indicators under it such that within a profile each indicator has equal weightage.
2. Base year 2000-2001
3. For indicator values presented in percentage maximum is considered as 100 and minimum as 0"

Indicators Index (Ix) = [Ib - I (min)] / [I(max) - I (min)]
"Ix = standardized value for the indicator
Ib = value for the indicator for a particular block (b)
I (min) = minimum value for the indicator across all blocks
I (max) = maximum value for the indicator across all blocks"

Profile (P) = (∑ni=1 Ixi) / n

"n= no of indicators in the profileIxi = index of the ith indicator"

"Component (C) = [(∑n i=1 WPiPi) / (∑ni=1 W Pi)]"

Vulnerability Index = (E-A) X Sensitivity

Scaling can be done from -1 to +1 indicating low to high vulnerability

LVI - IPCC (Livelihoods Vulnerability Index) methodology[5]

[5] "Reference: 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"

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About National Institute of Hydrology (NIH)

National Institute of Hydrology (NIH) is a premier R&D institute in the country, under the Ministry of Water Resources, River Development & Ganga Rejuvenation (GoI), to undertake, aid, promote and coordinate basic, applied and strategic research on all aspects of hydrology and water resources development. The Institute acts as a centre of excellence for transfer of technology, human resources development and institutional development in specialized areas of hydrology, and conducts user defined, demand-driven research through collaboration with relevant national and international organizations. The Institute vigorously pursues capacity development activities by organizing training programmes for field engineers, scientists and researchers, NGOs. Some of the significant contributions of NIH include studies related to augmentation of water supply and water management, glacier contribution in stream flow, watershed development, water quality assessment, water management plan, flood inundation mapping and flood risk zoning.

About MP Council of Science and Technology (MPCST)

The S&T requirements of the State are taken care by the M.P. Council of Science & Technology (MPCST), which is also the nodal agency for the Department of Science & Technology, Government of India, New Delhi. The Council was established in the year 1981 to cater to the needs of Scientific & Technological needs of the state and to advise government on policies and measures necessary to promote utilization of Science & Technology for achieving the socio-economic objectives of the State. The main objective of the Council is to identify area in which S&T can be utilized for achieving the socio-economic objectives of the State, particularly tackling the problems of backwardness, unemployment and poverty in rural areas and among the under privileged sections of the societies viz. SC, ST, Landless labour, artisans, small and marginal farmers and women.

About Development Alternatives Group

Development Alternatives (DA) is a premier social enterprise with a global presence in the fields of green economic development, social equity and environmental management. It is credited with numerous technology and delivery system innovations that help create sustainable livelihoods in the developing world. DA focuses on empowering communities through strengthening people's institutions and facilitating their access to basic needs; enabling economic opportunities through skill development for green jobs and enterprise creation; and promoting low carbon pathways for development through natural resource management models and clean technology solutions.

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