- Making a Difference –

Scientific Capacity Building & Enhancement for Sustainable Development in Developing Countries

Communicating Economic Implications of Climate Change Impacts and Net Benefits of Adaptation Measures to Policy-Makers to Enable them to Take Informed Decisions

Interim Final Report for APN CAPaBLE Project:

CBA2007-06NMY-Mathur

Development Alternatives

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Project Title

Communicating Economic Implications of climate change impacts and adaptation measures to Policy Makers for informed decision making.

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Interim Final Report submitted to APN

Overview of project work and outcomes

Non-technical summary

Bundelkhand region in the central part of India is one of the most backward regions in the country and very low on the development indicators. The poverty rate in the district is 31%. Agriculture is the main source of livelihood of the rural community in the district. As known to all Agriculture is dependent on water source.

The global phenomenon of **climate change** poses a serious risk to poverty reduction and threatens to undo decades of development in the region. As per India's National Communications (NATCOM) to the UNFCCC, the average temperature in the region is expected to increase by 3 to 4.6 ^{O} C while precipitation in the monsoon months is expected to decrease by 10-15% on an average. This is likely to further worsen the already precarious water situation in the region.

However, effective decision making to address this issue requires information on (i) what are the physical impacts of climate change on water resources, (ii) what social costs will be incurred due to these impacts, (iii) what are the different measures to minimize these impacts, and (iv) what are the costs and benefits of these measures. This information has not been estimated at a sub-district level in India. The decision makers are therefore in no position to make informed decisions on incorporating adaptation measures in water resource management planning and minimise any negative climate change impacts.

Objectives

The present project aimed to:

- To produce estimates of net Social Costs incurred due to climate change impacts on the agricultural production in 5 districts of Bundelkhand region.
- To produce estimates of the net benefits of adaptation to climate change impacts on water resources for the purpose of choosing between different adaptation options.
- To build the capacity of state and district level decision makers on mainstreaming adaptation to climate change into the development policies and programmes.

Amount received and number years supported

The Grant awarded to this project was:

- USD 15,000 for Year 1, 2007-2008

Work undertaken

To achieve the above objectives, activities conducted under the project so far have followed a number of steps. The initial step was to secure climate related and other agricultural data. There were significant initial hiccups in finding the appropriate data for the number of years and locations required, which led to 2 consequences, viz, delay in the delivery of project outcomes as well as narrowing down the scope of the project to 3 districts from 5 districts.

The second step was to conduct an economic analysis to estimate the climate change impacts on agriculture production, using an **agro-economic model** developed by Vincent et. al.

As a third step, a consultative meeting was organised with key district authorities to share the information learned The DA team also undertook a consultative assessment of current coping strategies and determining whether these coping strategies will be sufficient to cope in future under the impacts of climate change. At the same time, a process will also be undertaken to consult experts (local agriculture experts and water managers) to identify an array of adaptation options.

As a last step, we have not so far been able to conduct a multi criteria analysis to assess the feasibility of the options identified. This has primarily been due to inability to conduct a much larger workshop with the key decision makers, experts and community leaders in the study sites.

Results

So far the project has managed to estimate the costs, not in monetary terms, but in terms of reduced production, which was found to be more feasible given the project's resources. In addition, the project has also identified a number of adaptation measures that may be promoted to avoid this cost. Some of the key findings of the project so far are:

- The mean maximum temperatures have gone up by 0.28 degree Celsius in the sampling period 1980-2005 as compared the baseline period of 1960-1990. This increase in maximum temperatures is particularly evident in the summer months of March – June.
- The key findings from the climate scenario development are that temperatures throughout the year are likely to be higher in the range of 2-3.5° C in the Bundelkhand region, monsoon precipitation is likely to shift from July to August and winter temperatures to become erratic from the 1960-1990 scenario.
- In determining production and area harvested, the climate variables, especially June – September rainfall (both equations) and Minimum temperature in October - November (production function only) are statistically significant ($P<0.05$). The signs of co-efficient are expected: positive for rainfall and negative for temperature.
- Prediction of the impact of climate change on agriculture reveal a mean percentage decline of 18% of production, significant at 5% significance level in the future time slice 2071-2100. This is a significant change given the already perilous food security situation in the districts.
- A number of adaptation measures are available to reduce this impact. Quantification of the reduction possible by each of the measures however, was beyond the scope of this study.

Relevance to the APN CAPaBLE Programme and its Objectives

The main activity of the project is to estimate and disseminate policy relevant information using scientific knowledge and participatory processes. It therefore subscribes to the science-policy interfacing aspect of the CAPaBLE Programme. Local level decision makers are the primary target of the proposed research project. It has been felt that the level of awareness on climate change issues among state/district level officials is very inadequate. Once their interest and capacity is built on this aspect through this and other complementary projects, climate change adaptation will be mainstreamed in the developmental planning process. This will also ensure that regular channels between policy-makers and the scientific community are established in the project region.

Self evaluation

Despite the project being marred by many barriers and delays, we feel a significant amount of work has been carried out. There is clearly benefit in completing all the proposed activities of the project, which will help in full realization of the previously expected outcomes.

Potential for further work

The study is not yet complete and there are therefore immediate next steps. One, a refinement of the strategies for adaptation needs to be done to narrow them down and make them more policy relevant. Two, a multi-criteria analysis needs to be conducted to prioritise the adaptation options in the short, medium and longer terms. Three, the results of the overall study will need to be disseminated to a wider audience within the study districts, the states and national levels.

Publications

Not Applicable

Acknowledgments

Development Alternatives would like to thank APN who have provided financial support for the implementation of this Project. In addition, we would also like to thank various government departments who have provided us the relevant data such as the Indian Meteorological Department, Indian Institute of Tropical Meteorology, Pune, the Central and State level Statistics Departments etc. We would specifically like to thank the various stakeholders who we have consulted at various stages including District Magistrate of Tikamgarh; CEO, Zila Parishad, Tikamgarh; Director, National Centre for Agroforestry Research (NCRAF), Director, Indian Grassland and Fodder Research Institute (IGFRI).

Technical Report

Preface

Climate change is one of the most important challenges faced by humanity. In order to respond to climate change informed decisions need to be made across all levels. Whereas a number of studies for climate change impacts and implications have been made at the global level studies at regional level are lacking. Therefore there is a need for providing research based options and solutions to the decision makers so as to address the impacts of climate change. The project seeks to demonstrate to the policy makers at the local level the ways to estimate climate change damage costs and deciding on the kinds of investments to be made fro different adaptation measures. This information is lacking at the district level in India. The decision makers are therefore in no position to make informed decision on incorporating adaptation measures in resource management planning and minimise any negative climate change impacts

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1. Introduction

This section should include background information, scientific significance, objectives, and other relevant information leading to the development and justification of the current project.

Bundelkhand region in the central part of India is one of the most backward regions in the country and very low on the development indicators. The poverty rate in the district is 31%. Agriculture is the main source of livelihood of the rural community in the district. As known to all Agriculture is dependent on water source.

Water Scarcity in the Region: Throughout most of the year the residents of the region experience acute scarcity of water for agricultural and domestic use. Most agriculture is single-crop, rain-fed with supplementary water from open wells. Thus, large numbers of farmers are highly dependent on the monsoon rains to recharge these. Water is so precious and important that in certain regions there is a say*, "Gagari na phoote, Chahe Balam mar jaye"*, (The water pot should not be broken even if husband dies).

The global phenomenon of **climate change** poses a serious risk to poverty reduction and threatens to undo decades of development in the region. As per India's National Communications (NATCOM) to the UNFCCC, the average temperature in the region is expected to increase by 3 to 4.6 ^{O} C while precipitation in the monsoon months is expected to decrease by 10-15% on an average. This is likely to further worsen the already precarious water situation in the region.

However, effective decision making to address this issue requires information on (i) what are the physical impacts of climate change on water resources, (ii) what social costs will be incurred due to these impacts, (iii) what are the different measures to minimize these impacts, and (iv) what are the costs and benefits of these measures. This information has not been estimated at a sub-district level in India. The decision makers are therefore in no position to make informed decisions on incorporating adaptation measures in water resource management planning and minimise any negative climate change impacts.

The overall goal of the research project is to minimise the impacts of climate change on vulnerable communities by aiding the decision makers to incorporate climate change adaptation measures in water resource and agricultural management planning in the region.

The specific objectives of the research study are:

- To produce estimates of net Social Costs incurred due to climate change impacts on the agricultural production in 5 districts of Bundelkhand region.
- To produce estimates of the net benefits of adaptation to climate change impacts on water resources for the purpose of choosing between different adaptation options.
- To build the capacity of state and district level decision makers on mainstreaming adaptation to climate change into the development policies and programmes.

2. Methodology

Explain how you carried out the project, which should follow logically from the aims. Depending on the kind of data, this section may contain subsections on experimental details, materials used, data collection/sources, analytical or statistical techniques employed, study field areas, etc. Provide sufficient detail for a technical/scientific audience to appreciate what you did. Include flowcharts, maps or tables if they aid clarity or brevity.

2.1 Literature Review

In the context of estimating impacts of climate change on agricultural sector and the net benefits of possible adaptation options, there have been several attempts at the international scale. Many studies have focused on bringing out approaches to assess climate change impacts and identify adaptation measures. Some others have actually conducted simulations to estimate these impacts, both on particular sectors and economies as a whole. The following paragraphs depict what progress has been made in this field till date *(what is known)* and what are the gaps that need to be filled by further research *(what is not known).*

The first IPCC reports (1990a, 1990 b) contained a discussion of the climate change impacts, the philosophy of adaptation and a list of adaptation options suitable to the range of agriculture sector problems that are expected under climate change. This was followed by the Second IPCC report (1995) that discussed in great detail the potential impacts of climate change on agriculture (both in terms of production and yields) at the river catchment, regional and global scales. It also dwelt on the aspect of climate change adaptation and listed the possible adaptation options for different geographical scales.

In the successive years, several studies have been conducted to assess economic impacts of climate change on agricultural sector and the possible adaptation options. Most of these studies have primarily been of two types, viz. those done by agronomists using standard agronomic models and those done by economists using economic theory and tools. The agronomic studies (Peart et al, 1989; Mearns et al, 1996; Hundal and Kaur, 2002) mostly use physiologically based dynamic crop growth models, such as CERES, InfoCrop etc to simulate crop growth, development and yield taking into account the effects of weather, management, genetics, soil water, carbon and nitrogen. While they provide a range of contrasting interpretations (e.g. Higher temperatures may result in a reduction in yield due to reduced growth period duration, but elevated CO_2 concentrations could counter this (Wheeler et al, 2000), they do provide us the understanding that the form and magnitude of crop responses to CC will not be determined simply by the altered climate and CO_2 concentration, but by localised biophysical conditions as managed by individual farmers.

Schlenker and Roberts (2006) have highlighted that there are two general problems with crop simulation models. First, there is considerable uncertainty about physiological process (functional form) and the many parameters in these highly non-linear models. Given the complex dynamic and non-linear nature of the models, it is not possible to estimate them statistically. If it were possible, many agronomists would be sceptical about the physiological interpretation of these estimates and there are worries about possible misspecification and omitted variables biases. The second critical problem is the assumption of exogenous production systems and nutrient applications: there is no account for behavioural response on behalf of farmers.

In the second category of studies conducted, the economists have linked climate (average weather) to land values, crop yields and profits using simple regression models and more complex structural models. The hedonic approach (Mendelsohn, 1994) linking land values to land characteristics, including climate, can take into account a large degree of behavioral response but suffers from a possible confounding from omitted variables or model misspecification. In addition, in the rural areas of South Asia, land transactions are rare and therefore the land prices do not reflect the present discounted value of land rents into the infinite future.

In a few studies, economists have also tried to predict response of crop yields to climatic changes by combining agronomic and economic tools. Studies of this type include those done for The Gambia (Callaway et al, 2005) and USA (Schelenker, 2006). These kinds of studies, while providing theoretically sound results, have extensive data requirements.

Through these studies, while our understanding of climate change and its potential impacts has become clearer, the availability of practical guidance on adaptation has not kept pace. One important contribution in this arena has been in the third report of IPCC (2001) wherein approaches to assess vulnerability and identify adaptation options have been provided. Additionally, the practical roadmap to formulating adaptation policies has been brought out by Burton et al (2004). It provides guidance on scoping and designing an adaptation project, assessing vulnerability to current and future risks, formulating an adaptation strategy and continuing the adaptation process.

As far as the identification and ranking of adaptation options is concerned, once again several approaches have been followed. Two of the seminal works done in evaluating adaptation options and costing climate change impacts have been *"The Economic Issues relevant to costing climate change impacts" published by the Australian Greenhouse (AGO)* and *"Costing the Impacts of Climate Change in the UK – The Implementation Guidelines"* published by the UK Climate Impacts Program. Both the documents examine and provide guidance on the conceptual and methodological questions involved in evaluating the adaptation measures and estimating the benefits and costs resulting from investment in adaptation measures.

Actual evaluation of adaptation options and their ranking has also been done by several researchers for different contexts. Mizina et al. (1996) evaluated adaptation options for agriculture sector in Kazakastan. They examined the cost-effectiveness and barriers to implementations of adaptation options for climate change. The Adaptation Decision Matrix (ADM) was then applied to estimate benefits using expert judgment (using an arbitrary numerical scale, not monetary values) and benefits estimates were compared to costs to determine cost-effectiveness. In the Kiribati Adaptation programme, the adaptation options have been classified into 4 categories, viz (a) urgent adaptation options which can be done by the communities, (b) urgent adaptation actions for which communities need assistance from the Government, (c) Adaptation options that are less important / urgent, (d) Adaptation options that are not yet needed.

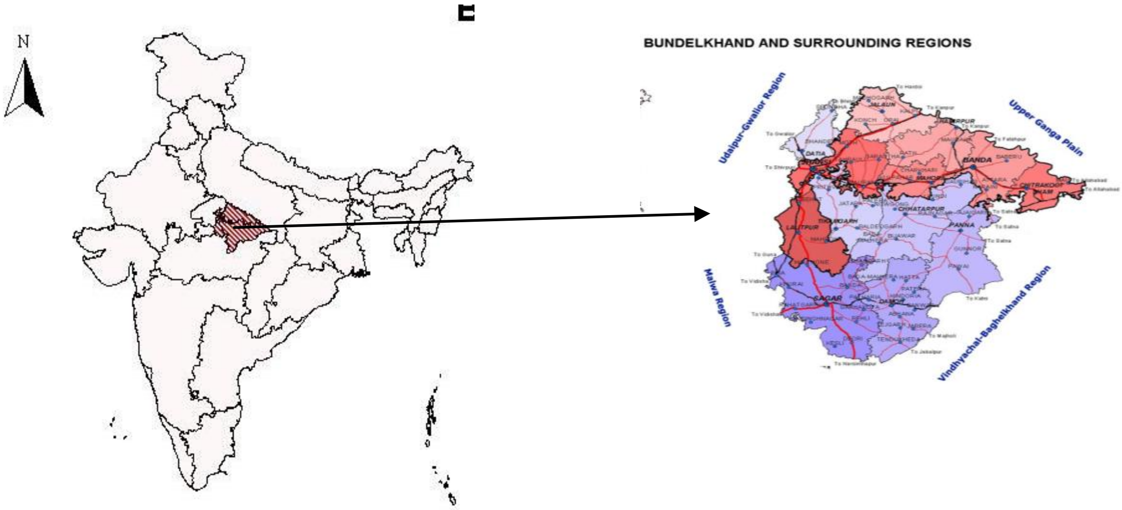
What is not known: At present, most studies have focused on modelling the impacts of climate change at the national or international level. This means that changes and impacts are aggregated over large regions, so the differential impacts of climate change on smaller areas are often lost. Nor is such analysis consistent with the fact that many adaptation decisions are made at the regional or local level. Regional analysis of the economic consequences of climate change is limited by the paucity of regional economic data and the difficulties involved in considering economic and biological interactions between regions. Although research frameworks have been developed to help address these concerns, there are few examples of these being used to facilitate economic analyses at the regional level.

In the case of India also, the above-mentioned issues are applicable. In India's NATCOM, potential changes in the climate have already been estimated and a listing of potential adaptation options derived. Kumar and Parikh (2001a and 2001b) have also examined the impact of climate change on agricultural crop yields, GDP and welfare at the national level. TERI has brought out a District level Vulnerability Index that superimposes potential climate change vulnerability on exposure due to globalisation. None of the studies have however provided region specific insights at a level where decisions regarding economic activities are implemented i.e. the district and the sub-district levels.

2.2 Study Sites

Administratively, the study site comprises 6 contiguous districts, viz. Sagar, Chattarpur, Tikamgarh, Panna, Damoh and Datia in Madhya Pradesh. The area is generally rocky. The climate of the area is the Central India type sub-tropical and may be characterised by a very hot dry summer and cold winter. The usual months of rainfall are from mid-June to the end of September. The literacy rate in the districts is approximately 56% with significant difference between male and female literacy levels.

Agriculture is the main source of livelihood in the region. The principal crops grown in the region are millets, pulses, cotton, oilseeds, gram and barley. The present sources of irrigation are mainly the age-old tanks and ponds, which collect the rainwater during the monsoon season. Besides these, some privately owned open wells and deep tube wells also provide water for irrigation to very small areas. At present the conventional method of applying water through minor irrigation channels, distributaries and water courses is being followed in these areas.



2.3 Study Approach

To achieve the above objectives, activities conducted under the project so far have followed a number of steps. The initial step was to secure climate related and other agricultural data. There were significant initial hiccups in finding the appropriate data for the number of years and locations required, which led to 2 consequences, viz, delay in the delivery of project outcomes as well as narrowing down the scope of the project to 3 districts from 5 districts.

The second step was to conduct an economic analysis to estimate the climate change impacts on agriculture production, using an **agro-economic model** developed by Vincent et. Al.

As a third step, a consultative meeting was organised with key district authorities to share the information learned The DA team also undertook a consultative assessment of current coping strategies and determining whether these coping strategies will be sufficient to cope in future under the impacts of climate change. At the same time, a process will also be undertaken to consult experts (local agriculture experts and water managers) to identify an array of adaptation options.

As a last step, we have not so far been able to conduct a multi criteria analysis to assess the feasibility of the options identified. This has primarily been due to inability to conduct a much larger workshop with the key decision makers, experts and community leaders in the study sites.

2.4 Climate and Other Data Collection

As a first step, the climate data was collected from 3 sources. One, the past climate data on rainfall and temperature was collected from the Indian Meteorological Department, which was able to provide us data for only 3 districts out of the 5 districts chosen. This data is primarily the actually monitored data by the Department from weather stations located within these districts.

The second source of climate data is the Indian Institute of Tropical Meteorology, which has provided the past and future data generated from the PRECIS Regional Climatic Model developed by the Hadley Centre, UK. A state-of-art regional climate modelling system, known as PRECIS (Providing Regional Climates for Impacts Studies) developed by the Hadley Centre for Climate Prediction and Research, is applied for India to develop high-resolution climate change scenarios. The present day simulation (1961–1990) with PRECIS is evaluated, including an examination of the impact of enhanced resolution and an identification of biases. The RCM is able to resolve features on finer scales than those resolved by the GCM, particularly those related to improved resolution of the topography. With a nominal resolution of 50 km versus 150 km for the GCMs, the RCM provides a more realistic representation of orographic features over South Asia. Simulations using PRECIS have been performed to generate the climate for present (1961–1990) and a future period (2071–2100) for two different socio-economic scenarios both characterized by regionally focused development but with priority to economic issues in one (A2 scenario) and to environmental issues in the other (B2 scenario). The data from this source has primarily been used for economic analysis.

The third source of climate data is that from the 'The AWhere Spatial Information System' (SIS), a GIS tool designed for non-specialists and that addresses many of these limitations by providing readily accessible, user-friendly tools designed to help decision-makers integrate vulnerability data. These tools have been used in the study to cross-validate results of other data sources as well as generate graphs and maps.

Besides the climate related data, the other data collected was that of agricultural information of the districts. The prime source of this data is the Annual Statistical Reports published by the Department of Economics and Statistics of the state. The reports are available for some of the years under consideration, while for the other years, data had to be collected from the Agricultural Department primarily and other concerned departments, depending on the requirement. Official data on agricultural inputs, labour inputs, minimum support price and inflation rates has been acquired from www.indiastat.com.

2.5 Agro-Economic Model

For the purpose of economic analysis, we adopted the economic model developed by Vincent et al (Auffhammer, V. Ramanathan, and Vincent, 2006). In line with the said study, we have compiled time-series data on agricultural and meteorological variables for 3 districts that receive monsoon rainfall during June– September and have predominantly rain-fed farms: Jhansi, Tikamgarh and Datia. The model uses 2 stage least squares method and consist of two interrelated equations, a production function and an area demand function.

The production function related annual wheat harvest in each district to area harvested, other agricultural inputs (labour, fertilizer, high yielding seeds, irrigation), and climate (rainfall, temperature). Consideration of crop calendars and previous studies (8–13) led us to test the significance of the seven climate variables.

To analyze the impacts of climate on area harvested, we also estimated an area demand function. This function related area harvested in the current year to area harvested during the previous year, prices of agricultural outputs and inputs, and the same climate variables as in the production function. We estimated the area demand function first, and used fitted values from it in place of the observed values of the area harvested variable when we estimated the production function. This two-stage procedure avoids statistical biases that could result from the simultaneous determination of quantity harvested and area harvested (22).

The intercepts in both equations are allowed to vary across both districts and years, to control for unobserved fixed factors that could cause mean harvest to differ along those dimensions. In line with previous studies (22), we expressed all variables in logarithmic form. The sample period for estimating both equations was 1972–1998, determined by data availability.

The model is specified as follows:

Production Function

$$\mathbf{Y_{it} = c_i + \theta_t + \beta_1 a_{it} + X_{it}\,\beta + Z_{it}\gamma + \varepsilon_{it}}$$

where i denotes district, t denotes year, yit is wheat harvest, ait is area harvested, Xit is a set of variables for other agricultural inputs (labour, fertilizer, high-yielding varieties, irrigation), Zit is a set of climate variables (rainfall, temperature), b1, b, and g are parameters, and eit is the error term. ci and qt are fixed effects for districts and years, respectively. All variables are in natural logarithms except the fixed effects.

The **input demand function** for area harvested is specified as

$$a_{it} = c_i^a + \theta_t^a + \delta_1 a_{it-1} + \mathrm{W}\delta + \mathrm{Z}\varphi + \mu_{it},$$

where a_{it-1} is area harvested during the previous year, W is a set of exogenous economic variables (inflation-adjusted prices of agricultural outputs and inputs), Z is the same set of climate variables as in the production function, δ1, δ, and φ are parameters, and µt is the error term. c_i^a and θ_t^a are again fixed effects for districts and years, and all continuous variables are again in natural logarithms. To correct for the endogeneity between wheat harvest and area harvested, we used the fitted values from this regression, $\hat{a}_{it}$, in place of the observed values of ait when we estimated the production function.

Given the two-equation structure of the agro-economic model, we are able to decompose the impact into a yield effect and an area effect. The yield effect refers to the change in harvest when area harvested is held at its historical level, whereas the area effect refers to the change in area harvested that occurs in response to differences in climate variables between the scenarios.

The impact on agricultural production due to climate change is then derived by taking the percentage difference between wheat harvest under current mean climate conditions and mean projected climate conditions in the future time slice.

2.6 Multi Criteria Analysis Methodology

For prioritising the identified options, the multi-criteria analysis is planned to be used. Although it has not been done so far in the project, a methodology of how it will be done has been developed and will be further evolved as per the situation.

The multi-criteria analysis would be done to prioritise the identified options. The criteria for scoring adaptation options will be:

- the importance of the option in terms of the expected gross benefits that can be obtained
- technical feasibility of the measures,
- cost effectiveness,
- the urgency of the option, reflecting the need to act soon and not later

- the no-regret characteristics of the option (it is good to implement, irrespective of climate change) cultural/social acceptability,
- distributional effects,
- capacity of implementation
- the co-benefits to other sectors and domains and
- the effect on climate change mitigation (for instance through changes in land-use that reduce emissions of greenhouse gases as a side effect)

In defining the criteria we aimed at selecting them as such that they are complete (all relevant criteria have been included), operational (each option can be judged against each criterion), mutually independent (options are independent of each other from one criterion to the next), contain no double counting and are consistent with effects occurring over time (Dodgson et al. 2000; Keeney and Raiffa 1976).2 In the course of conducting the MCA, however, these criteria will be refined and modified, if required to suit the needs of the situation better.

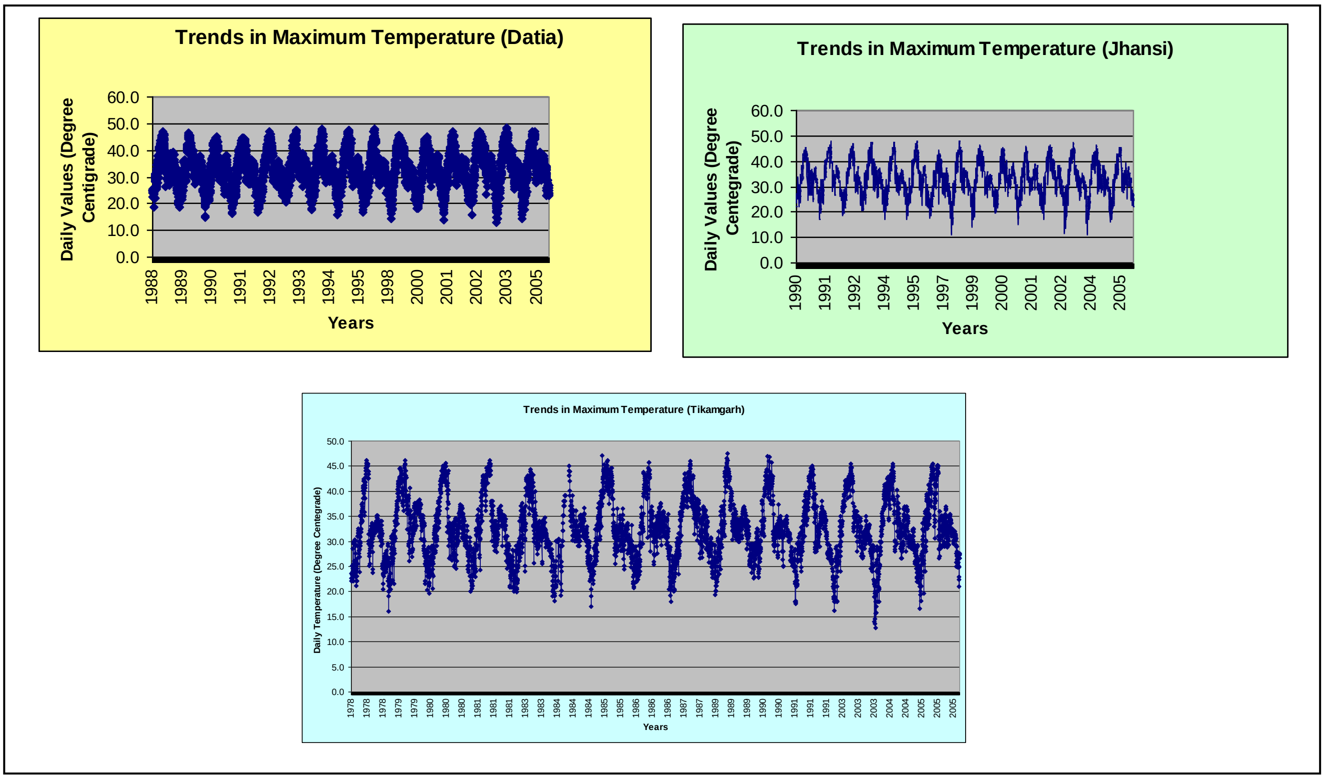
A multi-stakeholder workshop is planned to be organised to take this process forward. In the workshop, stakeholders will be asked to rank the various options based on criteria weighting. In criteria weighting, weights are given to each criterion that are supposed to reflect the preferences of the decision makers and the weighted sum of the different criteria is used to rank the options. The workshop will be so designed so as to derive the weights for different options. Based on the weighting, the prioritising of options is expected to emerge.

3. Results & Discussion

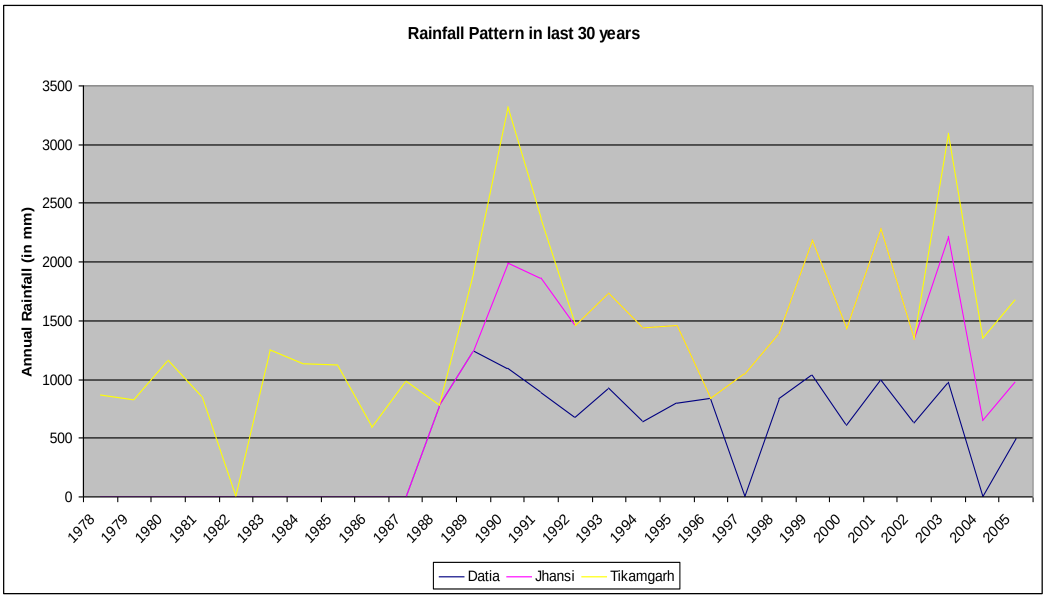
Explain your actual findings, including figures, illustrations and tables. Make comments on the results as they are presented, but save broader generalizations and conclusions for later. Discuss the importance of your findings, in light of the overall study aims. Synthesize what has (and has not) been learned about the problem and identify existing gaps. Recommend areas for further work.

3.1 Climate related findings in the Study Area

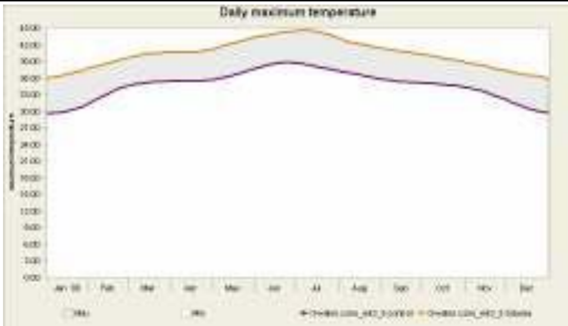
Analysis of the data collected from various sources mentioned above, clearly shows that there is a slight change in the climatic conditions of the 3 study districts. The mean maximum temperatures have gone up by 0.28 degree Celsius the sampling period 1980-2005 as compared the baseline period of 1960-1990. This increase in maximum temperatures is particularly evident in the summer months of March – June.

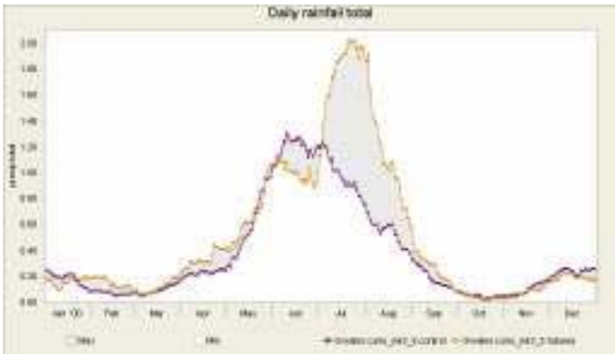


As regards the rainfall, while the region has always been one of scanty rainfall, rains have been highly erratic. The region has been experiencing droughts for the last 15 out of 20 years, as announced by the respective district administrations. However, a trend for the last 30 years cannot be discerned from the available data (which has several missing values).



Analysis of the simulated data generated by the climate models has presented the future climate scenarios. The PRECIS simulations that are made at IITM, Pune pertain to a baseline period of 1961-90 with observed GHG emissions (3 member ensemble) and for one future time slice of 2071-2100 with A2 and B2 GHG emission scenarios (3 runs for A2 and 1 run for B2). Daily meteorological data such as rainfall, max/min temperatures, humidity, vapour pressure, surface winds, solar radiation etc. (daily data on more than 100 meteorological variables are available) from these simulations were utilized for the proposed work. The key findings from the climate scenario development are that temperatures throughout the year are likely to be higher in the range of 2-3.5° C in the Bundelkhand region, monsoon precipitation is likely to shift from July to August and winter temperatures to become erratic from the 1960-1990 scenario. Roughly similar scenarios were also generated by the AWhere Spatial Information System (SIS) (graphical representation shown below).





3.2 Agriculture Impact of Climate Change

Application of the Economic model has yielded some crucial, yet sometimes previously reported results. It may be noted that because of the logarithmic specification of the model, the co-efficients are interpretable as elasticities. The climate variables, especially June – September rainfall (both equations) and Minimum temperature in October - November (production function only) are statistically significant ($P<0.05$). The signs of co-efficient are expected: positive for rainfall and negative for temperature.

Table 1 provides a summary of the coefficients of the production function equation. It shows that positive relationship exists between Total production and Area Harvested, use of high yielding variety seeds, irrigation, fertiliser usage and labour. The rainfall in June to September has less direct significance, because of wheat being a winter crop primarily. For the same reason, there is an inverse relationship with Solar radiation in both the period Oct-Nov and December – February. The second one is a little contrasting with the crop physiological studies that have shown that positive relationship exists between area harvested and solar radiation.

Table 1 Estimation Results for Production Function

Explanatory variables	Coefficient	Standard Errors
Area Harvested	0.821	0.105***
Percent HYV	0.091	0.042
Percent Irrigated	0.342	0.044***
Fertiliser	0.156	0.054**
Labour	0.291	0.122***
Rainfall: Jun - Sept	0.322	0.078***
Rainfall: Oct - Nov	0.155	0.022
Min Temperature: Jun-Sept	0.013	0.544
Min Temperature: Oct-Nov	-0.543	0.433**
Min Temperature: Dec – February	0.422	0.341**
Solar Radiation Oct-Nov	- 0.043	0.453*
Solar Radiation Dec – February	-0.052	0.411*
Constant	-4.233	3.764*

*Note: * = significant at 10%; ** = significant at 5%; *** = significant at 1%*

As regards the Area Demand Function, a positive relationship exists between Area Harvested in year t to that in the previous year, price in the previous year and rainfall in Jun-Sept. A large proportion of land in the study districts being non irrigated, the Jun-September rainfall directly reflects on the water availability for the winter crop as well and therefore the result is not surprising. On the other hand, there is an inverse relationship with Price of Labour, Price of fertilisers, price of the competing crop and solar radiation in Oct-November.

Table 2: Estimation Results of Area Demand Function

Explanatory variables	Coefficient	Standard Errors
Area Harvested (lagged)	0.843	0.089***
Price of labour	-0.061	0.051
Price of fertiliser	-0.083	0.049
Price of wheat (lagged)	0.048	0.054**
Price of competing crop	-0.088	0.173***
Rainfall: Jun - Sept	0.224	0.022***
Rainfall: Oct - Nov	0.155	0.098
Min Temperature: Jun-Sept	0.014	0.194
Min Temperature: Oct-Nov	-0.543	0.088**
Min Temperature: Dec – February	0.027	0.186**
Solar Radiation Oct-Nov	- 0.19	0.453*
Solar Radiation Dec – February	-0.052	0.411*
Constant	-2.759	1.876*

To predict the impact of forecasted climate change on wheat production, we have used the above equations along with the values of the climate variables forecasted for the future time slice. While it is realistic to assume that factors such as prices, labour input, HYV etc will be very different in the future period, their values have been taken to be the means of the sampling period values to derive a difference from baseline situation. The results from this prediction show a mean percentage decline of 18% of production, significant at 5% significance level. This is a significant change given the already perilous food security situation in the districts.

3.3 List of Identified Adaptation Measures

- Using cold frames to allow earlier seeding of plants
- Increasing knowledge of food preservation and canning techniques to respond to winter food insecurity
- Cultivating crops in coconut plantations
- Chemical, mechanical, and biological control of rodents and insects
- Using bamboo stems for drip irrigation during the dry season
- Using bamboo to transport water to irrigate plantations
- Adapting imported sprinklers
- Building diversion structures to irrigate fields
- Utilizing an ancient irrigation and drainage system
- Collecting and storing rainwater in small dams
- Incorporating drought cycle management into community organizations
- Breaking the vicious cycle of decreasing crop yields leading to poverty leading to less seeding
- Crop diversification
- Cultivating appropriate crops in arid regions
- Sharing drought related information between communities
- Cultivating, processing and storing surplus food

- Processing and storing fruits and vegetables
- Protecting food from pests
- Sun drying fruits, vegetables and edible insects
- Harvesting the fruits for oil and protein
- Domesticating wild fruit trees
- Use of wild foods and medicinal plants
- Implementing crop diversification, reforestation with fruit trees, usage of organic fertilizers
- Planting drought-resistant fruit trees to secure income
- Managing common pool resources
- Utilizing Jatropha as hedges and for oil production
- Using crop rotation, relay cropping, and intercropping
- Zero-tillage paddy cultivation
- Enhancing maize yield with organic fertilizers
- Intercropping with banana and utilizing plant residues
- Predicting seasonal events by observing animal and plant cycles
- Predicting rainfall using temperature, plant and animals as indicators
- Predicting drought and weather related diseases
- Farmers use atmospheric indicators, plant features and animal behaviour to predict rain and droughts
- Using meteorological, animal and plant indicators to predict rain and droughts
- Women increase cash income
- Seed priming by soaking in water
- Seed selection and storage
- Soil fertilization for improving water retention capacity of the soil and soil structure
- Temporary land redistribution
- Water allocation among the farming community
- Controlling weed growth through dry straw in paddy fields
- Bunds/ ridges/ terraces for harvesting water and preventing soil erosion
- Harvesting of wild foods such as gathering and domesticating snails and mushrooms
- Domesticating indigenous varieties of cereals and fruit trees
- Diversifying rice-based diets during the flood season
- Using grass barriers to make sloping farm land more weather-resistant
- Promoting measures to suppress fires in event of higher temperatures

4. Conclusions

Restate the study aims or key questions and summarize your findings

The project seeks to estimate the net costs of climate change on agriculture and the benefits of potential adaptation measures for prioritising them and integrating them into mainstream development policies. So far the project has managed to estimate the costs, not in monetary terms, but in terms of reduced production, which was found to be more feasible given the project's resources. In addition, the project has also identified a number of adaptations, measures that may be promoted to avoid this cost. Some of the key findings of the project so far are:

- The mean maximum temperatures have gone up by 0.28 degree Celsius in the sampling period 1980-2005 as compared the baseline period of 1960-1990. This increase in maximum temperatures is particularly evident in the summer months of March – June.
- The key findings from the climate scenario development are that temperatures throughout the year are likely to be higher in the range of 2-3.5° C in the Bundelkhand region, monsoon precipitation is likely to shift from July to August and winter temperatures to become erratic from the 1960-1990 scenario.
- In determining production and area harvested, the climate variables, especially

June – September rainfall (both equations) and Minimum temperature in October - November (production function only) are statistically significant ($P<0.05$). The signs of co-efficient are expected: positive for rainfall and negative for temperature.

- Prediction of the impact on agriculture of climate change reveals a mean percentage decline of 18% of production, significant at 5% significance level in the future time slice 2071-2100. This is a significant change given the already perilous food security situation in the districts.
- A number of adaptation measures are available to reduce this impact. Quantification of the reduction possible by each of the measures however, was beyond the scope of this study.

5. Future Directions

The study is not yet complete and there are therefore immediate next steps. One, a refinement of the strategies for adaptation needs to be done to narrow them down and make them more policy relevant. Two, a multi-criteria analysis needs to be conducted to prioritise the adaptation options in the short, medium and longer terms. Three, the results of the overall study will need to be disseminated to a wider audience within the study districts, the states and national levels.

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Appendices

Appendix –I : Conferences/Symposia/Workshops

Proceedings of Meeting on "Towards a Regional Strategy in Climate Change Adaptation" 15th October, 2008, TARAgram, Orchha, Tikamgarh District

Appendix –II : Funding sources outside the APN

A list of agencies, institutions, organisations (governmental, inter-governmental and/or non-governmental), that provided any in-kind support or co-funding for the project and the amount (s) awarded.

Appendix –III : Glossary of Terms

Acronyms and abbreviations used in the report.

Appendix- I

Proceedings of the Meeting on "Towards a Regional Strategy in Climate Change Adaptation" 15th October, 2008, TARAgram, Orchha.

Context: The **Development Alternatives** Group has been actively working with the communities in Bundelkhand, especially Tikamgarh and Jhansi district in creating sustainable livelihoods, for the last 20 years. As part of its commitment, it has conducted a pioneering research study on key climate risks specific to Bundelkhand, in association with Indian Institute of Tropical Meteorology, **(IITM), Pune**, and Indian Agricultural Research Institute, **IARI, New Delhi.** The research findings suggest that the situation of rural communities in Tikamgarh district are likely to face significant food and livelihoods insecurity due to impacts of climate change on agriculture and water. Urgent action is needed in this regard at the district and state levels.

In order to initiate a collaborative between civil society, research institutions and decision makers on identifying and implementing the measures to reduce the risks of climate change faced by the rural communities, a **half day** meeting of the concerned stakeholders was organized on **15th October, 2008**, at **TARAgram, Orchha**, as a first step towards a **"Regional Strategy in Climate Change Adaptation"**. The meeting was intended to share the scientific findings on key Climate Risks, specific to the Bundelkhand region, and identify the way forward to reduce these risks in the region generally and Tikamgarh district particularly.

The meeting started with welcoming the esteemed participants by Wing Commmander Pramod Sahni, Senior Advisor, Development Alternatives, TARAgram. The first half of the meeting was allocated to sharing the research findings, while the later one was completely dedicated to a moderated discussion on way forward.

Mr. Udit Mathur, gave a detailed presentation on the key research findings. His presentation is summarised below.He started with a brief definition of climate change, describing the climate change scenario projections and its implications on a global level and then at the national level. Thereafter he made a comprehensive presentation of the study with the possible implications for agricultural production and societal vulnerability of the region.

Climate Change

Climate Change may be defined as a long term shift in the average weather of an area. Weather includes average temperature, precipitation and wind patterns prevailing in an area. Climate change in the present context means that the earth has been experiencing a shift in the temperature regime as compared to the average temperature between 1951 and 1980. Data available indicates that there has been an increase in earth's temperature by 0.5 degree Celsius as compared to the average temperature of the last 150 years. If one looks at the very long term data it becomes clear that climate change is not a new phenomenon but rather it has been occurring at a very regular basis in earth's history. However, there has

been an anomaly in the pattern since the beginning of settled agriculture i.e., 10,000 years ago. The anomaly pertains to the rate of change in the temperature. This rate in the increase of temperature has never before been observed in earth's history. The increase in temperature is explained by the increase in emission of green house gasses (carbon dioxide, methane, nitrous oxides, chloro fluoro carbons and sulphur hexa fluoride) to the atmosphere. Green house gasses trap heat leaving the earth's atmosphere thus increasing earth's temperature.
Climate change will have wide ranging impacts, globally, and will severely affect the ability of ecological systems to provide a range of essential ecological goods and services, including food and fiber production, provision of clean and sufficient water, maintenance of biodiversity, maintenance of human health and storage and cycling of carbon, nitrogen and phosphorus.

Challenges for India:

Climate change is a major global environmental problem and an issue of great concern for India. The most vulnerable – the poorest – will suffer earliest and most. Adaptation to climate variability and change and mitigation of green house gas emission are essential to respond to the emerging impacts of climate change.

The surface air temperature in India is expected to rise by + 2 to 4° C by 2070-2100. Climate change is expected to affect the food security, natural resources, economic activities and human health. The sector specific impacts projected by different studies for India, is summarized:

- Agriculture – upto 30% decrease in crop yield in rain-fed areas (60% area in India is rainfed) threatening country's food security.
- Severe water scarcity - due to receding Himalayan glaciers and overall decrease in the number of rain days over a major part of the country, with a greater decrease in western and central regions by 2041-2060.
- Increase of extreme events (droughts, floods, cyclones)
- Sea level rise, storm surges and an increasing frequency of cyclones will affect low-lying deltas and coastlines, with infrastructure and agriculture in coastal regions under increased risk.
- People's health will be affected both directly through increased mortality from extreme temperatures and weather events, and also indirectly through increased incidence of vector-borne diseases and poorer nutrition.
- A shift in forest biomes. (tropical dry forest and tropical seasonal forest become dominant, replacing moist savanna)

Government of India's Initiatives:

At the national level, the integration of climate change in national development is guided by the **Prime Minister's Council on Climate Change**, which includes representation of key Ministries, as well as experts, and representatives of industry and of media. The Council provides overall strategic guidance on mainstreaming climate change in development, identifies key intervention priorities, and monitors the implementation of these interventions. The **Council** in June, 2008, has come out with a **National Action Plan on Climate Change (NAPCC).** The salient features of the NAPCC are discussed here.

Eight-Missions of the NAPCC

The National Action Plan on Climate Change promises extensive measures to tackle climate change, and seeks to "simultaneously advance economic and environmental objectives". Eight national missions targeted at key areas form the core of the plan. The missions will draw from respective ministries, the Planning Commission, industry experts, academia and civil society.

• The solar mission will be launched to increase the share of solar power in the total energy mix while recognising the need for expanding the scope of other renewable and non-fossil options such as nuclear energy, wind energy and biomass

• The national mission for enhanced energy efficiency will help accelerate the shift to energy efficient appliances

• The mission on sustainable habitats will include a major research and development programme focusing on energy efficiency in buildings, waste management and a modal shift to public transport

• The water mission will seek to optimise water usage, minimise wastage and promote more equitable distribution

• The mission for sustaining the Himalayan ecosystem will include measures for sustaining and safeguarding the glacier and mountain ecosystems, and institute an observation and monitoring network

• The "Green India" mission will enhance ecosystem services including creation of carbon sinks and large-scale afforestation programmes and revival of degraded forest lands

• The sustainable agriculture mission intends to identify and develop new varieties of crops that are thermal-resistant and capable of withstanding extreme weather

• The mission on strategic knowledge will promote knowledge-sharing and enlist the global community to collaborate in research and development of technologies that counter climate change

The present Study:

Climate Change Projections and Implications for Bundelkhand:

Bundelkhand is also not immune to climate change. An increase in the frequency of extreme weather events such as droughts has been observed (past 3 consecutive years of drought). Bundelkhand is a drought prone area and agriculture is in the major part rainfed. Thus, the present study was taken up to communicate the risk of climate change to policy makers and vulnerable communities for planning adaptation strategies at district level on a pilot basis. This is the first ever study of this type in the country. The specific objectives being: to use climate science to assess the vulnerability of the society in general and agriculture sector in particular, to communicate the risk to all stakeholders- especially local decision makers and rural communities and to devise practical adaptation strategies.

Indian Institute of Tropical Meteorology, Pune has generated climate forecasts for all 13 districts of Bundelkhand region using different climate models. The forecast is based on the dataset comprising of daily temperature, precipitation, vapour pressure, wind velocity, sunshine hours and humidity for the time period 1961 to 1990. The forecast mainly represents the A2 scenario of the IPCC (medium changes) and pertains to the time period of 2071 to 2100. It states that the summer temperatures in Bundelkhand will increase by approx. 3.2° C. Daily maximum temperature and minimum temperatures are also expected to rise in future. Monsoon precipitation will shift and winter temperatures will become variable as compared to 1960-1990 scenario.

For studying the impact of climate change on crop production, Infocrop model was used with assistance from Indian Agricultural Research Institute, New Delhi. The crops included for the study were wheat and soybean. Model was calibrated using baseline data of 1990 to 2005 while the projection is for the future time slice of 2071 to 2100. The study estimates that wheat yields might be reduced by 25 to 50 percent, by 2100. Days required for anthesis and maturity may be reduced by 3-12 days due to temperature increase. Additional weeds and pests may crop up and cause losses to the crops. Soyabean is not likely to be affected much. Although, water requirements for both wheat and soyabean crops will be higher.

Social vulnerability study brought out that 40% of the families are joint while 60% are nuclear in nature with 60% living in kachha houses. The percentage of Very Poor peole in the region has increased by 17 % over the last five years. Migration is quite common with 35% having migrated more than five times. Agriculture is the mainstay of the area (72%) and drought has affected the people a lot. The farmers are marginal and access to modern technology is limited. Upto 90% of the farmers are sensitive to climate change. Farmers' risk awareness on climate change and its impact on water and agriculture are very low and they are more concerned with problems such as survival and income. People are averse to experimentation and prefer direct handouts than change in their lifestyles. However, a ray of hope is provided by the faith the people have in the government.

Discussion:

In the next session following the presentation, intense discussions were held by the participants on approaches to address climate change. Participants highlighted the importance of anticipatory strategies rather than response measures. They emphasized the need for awareness generation among the common public on the issue. There was unanimous conclusion that agriculture, water and forestry sectors need attention for enhancing the resilience and coping capacity of the rural people.

The group also felt that we should also look for opportunities arising out of climate change. Concerns were raised about the gap that still exists between Laboratory research and taking it to the farmers' fields. The effective utilisation of different means of communication and extension was emphasized. Some participants were of the opinion that common mass is apprehensive of Government machinery, to which Government representatives reassured of their supportive attitude.

The participants identified broad categories of messages to be conveyed to the community.

- What is Climate Change?

- What might happen in the future?
- How it might affect an individual?
- What might be done to cope with the situation?

Participants opined that information should also flow to the policy makers, not only to the community. Participants discussed few issues regarding type of information. The following issues were raised and ways to tackle them were discussed and agreed by the participants.

1. Information regarding risks and impacts should be **reliable** and **easily understandable** by the common people and other stakeholders. All were of the opinion that the study done was unique in its way as it was for the first time that a study has been done at such a specific area (Bundelkhand region in general and Tikamgarh in particular). The modelling studies done by the premier institutes in India, Indian Institute of Tropical Meteorology, (IITM), Pune on climate projection for the area, and Indian Agricultural Research Institute (IARI), Pusa, New Delhi, on impacts of climate change on crop production in the area were highly appreciated by the participants and they were of the view that the work is highly commendable as well as acceptable internationally.

   The role of Radio, Schools, Traditional media, e-chaupal etc, may be explored in this connection.
2. **Technological Support & Interventions** – The workshop felt that rural communities need to be supported to adjust to the changing climatic conditions with technological support and interventions by the research institutions, line departments and NGOs. Some of the specific measures identified were:

   - New crop varieties and agricultural practices suitable for the changing climate are increasingly being developed. These need to be experimented in field conditions in the region and if successful, need to be transferred to the farmers. For such interventions, total solution packages (known as cultural practices for crops) need to be developed.
   - Extension agencies such as Krishi Vigyan Kendras need to be utilised for dissemination of such new and more suitable measures.
   - Communities also need to be supported in more efficient natural resource management as per the changing climatic conditions. The research institutions volunteered to develop packages for the same while the line departments (agriculture and irrigation) expressed their willingness to take them to the fields.
   - Close cooperation among Research Institutes and relevant Govt Dept. is needed in providing guidance in this regard.

3. **Social Aggregation/cohesion for enhancing coping capacity of the people**. The research findings have clearly brought out that adverse climatic conditions (such as drought) have led to reduced capacity of the communities to cope with the emergencies through information flow, mutual co-operation, collective action and productively accessing support services provided by the government. Based on this, the group felt that building

capacity of the communities needs urgent attention through a variety of policy based measures. Urgent need was felt on making combined efforts by all stakeholders, namely, civil society, research institutes and Government departments. The representatives from the Government present on the occasion expressed their willingness to extend fullest support from their side.

Role of civil society is very important here to act as a facilitator between the community and other stakeholders, namely Government and Research Institutes.

Way Forward in Tikamgarh District
Extensive discussion took place on how to proceed further in a methodical manner. It was decided that a small **core group** may be created as a first step. It was agreed that the core group should consist of representatives from key Govt departments, Research Institutes and representative/s from TARAgram, Development Alternatives. This core group may be provided guidance and vision by an Advisory Group, headed by the DM of Tikamgarh; CEO, Zila Parishad,Tikamgarh; Director, National Centre for Agroforestry Research (NCRAF), Director, Indian Grassland and Fodder Research Institute (IGFRI), and Project Investigator from DA being the other members of the Advisory group. A request to the DM, seeking his consent is to be communicated at the earliest. A request to the CEO, Directors of Research Institutes and concerned Departments, to this effect will also be communicated at the earliest.
The whole discussion was enthusiastically and prudently moderated by Mr. R. Ranjan, Programme Manager, with DA, TARAgram. The meeting concluded with vote of thanks from the moderator.

List of Invitees for the Workshop on 15th Oct, 2008, at TARAgram, Orcha

Local Government Officials: (Tikamgarh District)

Sl. No.	Name	Designation	Contact No.
1	Mr. K.P. Rai	DM	07683 - 242250
2	Mr. M.G. Verma	CEO	07683 - 242296
3	Mr. B.P Singh Parihar	Asst. Director (Hort)	099937423987
4	Dr. K.S. Kiral	DD- In Charge Ag.	09425814173
5	Dr. K.K. Vaidya	Ag Dept	09425167876
6	Mr. Ratmale	Exec Engg. (Irrigation)	09425145821
7	Mr. Alok Khare	Asst. Eng (Irrigation)	09893141310
8	Mr. Ciniami	DFO	07683–242315, 09424791350

Research Institutions

Sl. No.	Name	Designation	Contact No.
1	Dr. A.K. Singh	Director, IGFRI	0510 - 2730666
2	Dr. Dhyani	Director, NRCAF	0510 – 2730214/213, 09451658346
3		BundelKhand University	
4	Dr. Hritick Biswas	Scientist (Sr. Scale), CSWRI	

Appendix- II

Funding sources outside the APN

A list of agencies, institutions, organisations (governmental, inter-governmental and/or non-governmental), that provided any in-kind support or co-funding for the project and the amount (s) awarded.

Untied Nations Institute for Training and Research (UNITAR) executed its project titled 'Risk Communication for Adapting to Climate Change – Communicating Risks to Policy Makers and Vulnerable Community for assisting planning process in adaptation strategy to climate change at district level' in the Bundelkhand region of central India through Development Alternatives. The objectives of the project were (i) to asses vulnerability of agriculture sector to climate change (ii) to design and validate risk communication products to district level decision makers and vulnerable communities (iii) to devise site specific adaptation strategies in one representative district (iv) to promote integration of adaptation strategies into developmental policies of 12 districts (v) to facilitate two way communication between community and policy makers.

Appendix- III

Glossary of Terms

ADM	Adaptation Decision Matrix
APN	Asia Pacific Network
CEO	Chief Executive Officer
CO_2	Carbon dioxide
DA	Development Alternatives
GCM	Global Climate Model
GDP	Gross Domestic Product
IARI	Indian Agricultural Research Institute
IGFRI	Indian Grassland and Fodder research Institute
IITM	Indian Institute of Tropical Meteorology
IPCC	Intergovernmental Panel on Climate Change
MCA	Multi Criteria Analysis
NATCOM	India's National Communication
NAPCC	National Action Plan on Climate Change
NCRAF	National Research Centre fro Agroforestry
NGO	Non-Governmental Organisation
PRECIS	Providing Regional Climates for Impacts Studies
RCM	Regional Climate Model
SIS	Spatial Information System
TERI	The Energy Research Institute
TARA	Technology and Action for Rural Advancement
UNFCCC	United Nations Framework for Climate Change