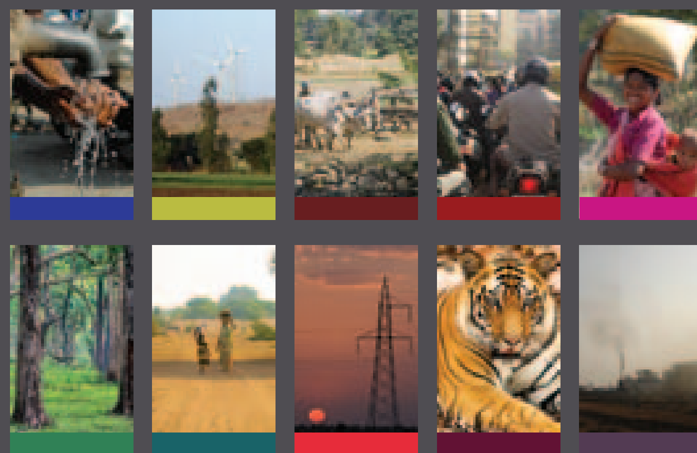
Environmental Planning and Coordination Organisation

Madhya Pradesh State Climate Change
Knowledge Management Centre



Climate change in Madhya Pradesh: A compendium of expert views

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Climate & Development
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State Action Plans on Climate Change (SAPCC): Constraints and challenges

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Introduction

Climate change is not only an environmental concern but also one of the world's greatest developmental challenges. The State of Madhya Pradesh has socioeconomic and ecological reasons to be concerned about the impacts of climate change, as the people of this large State are dependent on climate-sensitive sectors, like agriculture and forestry, for their livelihoods.

Madhya Pradesh is one of the first states in the country to have a State Action Plan on Climate Change (SAPCC) approved by the State Steering Committee and the National Steering Committee, which are headed by the Chief Secretary of the Government of Madhya Pradesh and the Secretary of India's Ministry of Environment and Forests, respectively. Given the socioeconomic profile and agro-climatic diversity of the State, the focus of the action plan is largely on issues relating to adaptation to climate change.

Madhya Pradesh's SAPCC aims to address regional concerns and it outlines the strategies required to develop a climate-resilient state. The strategies and recommendations of the SAPCC will strengthen the developmental planning process of the State with policy-level interventions. The strategies and activities proposed in the Madhya

Pradesh SAPCC by and large conform to the actions proposed in the respective mission documents of the National Action Plan on Climate Change (NAPCC).

Preparation of the SAPCC for Madhya Pradesh

The Government of Madhya Pradesh has accorded high priority to the issues of climate change and has constituted a committee under the chairmanship of the Chief Secretary with the objective of ensuring inter-sectoral coordination and integration of climate change concerns. The Environmental Planning and Coordination Organisation (EPCO), a registered society under the State Government's Housing and Environment Department, has been declared as the State's 'Designated Agency for Climate Change'.

The SAPCC formulation process was quite unique in that it followed a bottom-up approach. It was participatory and ensured multi-stakeholder deliberations at various levels. One-to-one consultations were held with line departments to understand their concerns and priorities at the state level. To get a feel for the regional issues, public consultations were held at eleven agro-climatic zones within the State. In all, 30 consultations were conducted over a period of two years, involving the participation of more than 1,700 people.

Efforts were also made to seek input from academic and research institutes working on climate change issues. Sectoral experts based in Madhya Pradesh were therefore consulted for their expert advice.

Constraints

The Madhya Pradesh SAPCC has been developed on the basis of existing knowledge and information available in the public domain. The compilation of the Madhya Pradesh SAPCC was not without technical constraints and challenges. Some of the key constraints are summarised in this section.

Access to scientific information and data

The Madhya Pradesh experience suggests that at a minimum the following three types of scientific studies are necessary before preparing a good quality and meaningful SAPCC:

- observed and projected climate scenarios, based on regional climate models
- a detailed and methodical 'vulnerability assessment' study, across sectoral, temporal and spatial levels
- greenhouse gas inventories for various sectors, giving likely projections and associated 'marginal abatement cost curves'.

Presently, the states have very limited understanding of these issues and relevant data are very difficult to obtain and access. In the absence of these significant scientific inputs it is very difficult for any state to prepare an SAPCC. Even if a state is called upon to conduct these scientific studies, the required technical capacity and knowledge is lacking.

Commissioning institutes to carry out these studies would entail additional costs and take a substantial amount of time. If external experts are used, then technical capacity within the Government is needed in order to use, understand and potentially customise the data in the future. It would have been better if the pertinent information and data had been made available in advance at the national level by the ministries concerned, to assist states in preparing their respective SAPCCs.

Capacity issues

The science of climate change is emerging and everybody is experiencing a steep learning curve. The understanding of climate change issues within states generally remains quite elementary. There is a great need for building capacity within states for understanding these issues in their context. The enhanced ability of states to appreciate the intricacies of climate change issues will help the states to formulate relevant projects.

Challenges

Implementing the SAPCC

One of the biggest challenges that most of the state governments must grapple with is finding ways and means to implement their SAPCCs – essentially this means mobilising the necessary financial resources.

Implementation of the SAPCCs will require adequate technical expertise and financial support to the states. The projected cost of SAPCC implementation is by and large indicative. It has been difficult for the states to arrive at exact numbers at this stage; for each of the activities suggested in the SAPCC, a detail project report should be prepared. These reports should cover the scope of work, estimated costs and the schedule for implementation. The information in these reports will facilitate a more realistic costing for the SAPCC.

On one hand there is a need to quickly mobilise funds within the State, access central government funds, approach bilateral agencies, and/or attract private investments. On the other hand, it is important to keep in mind the State's current capacities to absorb such large funds. The necessary re-engineering and restructuring for implementation of the NAPCC and SAPCC demands large investments that may bring large returns. Calculating this balance is complex but it starts with simple questions: What are the costs and benefits? Who puts up the money? Who gets the returns?

While the implementation of the SAPCC would largely depend on the actions of particular departments, it also calls for interdepartmental coordination since climate change is a cross-cutting issue. Developing an institutional mechanism that allows vertical and horizontal linkages – with climate change sectoral missions at the national level and state departments and field functionaries at the sub-national level – is yet another challenge that needs to be addressed adequately. The absence of such a mechanism may pose many difficulties, not only in effective implementation of the SAPCC but also in measuring the effectiveness of the interventions made.

Integrating climate change concerns

An important item on the agenda of each SAPCC is to ensure mainstreaming of climate change concerns into policies and programmes of the state governments. Mainstreaming is an effective mechanism for drawing attention to an issue and also for coming up with possible solutions. But it is easier said than done. Getting the buy-in of all the sectors without being seen as an intruder is a difficult proposition. In order to ensure effective integration, we need to be equipped with the right kind of mainstreaming tools. One such tool could be a checklist to help the department to screen existing policies, programmes and schemes from a climate change perspective, and assess the extent to which they are aligned to the SAPCC.

Monitoring and evaluation

Monitoring and evaluation (M&E) is an essential part of the action plan on climate change. In order to effectively monitor the implementation of the action plan, we need an institutional framework and sectoral baseline data. Baseline studies should be carried out before the actual field-level implementation of the SAPCC. The process of developing a set of criteria and indicators and formulating the M&E framework should be consultative and participative. This will help facilitate the smooth sharing of information and data.

Conclusion

The SAPCC is essentially a dynamic document which offers the flexibility to be revisited and refined as more scientific inputs become available. The State needs to recognise and understand that climate change is essentially an economic externality that includes both social and ecological costs. The next step is to respond and adapt to this reality, and ultimately learn to internalise this externality.

Forestry in Madhya Pradesh: Challenges and opportunities in the face of climate change

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Introduction

Madhya Pradesh is the second largest state in India with an area of 308,245 km^2, constituting 9.38% of the geographical area of the country. It lies between 21°17' and 26°52' N Latitude and 74°08' and 82°49' E Longitude. Physiographically, the State can be divided into four regions: the low-lying areas in the north and north-west of Gwalior, Malwa Plateau, and the Satpura and Vindhyan ranges. The rivers Chambal, Betwa, Sone and Narmada are the State's four most important rivers. Rainfall decreases from south-east and east to north-west and west. The average annual rainfall varies from 800 mm to 1,800 mm and annual temperature ranges from 22.5°C to 25°C (FSI, 2009).

According to the 2001 Census, the total population of the State was 60.35 million, with scheduled tribes constituting 22.3% of the population. According to the 2011 Census, the population of the State is now 72.60 million, which constitutes 6.0% of the country's population (GOI, 2011).

With regard to protected areas, Madhya Pradesh has 9 national parks and 25 wildlife sanctuaries covering an area of 10,814 km^2, which constitutes 3.5% of the State's geographical area. This includes five tiger reserves; namely, Kanha, Panna, Bandhavgarh, Pench and Satpura (FSI, 2009).

Forests of Madhya Pradesh

Forest cover

The forest cover in the State, based on interpretation of satellite data from October–December 2006, is 77,700 km^2, which is 25.21% of the State's geographical area. However, the officially recorded forest area of the State is 94,689.38 km^2 constituting 30.71% of the geographical area of the state and 12.44% of the forest area of the country. In terms of forest canopy density classes, the State has 6,647 km^2 of very dense forest and 35,007 km^2 of moderately dense forest. Reserved Forests constitute 65.36%, Protected Forests 32.84%, and Unclassified Forests 1.8% of the total forest area. The central, eastern and southern parts of the State are much richer in forest compared to the northern and western parts. Per capita forest area in the State is 0.16 ha; more than double the national average of 0.07 ha (FSI, 2009).

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Forest composition

Variability in climatic and edaphic conditions has resulted in significant differences among the types of forest found in Madhya Pradesh. There are four important forest types: Tropical Moist, Tropical Dry, Tropical Thorn, and Subtropical Broadleaved Hill Forests. Based on composition, there are three important forest formations, namely Teak Forest, Sal Forest and Miscellaneous Forests. Bamboo-bearing areas are widely distributed in the State. To obviate pressure on the natural forests, large-scale plantations have been planted in forest and non-forest areas to supplement the availability of fuelwood, small timber, fodder, etc. The total growing stock (volume of timber/wood) is 500 *lakh* m^3, valued at Rs.2.5 *lakh* crores (Forest Department website, undated).

Communities and the forest

Community dependence on forest resources

The population of the State is 72.4% rural and 27.6% urban, with population density being 236 people per km^2 (GOI, 2011). The total livestock population of the State is 40.6 million (Planning Commission, 2008). Among all 54,903 villages in the State, nearly half are located in or near forest areas (GOI, 2011). Being away from the mainstream of development, most of these villagers are dependent on the forest for their livelihoods. In addition to timber, a host of products like leaves, flowers, fruits, bark, seeds and roots, commonly referred to as non-wood forest products, also contribute significantly to the socioeconomic development of the rural communities.

Involvement of communities in forest management

Madhya Pradesh has been a pioneer in implementing Joint Forest Management (JFM). About 63% of the State's forest area is under the JFM regime. As of March 2005 there were 14,173 JFM committees managing 6 million ha of forest area. About 1.7 million families are involved in JFM, of which almost half (0.8 million) belong to scheduled tribes (FSI, 2009).

Climate change and its impact on the forests of Madhya Pradesh

Climate change has the potential to adversely impact forest ecosystems. Probably the climate is the most important determinant of vegetation patterns and has a significant influence on forest distribution, species dominance, plant productivity and the ecology of forests in general (INCCA, 2010). Plant communities are normally associated with certain climate conditions and thus any change in climate is likely to alter forests in different ways. Madhya Pradesh is

Box 1:

Evidence of past impact of climate change on the forests of Madhya Pradesh

Pollen analysis based on a 2-metre-deep sediment core from Kiktiha swamp, Shahdol district, has revealed that between 1,600 and 700 years Before Present (BP), tropical deciduous Sal forests comprising *Shorea robusta* (Sal), *Madhuca indica*, Terminalia, Lagerstroemia and *Aegle marmelos* flourished in the region under a warm and moist climate. Between the 700 and 300 years BP the deciduous Sal forests were succeeded by mixed deciduous forests, which became sparse and less diversified, reflecting a relatively drier climate attributed to the weak south-west monsoon. Since 300 years BP, the modern deciduous Sal forests were re-established with the timely arrival of an active south-west monsoon.

Source: Chauhan and Quamar, 2010

rich in biodiversity, but any adverse impact of climate change on forest ecosystems is bound to affect the communities of the 22,600 forest-fringe villages because of their dependence on forest resources.

According to the Third Assessment Report of the IPCC, forest ecosystems may be seriously impacted by future climate change. Even with global warming of just 1–2°C – much less than the most recent projections of warming during this century (Houghton et al., 2001) – most ecosystems and landscapes will be impacted through changes in species composition, productivity and biodiversity (Leemans and Eickhout, 2004).

Projected shift in forest type due to climate change

According to the IPCC Third Assessment Report, in addition to other threats and pressures, climate change may also endanger forest ecosystems. Though there are uncertainties with respect to projections of the impacts of climate change on forest ecosystems, evidence is mounting that climate change coupled with socioeconomic and land-use pressures is likely to adversely impact forest biodiversity, biomass productivity, carbon sink and/or carbon uptake rates.

An assessment has been made on the climate projection of the Regional Climate Model of the Hadley Centre ('Had RM3') using the 'B2' greenhouse gas emission scenarios for 2085 (i.e. 575 ppm CO_2; a moderate change situation), using the 'BIOME 4' vegetation response model (Ravindranath et al., 2006). Based on this study, the implications for the current and future status of forests in Madhya Pradesh are as follows:

1. Roughly 90% of the State is likely to experience shifts in forest vegetation type (see Figure 1).
2. The state's dominant vegetation type, compared to base-year 1975 characterised by Dry Savanna (roughly 80%) and Moist Savanna (15%), is projected to change to Tropical Seasonal Forest (roughly 10%), particularly in the eastern part of the state and Tropical Dry Forest (roughly 80%) predominantly in the western, central and southern part of the State and roughly 10% of Morena District and the adjoining district in the northern-most part of Madhya Pradesh remaining unaffected as scrub forest.

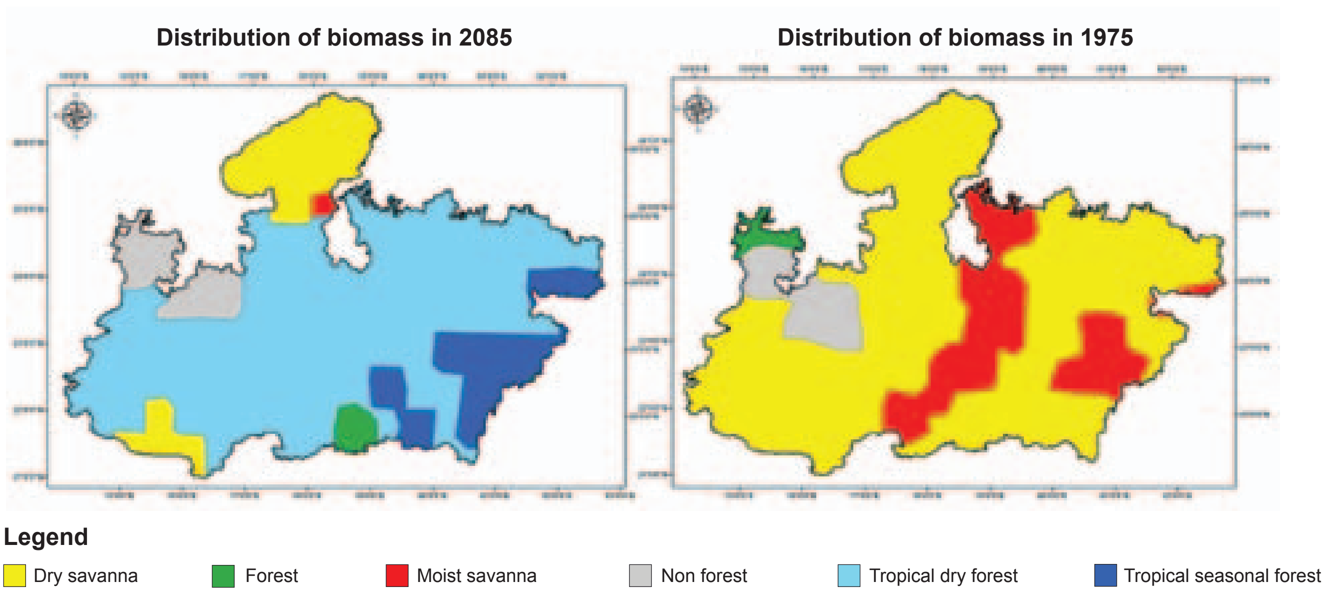
Limitations of the modelling approach to predict the future of the forests

The regional climate models and vegetation response models are being continuously modified to improve the reliability of projections. However, current knowledge of the impacts of climate change may not be adequate for micro-level decision-making on forest management at the state or district level (Ravindranath et al., 2006).

Hence the projected shift in forest type discussed above has to be considered with the caveat that there may not be a total replacement of one forest type by another under the projected climate change scenarios, due to differing climate tolerance of the various plant species in a forest. However, large-scale mortality of tree species is likely under the changing climatic conditions.

Figure 1:

The impact of climate change on the forest biome (B2 Scenario)



Source: Ravindranath et al., 2006

Some projected impacts of climate change on the health of forests

The study by Ravindranath et al. (2006) projected that the effect of future climate change would include increased frequency of climatic anomalies such as droughts, storms and periods of excess rainfall, putting additional stress on trees and forests. Climate change could have both negative and positive effects on forest health and susceptibility to pests and diseases. The negative effects may include: an increase in the rate of multiplication of insect pests due to increased temperatures, thus increasing their destructive potential; and forest dieback due to a combination of greater sensitivity to pests and disease and air pollutants. In Madhya Pradesh, extensive damage was recently caused by the spread of the 'Sal borer', and more such catastrophic epidemics can be expected. In contrast to these negative effects of climate change on forest health, some positive effects may include enhanced growth rates due to elevated CO_2 and temperatures, allowing forests to sustain higher levels of pest and disease damage without reductions in growth and yield.

Climate change could have both negative and positive effects on forest health and susceptibility to pests and diseases.

Facing the challenge of climate change: the way out for the forests of Madhya Pradesh

Given the dismal picture of extremes and uncertainty painted by the scientific studies in relation to the forestry sector, there are three ways to deal with it: do nothing, or attempt mitigation and/or adaptation.

A. Do nothing: Considering the high level of uncertainty about climate change, it is tempting to do nothing. But that would not be a wise strategy, given the risk of damage to forest resources and to society if the projections turn out to be even partially accurate. Any sensitive government would never adopt this strategy.

B. Mitigation: This would involve facing the situation head-on to minimise the problem by addressing the root cause. The root cause of climate change is 'global warming', which is considered to be due to anthropogenic emissions of greenhouse gases. The role of forestry in curbing such emissions is important in the efforts to mitigate the effects of climate change. An important and unique aspect of forests is their capability to convert atmospheric CO_2 into biomass, called carbon (C) sequestration, also known as the 'sink function'. In the interests of mitigation, there are numerous silviculture techniques that can be practiced by the forestry sector to combat the problem of climate change.

With reference to global liability under the Kyoto Protocol, India as a country is not mandated to carry out all such mitigation activities. However, prudence demands that countries like India, as far-sighted members of global society, should do their bit, albeit at a reduced level and scale. Thus, the Government of India has voluntarily agreed to cut emissions in a phased manner. This voluntary responsibility, when translated to the state level, makes it imperative for the state of Madhya Pradesh to also take action in this direction.

There are already incentives provided by market based instruments to develop forest-based projects under the Kyoto Protocol, or voluntary mechanisms. These schemes – mainly afforestation and reforestation under the Kyoto Protocol and more diversified forestry activities under voluntary mechanisms – are acting as a driver, with economic incentives in the form of carbon credits.

For the carbon sink function, economic incentives have been promised by many mechanisms, through the market for the carbon output of forestry (as long as the activity/project is 'additional' and not just business as usual). But the initial euphoria over the very high projected prices for such carbon was short-lived, and with the current price of carbon in the market, any forestry project cannot be economically viable on just carbon as output. But still the carbon credits generated can add a lot of economic value to forestry projects, beyond conventional outputs.

This additional incentive makes it very attractive for any individual, community, private company and even government body involved in growing trees/forestry to grow and manage forests at different scales and for different purposes. However, for getting the final carbon credit, there are different kinds of limitations and restrictions based on the type of forestry project. Hence the complex approval, audit and other processes have a bearing on the economics, finances and legal dimensions of these projects, resulting in poor prices fetched for carbon. But things are improving and prices of carbon have also improved, along with acceptance of the forestry projects (afforestation and reforestation projects under CDM), due to several factors.

Despite being a forest-rich state and still having a lot of barren land with potential for planting trees/forests, Madhya Pradesh is making attempts to tap this opportunity. Some established paper manufacturing companies, which have been successful in neighbouring states, are trying to replicate such 'carbon forestry' in Madhya Pradesh. Districts like Devas, which have a lot of land with good tree cover owned by individuals, are already getting incentives under 'Lok Vaniki Yojana'. This tree/forest-growing culture can further be promoted if the carbon output is also appreciated by the market.

C. Adaptation: This strategy means coping with the situation – if you cannot fight the problem directly then try to adapt to it.

'Adaptation' has two important aspects associated with forestry. First of all, as the forest resources are organic in nature, they are vulnerable to the effects of climate change. Any change in temperature, rainfall and atmospheric carbon content, and different combinations of these changes, will affect the quality of vegetation, which in turn would have on impact on other life forms present in the forests.

Hence, the current breed of forest managers has to anticipate the impending effects of climate change, both in the short and long term. Accordingly, they will have to apply their scientific knowledge of forestry science to help the forests to gear up for change.

The forests are not simply natural resources offering a range of products and services and livelihood opportunities to the surrounding villages (Gitay et al., 2002). The forest-fringe villages of India have long benefitted from the forests. Hence, any change in the health of the forests (including the effects of climate change) would affect the dependent population. Forest-fringe villagers also depend partially on agriculture, which is even more climate sensitive. Therefore,

Box 2:

Glimpses of climate change affecting the forest

The widespread prevalence of 'Sal borer attack' in the forests of Madhya Pradesh is one sign of the effect of a combination of climate factors, causing havoc in the forests in recent times. There have been numerous such instances of disease outbreak in different areas of the State's forests. Though forests have enough resilience to withstand certain changes in climate, there is a limit beyond which they cannot adapt and they will either degrade or perish, giving way to new forms and composition of vegetation.

the locations of these villages near the forests help them to cope with the effects of extreme weather events that affect their crops, by providing alternative products and services to the villagers, including fruits, flowers, water, etc. Thus forests play a very important role in the climate change adaptation strategy, boosting the resilience of the dependent villagers. In this context, the role of forest managers should be widely expanded to improve the health of the forests, using appropriate adaptation strategies to assist the dependent villagers.

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To develop effective adaptation strategies, it is necessary to have a good understanding about climate change impacts. But due to the uncertainties inherent in the climate change parameters and projections, particularly at the regional level, and thus uncertainties about the responses of forest vegetation, it is difficult to suggest effective adaptation strategies at this stage. The climate impact assessment made for the Indian forestry sector using a range of climate models indicates that over half of the country's vegetation is likely to find itself poorly adapted to its existing location, making it vulnerable to adverse climatic conditions and biotic stresses (Ravindranath et al., 2006).

The plan for combating climate change at the strategic level

The punchline of the Stern Review may provide direction to policy-makers: "There is still time to avoid the worst impacts of climate change, if we take strong action now" (Stern, 2006).

In fact, this is one of the most proactive approaches to deal with the uncertainties of climate change in the context of forestry and in general. We cannot afford to sit idle, despite the theorists from the other school of thought urging us not to take hasty action.

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Many reports, including Stern's (2006), have estimated the huge costs of tackling climate change, including both adaptation and mitigation. These costs are prohibitive for a developing state like Madhya Pradesh. While the initial estimates have been the subject of much debate, the second generation of estimates are slightly more refined and realistic, taking into account location-specific data. This underscores the desirability of 'participatory', 'location-specific' and 'decentralised' planning and action. Still, how to justify these huge costs for something that is still not very certain? Expenses to tackle climate change can be justified on the count that many of the suggested activities will lead to savings in terms of energy and reductions in carbon emissions. These 'additional carbon-saving activities' also function to make societies more energy efficient. This approach will guide society onto a more 'low carbon' path.

The future management of forests in the global regime: REDD and REDD+

REDD (Reducing Emissions from Deforestation and Forest Degradation) is the emerging concept and effort to create an incentive for developing countries to protect, better manage and save their forest resources, in order to reduce emissions and thus slow the pace of climate change. REDD+ is yet another emerging concept which goes beyond merely checking deforestation and forest degradation, but also includes incentives for positive elements of conservation, sustainable management of forests and enhancement of forest carbon stocks. REDD+ attempts to provide incentives for demonstrated reduction in deforestation or for enhancing the quality and expanse of forest cover, and these incentives are based on creating a financial value for the carbon stored and enhanced in the biomass and soil of standing forests. Both the REDD and REDD+ approaches incorporate important add-on benefits of livelihoods improvement, biodiversity conservation and food security services. The State of Madhya Pradesh could be a significant beneficiary of these schemes as it already has large areas of forest being managed under the principles of sustainable forest management (SFM). A preliminary taste of this concept has been evidenced in the ad hoc dispensation from the 13th Finance Commission for the State for conserving a large forest area.

At the global level, there is broad interest in conservation of forests and in incentivising such conservation efforts under the REDD concept. Subsequent developments should be closely watched by Indian forest managers.

Box 3:

The desired strategic policy mix for the forestry sector?

- Combating the ills of climate change up-front, i.e. mitigation.
- Apply both adaptation and mitigation side by side.

There is no 'either/or' solution. The low-carbon development path could be the safest bet for the forestry sector. Fortunately, this reflects in the strategy of the Government of India, in approaching the formulation of the National Action Plan on Climate Change (NAPCC). The salient features of the 'Green India Mission' (see Box 4), part of NAPCC, highlight this. The State of Madhya Pradesh is also trying to come out with its own Action Plan, following the established principles and with active involvement of all the stakeholders in the process.

Box 4:

The Green India Mission: India's forestry sector's response to climate change

The Government has put in place a 'National Mission for a Green India' as part of the country's National Action Plan for Climate Change, with a budget of Rs.46,000 crores over a period of 10 years. The overarching objective of the Mission is to increase forest and tree cover in 5 million ha and improve the quality of forest cover in another 5 million ha. Thus, the Mission will help in improving ecosystem services in 10 million ha of land, and increase the flow of forest-based livelihood services to (and incomes of) about 3 million forest-dependent households.

The Mission is innovative in these respects:

1. The Mission proposes a fundamental shift from our traditional focus of merely increasing the quantity of our forest cover towards increasing its quality and improving provision of ecosystem goods and services.
2. The Mission proposes to take a holistic view of greening, not merely focusing on plantations to meet carbon sequestration targets. There is a clear and more important focus on enhancing biodiversity, restoring ecosystems and habitat diversity.
3. There is a deliberate and major focus on autonomy and decentralisation. The Mission will be implemented through an autonomous organisational structure with a view to reducing delays and rigidity, while ensuring accountability.

Furthermore, local communities will be at the heart of implementation. This is in consonance with the fact that forests are a source of livelihoods for over 200 million people in the country, and hence the centrality of their participation is critical. Another key innovation is the idea of engaging a cadre of young 'Community Foresters', most of whom will be from scheduled tribes and other forest-dwelling communities, to facilitate planning, implementation and monitoring of Mission activities at the local level.

Source: MOEF, 2010

Epilogue

Forestry in Madhya Pradesh is in a transitional phase because of the imperative imposed by the factors of climate change, which may further be accentuated or triggered by subsequent changes in policies, social values and the broader economy. Since the forests are such a valuable resource for people (both directly and indirectly, for every segment of society), it becomes extremely important for society to anticipate and cope with this change, by way of changed understanding, changed perceptions and changed expectations of the forests. Similarly, the various responsible agencies, like the Forest Department, the Forest Corporation, the Agricultural Department and the Horticulture Department, as well as the community, individuals and industry, which either own or manage forests or tree cover under different tenurial systems, need to understand and change their perspectives to bring change in forestry management. But this is not easy to achieve given the uncertainty (in terms of quality and quantity) of the evidence of climate change and uncertainty of adequate support from the policy environment. Yet as one of the nation's most forward-looking states, Madhya Pradesh cannot afford to lag behind in its preparedness to face this new challenge. It must gear up for it, based on the existing knowledge and

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evidence of climate change, which, if improved in future, may lead to an improved plan of action. Only this kind of phased approach is likely to work, given the low reliability of our current scientific predictions on the complex phenomenon of climate change.

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Economics of REDD+ as a mitigation strategy for climate change in Madhya Pradesh

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Introduction

There is clear scientific evidence that the increase in greenhouse gases, which are contributing significantly to global warming and climate change, is caused by anthropogenic sources. Impacts of climate change have been studied across various sectors and it is well established that it affects many biological and physical systems. Impacts include poleward and altitudinal shifts of plant and animal ranges, earlier flowering of trees and emergence of insects, and uncertainty in the occurrence of extreme weather events like flash floods, hurricanes and droughts.

Many of these events would directly affect the social and economic well being of the human race. Thus, it is essential to assess the economics of climate change, to serve as an indicator of the extent of damage and form a basis for investments into climate change mitigation and adaptation.

Climate change is a global challenge that is leading to changes in biological and physical systems. To estimate the impacts and build capacities to overcome them, it is essential to estimate the costs and benefits.

In terms of economic analysis, greenhouse gas emissions, which cause planetary climate changes, represent both an environmental externality and the overuse of a common pool resource (Harris and Codur, 2008). An understanding of the economics and the valuation of the climate change and its response in terms of ex-ante and ex-post strategies is needed in order to underpin an effective response to this challenge.

REDD+ (see Box 1) is proposed as a mitigation strategy that can incentivise forest-dependent communities to conserve and enhance forests. The forests of Madhya Pradesh have been valued and three villages are identified where joint forest management (JFM) as an institutional framework could claim the benefits of REDD+, using conservation finance to reward and compensate the communities engaged in protecting and enhancing forest cover.

Case study: valuing forest carbon in Madhya Pradesh

The state of Madhya Pradesh is endowed with rich and diverse forests, covering 25% of the geographical area (FSI, 2009) comprising very dense, moderately dense and open forests. The primary species found in the forests are teak (*Tectona grandis*) and sal (*Shorea robusta*). In this case study, an economic value of the net carbon stored, comprising carbon storage and sink values, is estimated using the market price approach, based on IPCC (Intergovernmental Panel on Climate Change) methods to estimate carbon storage services for forests. Forest

Box 1:

REDD and REDD+

REDD+ is a mechanism to incentivise forest conservation and enhancement. It stands for Reducing Emissions from Deforestation and Forest Degradation through sustainable forest management (SFM) and afforestation and reforestation (A/R). The '+' signifies the enhancement of the carbon stock and subsequent increase in the forest area.

REDD+ is a market-based mechanism at its nascent stage that has captured global interest through its potential to deliver reductions in carbon emissions and co-benefits. Countries are currently preparing to be 'REDD Ready', with pilot projects undertaken through various multi-bilateral initiatives such as World Bank Forest Carbon Partnership Facility (FCPF) and the UN REDD programme (Lal et al., 2011).

Survey of India (FSI) data were used for the extents, composition, density, growing stock and annual increment of India's forests (Verma and Vijay Kumar, 2006a and 2006b).

The case study uses a gross valuation (based on the rate of US$6 per tonne of CO_2) and then adjusts the carbon stock due to various diversions and extractions, giving a monetary valuation of the decrease in the carbon stock which indicates the monetary input that would be required through carbon market transactions.

Calculating carbon stocks

The total forest biomass is required to calculate the carbon storage in the trees. This consists of the above-ground (stem) biomass and the below-ground (root) biomass. Table 1 demonstrates that the value of the carbon stock in Madhya Pradesh forests is estimated to be Rs.24,242 crores. To estimate the annual carbon flux, the annual biomass increment and addition of stocks due to afforestation and regeneration, is subtracted from the biomass stock 'leakage' due to fire, harvesting, fuelwood collection, encroachments and conversion of forest land to other land uses is shown in Table 2. Thus, the net worth of carbon sequestered annually is valued at Rs.426.689 crores for 2003–2004.

The financial incentives for increasing the forest carbon stock as demonstrated above can be accessed through international mechanisms like REDD+, which functions by rewarding community participation and generating co-benefits such as biodiversity conservation, regulation of ecosystem services and improved livelihoods.

REDD+ in Madhya Pradesh

The financial flows demonstrated through the valuation of forest stocks have the potential to foster development in forest-dependent communities who are the true forest stewards. Considering three villages under JFM in Madhya Pradesh, Verma et al. (2010) estimated the amount of carbon sequestered in these villages annually and identified JFM as a mechanism to deliver/distribute the financial flows to the primary stakeholders.

The value of carbon sequestration by forest ecosystems indicates the cost of avoiding future global warming by the fixing of carbon. Valuation of any loss of this function of forests requires two parameters: an estimate of the future damage from global warming and the net release of carbon to the atmosphere from conversion of a forest ecosystem to an alternative land-use (Pearce and Moran, 1997). The geographic details of the three villages identified for the REDD+ study are given in Table 3.

Table 1: **Carbon stocks in Madhya Pradesh forests, 2003–2004**

Species	Above-ground biomass ('000 tonnes)	Below-ground biomass ('000 tonnes)	Total living biomass ('000 tonnes) (col 2 + col 3)	Carbon content ('000 tonnes) (0.5*col 4)	Carbon dioxide ('000 tonnes) (3.67*col 5)	Carbon dioxide (US$) (6*col 6)	Value in crores (43.82*col 7)
Sal	38,915	10,507	49,422	24,712	90,690	544,137,786	2,384
Teak	138,771	37,468	176,239	88,120	323,399	1,940,395,163	8,503
Other	217,969	58,852	276,821	138,411	507,967	3,047,801,345	13,355
Total	395,656	106,827	502,483	251,241	922,056	5,532,334,294	24,243

Source: Verma and Vijay Kumar, 2006a

Table 2: **Annual carbon flux in Madhya Pradesh forests, 2003–2004**

Species	Addition in volume ('000 m^3)	Total leakage volume ('000 m^3)	Net volume increment ('000 m^3) (col 3-col 2)	Net biomass increment ('000 tonnes) (col 4*density)	Net carbon content ('000 tonnes) (0.5*col 5)	Carbon dioxide in ('000 tonnes) (3.67*col 6)	Value of carbon stock (US$ thousands) (6*col 7)	Value in Rs Crores (43.82*col 8)
Sal	422.27	1,701.87	-1,279.60	-921.31	-460.66	-1,690.60	-10,144	-44.4493
Teak	2,385.33	7,807.06	-5,421.73	-3,036.17	-1,518.09	-5,571.37	-33,428	-146.483
Others	3,956.53	13,729.69	-9,773.16	-4,886.58	-2,443.29	-8,966.87	-53,801	-235.757
Total	6,764.14	23,238.63	-16,474.50	-8,844.06	-4,422.03	-16,228.80	-97,373	-426.689

Source: Verma and Vijay Kumar, 2006a

Table 3: **Geographical details of selected villages of Madhya Pradesh**

Village name	District	Forest area (hectares)	Type of JFM committee
Khumi	Harda	2,003	Forest Protection Committee
Jhilmili	Seoni	404	Village Forest Committee
Gurshivehra	Balaghat	622	Eco-development Committee
Total forest area (hectares)		**3,029**	

Source: Verma and Vijay Kumar, 2010

The estimation of the carbon stock has been obtained from the difference between the growing stock from 2005 to 2007, from which the annual growth percentage has been deduced. It is assumed that the forest has a uniform annual biomass increment. Hence, over the last decade (2000–2010), approximately 1.2 tonnes per hectare of annual CO_2 equivalent has been generated in the three villages, which should be attributed to increased forest protection and conservation due to institutions such as the JFM committees (Verma et al., 2010).

Using the estimates from Table 4, the JFM committee should be compensated by US$120 to US$600 for their role in conserving forests. This amount represents the compensation that should be awarded for their commitment to protect forests in the past, and can be used for developing better response systems to mitigate and adapt to future climate change, as well as for infrastructural development in the villages.

Utilising REDD+ for carbon stock conservation and enhancement in Madhya Pradesh

REDD+ holds promise to deliver economic benefits for forestry conservation. The State of Madhya Pradesh can benefit from this mechanism and mobilise resources to invest in combating deforestation and enhancing forestry stocks. However, to utlilise REDD+, the State would need to develop considerable baselines datasets demonstrating the prevalent and projected deforestation rates, which can be achieved using a combination of satellite data linked to ground truthing. Current JFM structures can be modified and also used for assessing project activities and interventions that can reduce deforestation, implementation of these activities, and distribution of benefits amongst the community. Implementing community-friendly activities and the sharing of benefits is a crucial

Table 4: **Proposed compensation to each JFM committee and each household**

Village name	No. of households	Total carbon sequestered (tonnes)	Compensation to JFM committees in US$ (Rs.)		Compensation to each household in US$ (Rs.)	
			Min estimate (US$10)	Max estimate (US$50)	Min estimate (US$10)	Max estimate (US$50)
Khumi	35	2,404	24,036 (1.1 million)	120,180 (5.5 million)	687 (31,590)	3434 (157,950)
Jhilmili	80	486	4,856 (0.2 million)	24,280 (1.1 million)	61 (2,800)	304 (14,000)
Gurshivehra	55	747	7,472 (0.3 million)	37,360 (1.7 million)	136 (6,250)	679 (31,000)

1 US$=Rs.46

Source: Verma and Vijay Kumar, 2010

part of the international REDD+ regime. The State can identify potential REDD+ project areas and establish REDD+ committees, with representation from concerned JFM committees and government officials. Lastly, the State must ensure there is a very robust monitoring mechanism in place to assess changes in the forest stock. This monitoring data along with baseline data is crucial to actualise REDD+ benefits.

Conclusion

This paper broadly demonstrates the economics of climate change with the example of the State forestry sector, where financial incentives can help to build resilience towards climate change. Many countries are in the process of estimating the costs for REDD+, which requires data at the primary level and site details. It is a mechanism with a community focus, and has the potential to deliver many benefits including biodiversity conservation, improving livelihoods, and building capacities for reducing vulnerabilities associated with climate change.

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Understanding the livestock–climate interaction to plan sustainable development in the State of Madhya Pradesh

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Introduction

Climate change has always been there; we have lived with it and the evolution of life and human settlement has been closely linked with it. Climate change is reported to have influenced the migration of early humans from Africa to other continents, and later migrations as well. More recently, however, increased human activity and industrialisation have increased the pace of climate change.

The key motivation for this note is the realisation that climate change has a bearing on sustainable development; its intensity is increasing and the impacts will affect the livelihoods of the resource-poor more adversely. Moreover, the livestock–climate interaction is influenced by production systems and is a good example of a 'cause–effect relationship' in which livestock could be at any point in the chain of interaction. Some impacts of climate change could be reversible and some irreversible; a balance could be reached through a proper approach.

This paper highlights hot spots of the livestock–climate relationship and the characteristics and functional roles of livestock production systems, and makes a case for adopting an environment-friendly approach for achieving sustainable livestock development in Madhya Pradesh.

Livestock production systems: global, national and local

Global view of livestock production and changes in production systems

Globally, the livestock sector contributes around 33% of human protein intake, accounts for 40% of agricultural productivity, employs 1.3 billion people and provides a livelihood for 1 billion of the world's poor. The demand for livestock products is increasing the world over, but the rate of increase is higher in developing countries compared to developed countries. The pressure phenomenon, due to the 'push' of high demand and the 'pull' of technology, is bringing about shifts in the livestock sector that have a bearing on the livestock–climate interaction (see Box 1 and Table 1).

Box 1:

A global view of shifts in livestock production systems

- Change in herd size and structure of livestock units.
- Shift to high producing/more uniform animals, resulting in loss of biodiversity.
- Shift from extensive to semi-intensive to intensive livestock production system.
- Increase in use of grains for feeding livestock (even for ruminants).
- Shift from ruminants (dairy/beef) to non-ruminant livestock (pigs) due to higher production efficiency.

Table 1: **Relationship of livestock–environment interaction and production systems**

Problem areas	Production systems / Degree of interaction							
	LLR	LGT	LGH	LGA	MRH	MRA	MIH	MIA
Range utilisation	---	A	A	A	A	A	C	B
Forest utilisation	**C**	A	C	B	A	B	C	C
Waste	A	A	C	C	B	C	C	C
Waste process	A	A	C	C	B	B	B	B
Methane	A	A	B	A	B	A	A	A
Livestock genetics	B	C	A	C	A	B	C	C
Concentrated feed	A	A	B	C	B	C	C	B
Input-cropping	A	A	B	B	A	A	A	A

Interactions: A = strong, B = moderately strong, C = weak.

Production systems: LLR – livestock landless ruminant; LGT – livestock landless temperate/tropical highlands; LGH – livestock grassland humid-subhumid tropics; LGA – livestock grassland arid/semi-arid tropics; MRH – mixed farm rainfed humid-sub-humid tropics; MRA – mixed farm rainfed arid and semi-arid tropics and subtropics; MIH – mixed farm irrigated humid and sub-humid tropics; MIA – mixed farm irrigated arid-semi arid tropics.

Source: Haan, 1995

Production systems and functional roles of livestock in India

India has the largest number of families depending on livestock for their livelihoods and also has the largest population of livestock. The country is emerging as a major producer of livestock products (milk, meat and eggs). The livestock in India have some characteristic features related to production systems and the functions they perform. The features are worth noting since they are not only different from those in most developed countries and some developing African and Asian countries but also have a bearing on the livestock–climate relationship. The characteristics of livestock production systems prevailing in India are summarised in Box 2.

One feature of the livestock systems in India is their multi-functionality – particularly in rural areas. The functions can be grouped into four broad categories, as shown in Box 3.

The relative importance of these functions varies among regions, depending on stage of development and the sociocultural characteristics of the region. These functions also have a bearing on the relationship between livestock and climate.

Box 2:

Characteristics of livestock production systems in India

- Mixed crop/livestock farming and smallholder systems are prevalent.
- There is high diversity and multi-functionality of livestock.
- A large number of rural families depend on livestock for their livelihoods.
- Increasing demand and prices of livestock products provide opportunities for extra income.
- Ruminants, particularly dairy animals, dominate livestock production.
- Feeding is based on a ‘low external input system’ utilising crop residues and by-products
- Distribution of livestock is more equitable than land.

Source: Rangnekar, 2006

Box 3:
Functions performed by livestock

- Output/economic function: food and non-food products and income.
- Input function: draught power, organic manure for crop production, and others.
- Risk coverage/asset function: in times of exigency, e.g. crop failure.
- Sociocultural function: social status and cultural functions.

Source: Rangnekar, 2006

The pressures of increasing demand, urbanisation, development of marketing networks and technological advancements are bringing about changes in livestock production systems in some parts of India. Commonly observed changes include the shift to commercial intensive systems and an increase in herd/flock sizes with high-producing livestock, similar to the global situation shown in Figure 1.

Livestock in Madhya Pradesh

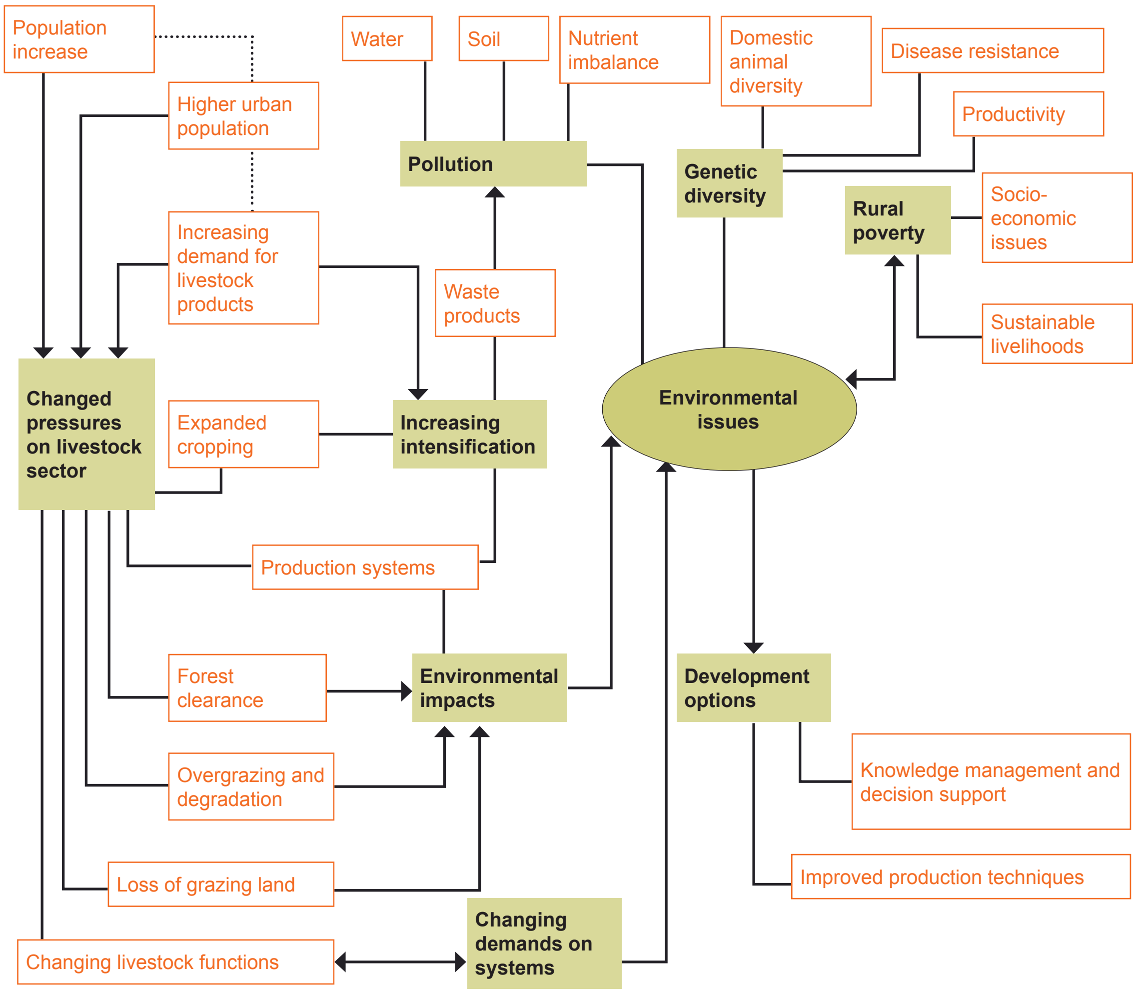
The livestock population of Madhya Pradesh is the third highest among the states in India. Cattle, goats, sheep and buffalo are the main animals and most are classified as 'non-descript'. There are only two recognised breeds of cattle (Malwi and Neemadi) and only one of buffalo (Bhadawari) and none of these are 'dairy breeds'. The dynamics of the livestock population show that during the last 15 years the increase in population was highest for goats, followed by buffalo and cattle, while the poultry population remained static and that of sheep decreased. The increase in the goat population is an indicator of high preference for goats as well as of a decline in feed resources for other livestock. Livestock production systems in Madhya Pradesh are similar to those already described for India; however, there are some subtle differences and the main features are summarised in Box 4.

The contribution of livestock to the State GDP has been maintained at around 9% while that of agriculture has declined from 31% to 23%, indicating the growing importance of the livestock sector for the rural economy.

Like in most other parts of the country, breeding intervention dominates livestock development programmes in the form of cross-breeding with exotic

Figure 1:

An outline of environmental issues related to livestock production



Source: Campbell et al., 2005

Box 4:

Features of livestock in Madhya Pradesh State

- The livestock population is dominated by ruminants and there are very few non-ruminants.
- The majority of livestock (>90%) are classified as 'non-descript'.
- In many districts, the main purposes of keeping cattle are production of bullocks and dung.
- The male–female ratio in cattle is 1.3:1 in tribal areas against 1:1 in non-tribal areas.
- Goats and backyard poultry are kept by almost all tribal families.
- In many districts, livestock feeding is based on forest resources (i.e. tree leaves and pods).

breeds and upgrading with high-potential Indian breeds. This approach to livestock development needs to be critically examined from the perspective of climate change, loss of biodiversity and sustainable development.

Climate–livestock interaction

The climate–livestock interaction is being extensively studied in view of the need for a better understanding of the process and potential impacts, and to investigate possibilities for achieving a balance. The subject has been extensively reviewed from different angles by the International Livestock Research Institute (Thornton et al., 2008), with the added dimension of poverty in view of the hypothesis that the resource-poor would suffer most from the effects of climate change. Swaminathan (2011) has summarised the likely impacts of climate change on crop production, which also have a bearing on livestock, as follows:

- A rise in sea level may submerge large areas in Sunderbans, Andamans and coastal Kerala, among others.
- More frequent floods in the Indo-Gangetic plains and droughts in the arid and semi-arid areas.
- Effects will be more adverse in countries with inadequate coping mechanisms and in areas at lower altitudes.
- A 1˚C rise in mean temperature translates into wheat yield losses of around 6 million tonnes per year in India, due to a reduction in the maturity period.

Impact of climate change on livestock

The impacts have to be considered from both the global and the local perspective, since the significance and implications are different. The impact can be 'direct', wherein variation in climate affects the bio-characteristics of animals, and 'indirect', through the effect of climate change on related factors such as availability of fodder and water, which will affect the health and performance of the animals. It was probably Burns (1946, cited by Mishra and Dixit, 2004) who first drew attention to the effect of temperature and rainfall on the milk yield of cows and the working capacity of bullocks in India. This paper draws heavily from a review by Thornton et al. (2009) on the work done in developing countries, covering all related aspects.

A rise in temperature results in heat stress and causes a reduction in feed intake, growth and production and a decline in the rate of reproduction.

Direct impact: The direct impact of climate change on livestock mainly relates to the rise in atmospheric temperature (warming) and increasing scarcity of water (drought). The 'best estimates' of the Intergovernmental Panel on Climate Change (IPCC, 2007) indicate that the rise in temperature will be between 1.8˚ and 4°C by the end of the century, depending on the intensity of greenhouse gas (GHG) emissions. A rise in temperature results in heat stress and causes a reduction in feed intake, growth and production and a decline in the rate of reproduction. The concepts of 'thermal comfort zone' and 'thermal comfort index' have emerged in the last decade or so. This is based on variation in atmospheric temperature and humidity and defines and identifies regions and periods that are conducive to the expression of production potential. The comfort indices will differ between breeds, and the temperature range tolerated by tropical livestock is much wider than that of temperate livestock (Thornton et al., 2009). Very few studies have been undertaken on this aspect in India and observations are gathered only on a few breeds of dairy animals and their exotic cross-breeds. Singh (2010) presented results of studies on Murrah buffalo, Gir cattle and their exotic cross-breeds carried out at Jabalpur. He stated that buffalo and higher exotic cross-breeds have poor thermoregulatory mechanisms compared to pure Gir and Gir–Jersey cross-breeds. Upadhyaya (2010) presented studies on identifying comfort zones in India and parts of Madhya Pradesh, reporting that such areas and the number of days with a conducive comfort index are very limited. A rise in atmospheric temperature will have an adverse effect on livestock health. Bayliss and Githeko (2006) reviewed a small number of studies available on this aspect and their observations are summarised in Table 2.

Table 2: **Impact of rise in atmospheric temperature on livestock**

Health-related aspects	Impacts
Disease distribution	Shifts in distribution pattern of diseases and emergence of new diseases
Effects on pathogens/ parasites	Rate of development may decrease for some and increase for temperature-sensitive pathogens/parasites
Effects on vectors	May affect distribution, population, feeding and transmission habits as observed with the brown tick and tsetse fly in Africa and Boophilus in Australia

Source: Bayliss and Githeko, 2006

Indirect impact: The indirect impact of climate change on livestock is essentially related to the effect of climate change on the quantity and quality of water, crops and vegetation in general, as these in turn have a bearing on the performance of livestock. The impact is variable since a rise in temperature may improve crop production in high altitude areas and decrease production in low altitude areas (particularly in rainfed areas).

The indirect impact of climate change on livestock is essentially related to the effect of climate change on the quantity and quality of water, crops and vegetation in general, as these in turn have a bearing on the performance of livestock.

- *Water* – Climate change is expected to increase the frequency of droughts in semi-arid and arid areas and the frequency of floods in river basins. Global estimates indicate that the agriculture sector is the largest user of fresh water, using 70% of available fresh water. Competition for water is bound to intensify with increasing demand from other sectors, such as the industrial sector, due to development. Water availability will become one of the main constraints for livestock production. Hence, due care should be taken while planning livestock development in rainfed, semi-arid areas of Madhya Pradesh. Scarcity of water has a direct effect on livestock production, with milk production being most sensitive, followed by growth. A rise in temperature increases the water requirements of livestock from 3 litres per kilogram of dry matter intake at 10°C to 5 litres at 30°C and 10 litres at 35°C. The availability of green fodder also has a bearing on water intake. Although the role of livestock in the global water equation is not well defined, it is strongly debated. Livestock from arid and semi-arid areas have the ability to tolerate limited water availability, but this is not well studied. Water demand models for livestock exist in some countries and can be useful for planning as they contribute to an understanding of the water use efficiency of different types of livestock. A shift to intensive systems would increase water consumption, as is apparent from reports from Australia showing that the water requirements of grain-fed beef production systems range from 15,000 to 100,000 litres per kg of beef.
- *Crops and vegetation* – In general, crops and vegetation are adversely affected by changes in atmospheric temperature, humidity and water availability. In terms of livestock, effects are observed on quantity and quality of feed material available from these sources, which in turn adversely affects livestock production. The nutritive value of crops and vegetation grown under conditions of water stress is poor. Based on the IPCC Fourth Assessment Report and predictions on climate change, the impact on crop yields will be variable: there would be some increase in crop productivity at high altitudes but a decrease at lower altitudes, and in tropical/subtropical areas the crop yields will fall by 10–20% (IPCC, 2007). There is need for caution for Madhya Pradesh since most of the area is at lower altitude and is rainfed.

Impact of livestock on climate

This is currently a hot topic because livestock production is projected to have a profound negative impact on climate (Steinfeld et al., 2006). Developing countries like India are marked out as major contributors because of the large populations of ruminants. Haan (1995), Haan and Blackburn (1995) and Mishra and Dixit (2004) have presented positive as well as negative impacts of livestock on climate/environment and have suggested the need for a comprehensive approach (see Box 5). They indicate that the nature and extent of the impact will be different at the global and local levels and that effects will vary with systems of livestock production and functions performed by livestock. Similar views were expressed by Thomas et al. (2009) in a review of the impact of climate change on livestock. Haan (1995) developed a matrix to analyse and understand variations in impact according to the prevailing production systems (see Table 1). He concluded that mixed crop/livestock farming is best for maintaining a balance between positive and negative impacts. This paper briefly reviews these reports to present 'direct–indirect', 'global–local' and 'positive–negative' impacts of livestock on climate.

The relative importance and significance of the impacts mentioned in Box 5 (positive/negative) varies between the global and local situations and with the system prevailing in an area/region, and will be briefly discussed in the next paragraphs.

Negative impacts of livestock on climate: Direct and indirect negative impacts are discussed separately in the following paragraphs.

The direct negative impacts relate to greenhouse gases (GHGs) produced mainly through enteric fermentation by ruminant livestock, as well as small quantities from the excreta. The main GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrogen dioxide (NO_2). An increase in GHGs has resulted in global warming by 0.74°C over the past 100 years and 11 of the 12 warmest years were recorded during the period 1995–2006. The IPCC projects a temperature increase of 1.8–4.0°C by the end of this century (IPCC, 2007). The warming impact of CO_2 is greatest since the quantities emitted are highest, followed by methane and nitrogen dioxide, which are 21 times and 296 times, respectively, more effective than CO_2 in trapping heat. Some of the salient observations on GHGs are summarised below:

- The contribution of livestock is about 18% of the total GHG pool and 80% of GHGs produced by agricultural activities. The calculations for these figures are based on CO_2 equivalents, and methane is 21 times more potent in its greenhouse effect.

Box 5:
Impacts of livestock on climate

Negative impacts:
- greenhouse gases from enteric fermentation and waste
- water overuse and pollution (for and due to production and processing)
- overgrazing and desertification
- deforestation (to create pastures)
- land use for feed/fodder
- loss of biodiversity.

Positive impacts:
- saving of fossil fuels through draught animal power and use of dung as manure and fuel
- soil improvement through manure and leguminous fodder and trees
- saving in CO_2 production by preventing burning of crop residues
- carbon sink and soil-water conservation by cultivation of grasses/legumes on pastures/silvipastures.

Source: Haan, 1995

- The amount of gas produced by a ruminant animal varies with body weight, level of production, feed intake and type of feed consumed by the animal, since the gases are a product of microbial digestion processes in ruminants. In general, the coarser the feed the more methane is produced, and that also results in energy loss from feed in the digestion process.
- African and Asian countries with large ruminant populations make major contributions to the methane pool. According to Steinfeld et al. (2006), India was the second highest in global methane emissions from enteric fermentations in 2004. And according to Sirohi (2010), among the states in India the State of Madhya Pradesh is the second highest contributor to methane emissions.
- Manure and its decomposition contribute to methane emissions. Steinfeld et al. (2006) arrived at a figure of 17.5 million tonnes (mainly from pigs), indicating the need for careful handling of livestock waste to reduce methane emissions from manure.
- Thornton et al. (2008) stated that there are large differences in methane emissions between production systems when compared on the basis of 'tropical livestock units' (a TLU is based on a standard of one animal weighing 250 kg), ranging from 21 kg of methane for a low production system to 40 kg for a high production system.

The indirect negative impacts of livestock on climate are mainly due to the release of carbon from activities that are supportive of, associated with and related to livestock production. These are briefly discussed below:

- Grazing and feed production for livestock have caused extensive land use changes. At the global level, livestock represents the largest form of anthropogenic land use (Steinfeld et al., 2006). The total area occupied for livestock grazing is equivalent to 26% of the ice-free terrestrial surface and that dedicated to feed crop is equivalent to 33% of total arable land. While most grazing areas are too dry or cold for crop cultivation, the major issue is in tropical Latin America where 0.3–0.4% of forest is lost to pastures or for feed/fodder production annually. Such changes in land use increase carbon release from soils while use of fertilisers for feed/fodder production increases emissions of nitrogen. These issues have little relevance for India and particularly Madhya Pradesh, considering the prevailing livestock production systems. The area under fodder production has not exceeded 4–5% of the cultivated area and there is hardly any large-scale pasture development. However, the causes of concern for India and states like Madhya Pradesh are degradation of forests and grazing lands, which would result in soil erosion and carbon losses, and there is a need to take corrective measures. Livestock (particularly 'small stock', e.g. sheep, goats) has been blamed for devegetation and desertification due to overgrazing, and small ruminant production and development was discouraged for many years. However, the Hanumantha Rao Commission Report (Ministry of Rural Development, 1994) made after a detailed study, has dispelled these doubts. The report pointed out that the damage is caused by mismanagement of the animals. Moreover, studies on grazing of livestock reveal that it is not the number of animals grazed that causes damage but rather the time spent in grazing at a particular site. Another cause of concern is that the area under maize production for poultry feed is increasing and cultivation practices need to be examined.
- Processing and transport of livestock feed and products is emerging as a major activity with the ever-increasing size of processing units worldwide. The transportation of material to and from the factories utilises large quantities of fossil fuels and is a source of carbon emissions – a negative aspect of development. For Madhya Pradesh it is a blessing in disguise that nearly 80% of handling of livestock products is in the informal/traditional sector where the operations are not centralised and few large feed factories or processing units exist.
- Waste from livestock, slaughterhouses and livestock product processing units is a substantial pollution problem due to lack of strict controls on waste disposal. Waste disposal is creating problems around most large cities in India with the emergence of large commercial dairy herds and the lack of facilities and systems for waste disposal. Anaerobic decomposition of organic material in livestock manure releases methane (this occurs mostly when manure is managed in liquid form). Methane emission from livestock manure is influenced by a number of factors, such as ambient temperature, moisture, storage time and energy content of the manure (which depends

on the diet of the livestock). Globally, manure from pig production systems makes the largest contribution followed by dairy, but in the case of India and Madhya Pradesh the dairy sector makes the largest contribution. Use of improved biogas systems and methods of composting would enable trapping of nitrogen. Burning of dung cakes for cooking also releases CO_2 into the atmosphere, but it saves considerable quantities of firewood.

- Loss of biodiversity is another way in which livestock has an indirect negative impact on climate. According to the Millennium Ecosystem Assessment Report, the major drivers of biodiversity loss can be summarised as follows: habitat change (land, rivers, etc.), climate change, invasive alien species, overexploitation and pollution (Millennium Ecosystem Assessment, 2005). Since biodiversity loss is the result of a combination of various processes it is difficult to single out livestock as the main cause, although it does contribute in various ways. Steinfeld et al. (2006) attempted to identify livestock-production-related mechanisms that influence biodiversity. They identified the following 12 mechanisms through which livestock induced loss of biodiversity: forest fragmentation, land use intensification, desertification, forest transition, climate change, invasive livestock, plant invasions, competition with wildlife, overfishing, livestock diversity erosion, toxicity and habitat pollution. They mentioned that large differences exist in the extent to which biodiversity is influenced by different production systems and that these influences change over time. For example, overgrazing and conversion of forest area into pastures are threats posed by the 'extensive system' but not by the 'intensive system' of livestock production. The major threat posed by the intensive system is loss of livestock biodiversity.

Positive impacts of livestock on climate: Livestock are a natural resource that play a crucial role in human livelihood systems by performing multiple functions. Livestock systems are bound to have both positive and negative impacts on the environment. While many reports are published on the negative environmental impacts of livestock there are very few on the positive impacts and working out a balance. As stated by Haan and Blackburn (1995), "Currently misinformation on the role of livestock in environmental degradations abounds". They presented a conceptual framework (the ‘Pressure-State-Response’ framework) to facilitate understanding of the dynamic processes of the livestock–environment interaction (this version of the framework is shown in Figure 1). Haan and Blackburn (1995) provide examples of beneficial and harmful effects of livestock production on the main components of the environment, like soil, water, air and non-renewable energy sources (fossil fuels). Rangnekar (2011) emphasised the need for a balance study, identifying both positive and negative contributions of livestock. Such an analysis can provide guidelines for a sound policy for sustainable livestock development in Madhya Pradesh, by minimising negative impacts and maximising positive ones. The direct positive impacts of livestock are briefly discussed in the next paragraphs.

The direct positive impacts of livestock on climate are those that result directly from livestock activity. The major impacts are as follows:

- Fossil fuels are saved through the use of animal power for farm operations and transport. It is likely that domestication of animals was initiated to meet transport needs. Providing animal power is one of the ‘input functions’ of livestock (see Box 2), but this contribution is not well documented. While there are a few reports available on the contribution of bovines (as draught animals for farming and transport), there are hardly any on the contributions of work animals like camels, donkeys, mules, yak and *mithun* (a domesticated bovine species), but these animals provide power in areas where mechanisation is difficult. Mishra and Dixit (2006) made a detailed study of the direct positive contributions of livestock and they stated that the major contribution is through 70 million animals that are used in India for various farming-related operations, including ploughing, seeding, inter-culture and haulage. They worked out factors to calculate the amount of fossil fuels (non-renewable energy sources) saved by animal power (renewable energy source) and reported that 19.5 million litres of fuel is saved each year, which is equivalent to preventing the emission of 6.19 million tonnes of CO_2 per year. Ramaswamy (2010) in a note submitted to a planning commission pointed out that animal power provides energy for ploughing about 50% of cultivated land, hauling 25 billion tonnes of freight (using 14 million carts). He further states that animal power is neither mentioned in the national Economic Survey nor included as a contribution to GDP.
- Saving of land and GHG emissions due to prevailing systems occurs in the following ways:
  - The livestock feeding systems prevailing in India are based on the use of crop residues and agricultural by-products, unlike the use of grain-rich compounded feed-based feeding systems of developed countries. According to Mishra and Dixit (2006), the type of systems used in India result in saving land from being used for production of feed and green fodder, as well as prevention of GHG emissions that would have occured due to processing and transportation of grain/feed. In the State of Madhya Pradesh, forests and common property resources (CPRs) are major sources of feed for livestock (in the form of grass and tree fodder) in addition to agricultural by-products. Mishra and Dixit (2006) have described their methodology for assessing the extent of land and GHGs saved due to this system. However, such estimations have not been attempted for Madhya Pradesh and there is a need for such a study in order to find ways of improving these environment-friendly resources.
  - Wood and other fuel is saved through the use of dung as fuel and organic manure. It is traditional practice to use dung as organic manure while some is converted into ‘dung cakes’ and used as fuel. Rough estimates show that about 60% of dung is used as manure, 25–30% as fuel and about 15% is wasted. Dung is an important source of fuel in rural and peri-urban areas, particularly in Madhya Pradesh, and its use saves considerable amounts of wood and other fuel. Mishra and Dixit (2006) have calculated the amounts of fuel wood saved as well as the area of land that would have been required to produce an equivalent amount of fuel wood.
  - According to Mishra and Dixit (2006), “The total value of positive environmental effects of India’s livestock production system is Rs.1,16,518 crore”. This can be compared against the total value of output of the livestock sector of Rs.78,682 crores (for 1997–1998, at 1993–1994 prices). Such reports indicate the environment-friendly potential of livestock.

Suggestions on adaptation, mitigation and coping with adverse impacts and promoting positive impacts of livestock production

The directions in which livestock and climate interactions proceed are not determined by livestock but exclusively by human demands and policies, which are shaped by changing societal values, and livestock production responds accordingly. Livestock–climate interaction is dynamic and reciprocal and there is a lack of in-depth understanding and sensitivity about the nature and intensity of that interaction. The situation is complicated by the fact that on one side the adverse impacts of livestock on climate are emphasised in some reports, while on the other side the pressures of market demands for livestock products and the potential of livestock to improve incomes of the resource-poor clouds clear thinking about the future implications (see Figure 1).

A three-fold approach is suggested for balancing the livestock–climate relationship and developing an environment-friendly and sustainable livestock sector:

1. Appropriate policy support for sustainable livestock development
2. Selection/development and utilisation of appropriate technologies
3. Sensitisation of policy-makers and stakeholders in the livestock sector to the implications and impacts of climate change.

It is suggested that formulation of appropriate policies be done in two steps:

1. Analysis of the situation related to the livestock–climate relationship in Madhya Pradesh and use of environmental models, like the 'Pressure-State-Response model' used by Thornton (1995) and others, may be considered (a multidisciplinary team will be needed).
2. Objective analysis of livestock development policy, considering the long-term implications, particularly for rainfed areas and resource-poor families.

Aspects to be considered from a policy perspective include the following:

- Review the 'Livestock/Poultry Breeding Policy' to ensure that it follows recommendations of the Food and Agriculture Organization (FAO, 2009), which are aimed at facilitating and promoting broader use of livestock biodiversity for sustainable livestock development in the context of the predicted impact of climate change. This is crucial for Madhya Pradesh, where the adverse impacts are likely to be substantial. According to Thornton et al. (2009), "Increasing intensification of dairy systems in the developing world through use of temperate breed genetic stock could lead to greater vulnerability to increasing temperatures".
- Provide incentives for smallholders and those using mixed farming methods (these have the least negative impact), and only permit large commercial livestock units very selectively, since these have greater negative impacts.
- Integrate livestock development with natural resource development programmes.
- Provide incentives for use of biogas systems (family size as well as large units).
- Provide incentives for proper handling of livestock waste, encouraging use of organic manure and reducing subsidies for chemical fertilisers.
- Reserve village commons for fodder and fuel production (through silvipasture).
- Develop barren uncultivated lands, culturable wastes, permanent pastures, old and current fallows for fodder and fuel by establishing silvipastures.
- Develop non-forest and open forest areas under the Forest Department for fuel and fodder.

The following technological interventions are suggested, to mitigate the adverse impacts of livestock on climate:

- Swaminathan (2011) recently recommended that one woman and one man from each *panchayat* should be trained to understand and deal with climate change; establish one biogas unit and a farm pond to reduce emissions and ensure energy and water security.
- Study the feasibility of large biogas units being established by the Madhya Pradesh Biogas Initiative and promote this if it is found to be feasible.
- Popularise improved methods of handling manure and making compost, in order to reduce emissions.
- Improve handling and utilisation of slaughterhouse waste.
- Develop silvipastures on degraded, uncultivated lands and degraded forests, as these are the most efficient carbon sinks and this will conserve soil and moisture and provide better quality fodder.
- Integrate livestock development with watershed development and agro-forestry projects.
- Promote the use of feed supplements like molasses, corn steep liquor, maize gluten and rice bran, among others, based on availability, to reduce methane production by ruminants (provide supplements in place of compounded feed).

The following knowledge gaps remain to be covered through research to enable objective policy analysis:

- Predictions on the impact of climate change using simulation modelling techniques are needed, to help frame future approaches and polices.
- The extent of usage of animal power for tillage, haulage, etc., should be documented for different regions of Madhya Pradesh.
- Assess the scope for improving animal-drawn farm implements, carts and utilisation of bullocks.
- Utilisation of animal waste from farms, slaughterhouses, dairy processing units, etc., should be documented.
- Create an inventory and characteristics of local animal genetic resources (Global Action Plan, FAO, 2009) to conserve, develop and use the genetic resources strategically and sustainably.
- Study the prevailing livestock feeding systems in different parts of Madhya Pradesh.
- Study the methane production of local large and small ruminants under the prevailing livestock feeding systems.
- Evaluate the potential of locally available feeds/tree leaves, etc., for reducing enteric methane production.
- Assess the water use efficiency of different livestock species/breeds and production systems.

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Climate change and health with special reference to vector-borne diseases in India

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Introduction

What is climate change?

Human activities are known to alter the global climate. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (IPCC: Houghton et al., 2001). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) also projects a rise in temperature of up to 4°C and a sea level rise of up to 0.59 metre by the year 2100 (IPCC: Parry et al., 2007). India has reason to be concerned about climate change as over 650 million people depend on climate-sensitive sectors, such as rainfed agriculture and forestry, for their livelihoods (Garg et al., 2009). Furthermore, climate change in India represents an additional stress on ecological and socioeconomic systems that are already facing tremendous pressure from population and economic growth, increased urbanisation and resource use.

Basic determinants of health that are vulnerable to climate change

Climate change can no longer be considered simply an environmental or developmental issue. The changing climate will affect the basic requirements for maintaining health: clean air and water, adequate food and shelter. Each year, about 1.2 million people die worldwide from causes attributable to urban air pollution, 2.2 million from diarrhoea due to lack of clean water and sanitation and from poor hygiene, 3.5 million from malnutrition, and approximately

60,000 in natural disasters (WHO, 2009a). A warmer climate further threatens to lead to higher levels of air pollutants and increased transmission of diseases through contaminated food and water and vector-borne diseases. Increased levels of pollution and disease will further affect the agricultural production in underdeveloped states.

How climate change affects health

Increasing population growth will lead to more severe climate change. Climate change has so far remained a marginal issue in the immediate policy-making agenda in India in view of more pressing concerns of underdevelopment, such as poverty, food insecurity and inadequate access to health and education services. However, climate change affects human health in many ways – mostly adversely. For example, there is a link between obesity and climate change (Roberts and Stott, 2010). As a result of an increase in the number of cars/vehicles in towns and cities, levels of physical activity have reduced greatly. The evidence for links between physical activity and health points to a direct correlation, as physical activity has been linked to a 10–20% reduction in ischaemic heart disease and stroke, a 12% reduction in breast cancer, an 8% reduction in dementia and a 6% reduction in depression (Woodcock et al., 2009). A large increase in motor vehicle traffic has accompanied rapid population growth, and it leads in turn to an increase in pollution.

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The actions to mitigate climate change can also provide benefits for health, though there are substantial knowledge gaps. For example, in the Indian context, increasing the efficiency of cooking stoves could result in reductions in childhood respiratory infections and in adult heart and lung disease. It has been estimated that the introduction of 150 million low-emission stoves could prevent about 2 million premature deaths in a decade (Ganten et al., 2010).

Undernutrition, diarrhoea and vector-borne diseases are the most important health effects of climate change (WHO, 2009a). There is scientific consensus that greenhouse gas emissions generated by human activity will change the Earth's climate. The recent global warming by an average of 0.5°C is partly attributable to such anthropogenic emissions. Both salmonella and cholera bacteria proliferate more rapidly at higher temperatures; salmonella in animal gut and food, cholera in water (McMichael et al., 2006). Additionally, childhood pneumonia, which is responsible for 17% of childhood deaths worldwide (WHO, 2008), is rarely mentioned in the context of climate change. Bacterial survival and virus stability in aerosols might be increased by higher humidity (Yusuf et al., 2007). An increase in childhood undernutrition due to climate change will increase the rate of deaths from pneumonia. It is estimated that 44% of pneumonia deaths in children under the age of five years are caused by undernutrition (WHO, 2009a).

Further, about 973 million people are exposed to vector-borne malarial parasites in India (Garg et al., 2009). Temperature is very crucial in determining the distribution and seasonality of malaria. In areas with temperatures below 19°C, transmission cannot take place as it would require an *Anopheles* mosquito to survive for about 55 days, which is unlikely. Between 32°C and 39°C there is high mortality in mosquitoes (Craig et al., 1999), and at 40°C they cannot survive (Martens et al., 1997). However, the combination of optimum temperature (24–27ºC) and relative humidity (RH) (55–75%), low immunity in the population and excess rainfall results in outbreaks of malaria. The transmission of vector-borne diseases is also much affected by socioeconomic conditions and by the robustness of public health care. For example, case surveillance and treatment in forested areas (Singh et al., 1996; Singh et al., 1998), during dam construction (Singh et al., 1997; Singh et al., 1999) and during migration for collection of forest products (Singh et al., 2004) would tend to offset the increased risk due to climate change. It is worthwhile to mention that India accounts for approximately two thirds of the confirmed malaria cases reported in South East Asia (Silva and Wickremasinghe, 2010). Five states are responsible for more than 60% of malaria in India: Orissa, Chhattisgarh, Madhya Pradesh, Jharkhand and West Bengal (WHO, 2009b). Predominantly, these are underdeveloped states having large populations of ethnic groups. Furthermore, it is estimated that in India about 200,000 persons below 70 years of age die annually due to malaria (Dhingra et al., 2010), of which Orissa accounts for about 51,000 deaths, followed by 20,000 deaths each in Madhya Pradesh and Jharkhand, and 12,000 in Chhattisgarh. In the context of Madhya Pradesh, currently the transmission window for malaria is open for seven months. In view of a projected 2.5°C rise in temperature by 2050 (IPCC: Houghton et al., 2001), the transmission window will be open for eight months in Madhya Pradesh.

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Climate conditions play a very important role in the transmission of dengue fever as well, and Madhya Pradesh is very susceptible to dengue transmission. The State Vector-Borne Disease Control Programme in Bhopal reported 5 confirmed and 85 suspected deaths due to dengue in 2009. Researchers have also estimated the effects of climate change on dengue fever. For example, warmer temperatures shorten the time it takes for mosquitoes to become infectious, increasing the probability of transmission (Jetten and Focks, 1997). The minimum temperature required for survival of dengue viruses in *Aedes* mosquitoes is 11.9°C (IPCC: Houghton et al., 2001) and the viruses cannot multiply in the vector at temperatures below 18°C (Watts et al., 1987). Higher temperatures beyond 42°C are inimical for survival of immature stages of Aedes mosquitoes (Rueda et al., 1990).

The *Aedes* mosquito is also responsible for chikungunya, a disease that was almost eliminated from India except for a few cases between 1963 and 1965 reported in Sagar (Madhya Pradesh), West Bengal, Tamil Nadu and Maharashtra (Dhiman et al., 2010). The disease re-emerged in 2006 in most parts of Madhya Pradesh. The presence

of this viral disease in Madhya Pradesh indicates that transmission occurs in areas with moderate temperatures that do not have severe winters. With the projected rise in temperature, this disease is likely to spread towards northern parts of India.

What should we do to address the threat of climate change?

Climate change brings new challenges to the control of communicable diseases. Decision-makers also need to understand how quickly climate change might occur, because rapid climate change might require different mitigation and adaptation options than a gradual change in climate. Therefore, there is a need to undertake retrospective and prospective studies on communicable diseases (particularly on vector-borne diseases) and climate change (WHO, 2010), (a) to understand the relationship between climatic factors and vector-borne diseases, (b) to assess early evidence of climate change and future scenarios in view of projected climate change, and (c) to assess local preparedness to respond to the impact of climate change on vector-borne diseases.

A greater appreciation of the human health dimensions of climate change is necessary for both the development of effective policy and the mobilisation of the public for action.

These studies will be helpful in understanding the role of climate determinants of disease transmission, which will serve as a baseline for assessing the impact of climate change and will suggest a range of actions that health professionals can take. Moreover, environmental indicators suitable for use as early warning signs will be identified. Above all, the outcome of the studies would be useful for public health specialists and policy-makers to develop intervention measures, preparedness plans and allocation of funds for development of tools for early warning on outbreaks of diseases.

Conclusion

Climate change will continue to have a major adverse impact on the health of the human population (McMichael et al., 2006). Therefore, health improvement should be one of the main criteria in deciding on mitigating measures for climate change. Most parts of Madhya Pradesh – particularly tribal areas, where socioeconomics play an important role in health-seeking behaviour, personal protection methods and compliance with treatment for endemic diseases – require strengthening of infrastructure and intervention strategies (Singh et al., 2009). A greater appreciation of the human health dimensions of climate change is necessary for both the development of effective policy and the mobilisation of the public for action.

We hope that with further strengthening of health infrastructure, identification of constraints and policy gaps, and availability of better assessment tools, we may negate the threat of climate change on vector-borne diseases in India.

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Climate change and health in Madhya Pradesh: Projected impacts and required adaptation

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Introduction

Rising temperatures and other adverse weather conditions directly attributable to human activity are already having an impact on human health. WHO estimated that in the year 2000 in South and East Asia climate change was directly responsible for an additional 2.6 million DALYS (Disability-Adjusted Life Years – a measure of excess mortality and morbidity combined). Future impacts of worsening climate change on health are projected to be even greater, including a higher burden of vector-borne diseases (such as malaria), poorer nutritional status due to drought, and a greater incidence of respiratory ailments resulting from poorer air quality. The impacts of climate change will be greater in states like Madhya Pradesh, which already suffer from poor health status, have fragile and underdeveloped health systems and large proportions of poor and marginalised populations. There is clearly an urgent need for the Government of Madhya Pradesh to adopt policies and actions to help mitigate further impacts of climate change on health, as well as for the health sector to adapt in order to effectively respond to these impacts.

This paper aims to estimate some of the likely impacts of climate change on health in Madhya Pradesh, and puts forward a programme of action for the State to help mitigate impacts and be ready to respond to adverse health conditions arising from climate change.

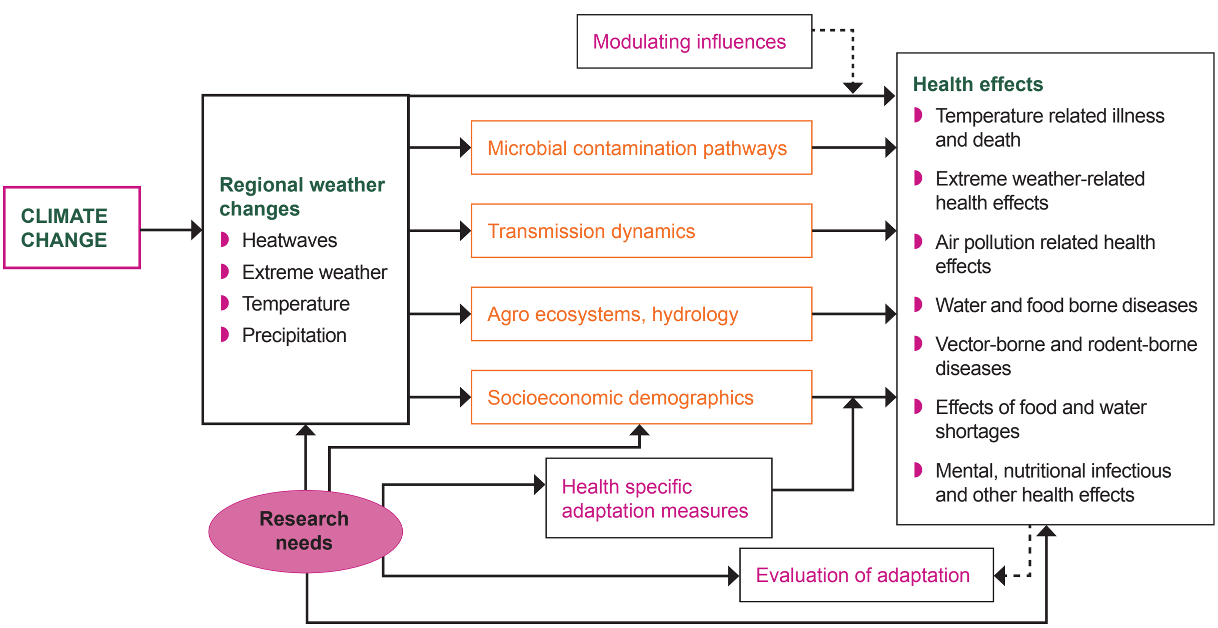
Pathways of impact

Increased frequency of mental health problems associated with crop failure is already apparent in India. The most extreme and visible manifestation of this is farmer suicides.

Figure 1 shows the multiple pathways through which changes in temperature and precipitation impact on health status. For example, incidence of malaria is affected by the transmission dynamics of the parasites (*P. vivax* and *P. falciparum*) from the vector (the mosquito) to the host (humans), and these transmission dynamics are affected by temperature and humidity. As mosquitoes are cold-blooded creatures, their life cycle and the development of the parasite in their bodies are affected by climatic conditions, including temperature, rainfall, relative humidity, frost and wind velocity (INCCA, 2010). For example, the minimum temperature required for development of the *P. vivax* parasite in Anopheles mosquitoes is 14.5–16.5°C while for *P. falciparum* it is 16.5–18°C. At 16°C it will take 55 days for the *P. vivax* to complete sporogony, while at 18°C it will take 29 days and at 28°C the process can be completed in 7 days. At temperatures between 32°C and 39°C, there is high mortality in mosquitoes and at 40°C they are not able to survive. Higher temperatures are also shown to affect the rate of digestion of blood meal by the mosquito, which in turn affects the frequency of feeding, egg laying and density of mosquitoes.

Other effects of climate change on health include: higher risk of diarrhoea resulting from contaminated water due to flooding; higher risk of poor nutritional status due to the impact of crop failure on livelihoods as a result of drought conditions; and increased frequency of mental health problems associated with crop failure. The latter is already apparent in India, the most extreme and visible manifestation of this being farmer suicides.

Figure 1:
Health effects due to climate change



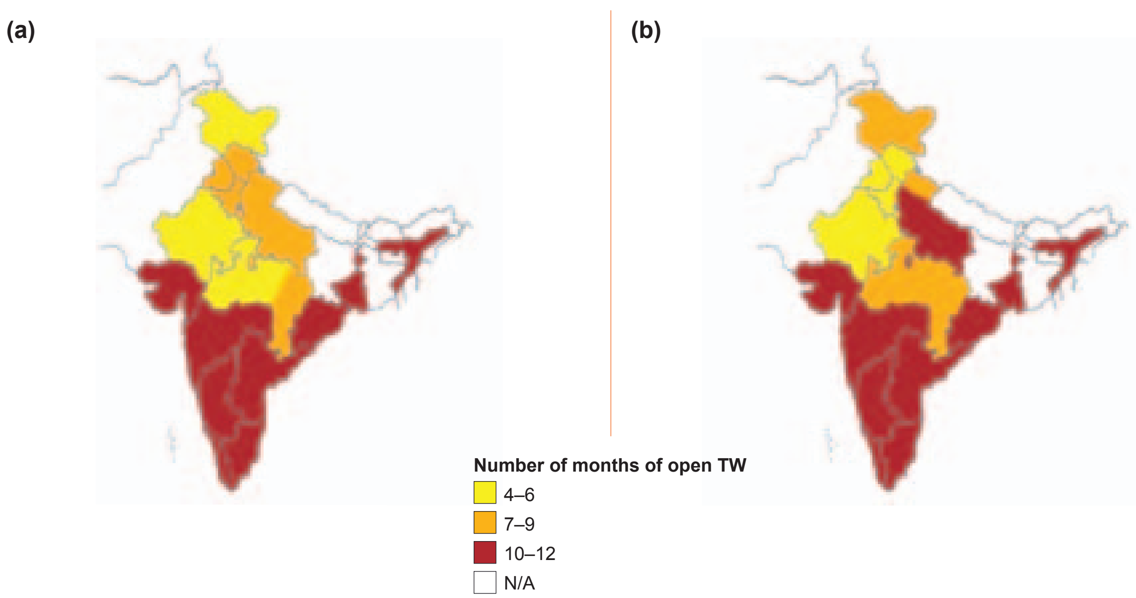
Projected health impacts of climate change in Madhya Pradesh

Though the Government of Madhya Pradesh has recently made some progress towards reducing the infant mortality rate (IMR) and child underweight rates, these rates still remain among the highest in the country. One in fifteen children in Madhya Pradesh die before reaching their first birthday and half of the children in the State are underweight. In particular, over 10% or one million children are suffering from severe acute malnutrition (SAM) – a condition that increases their risk of dying by eight times in comparison to their healthier counterparts. Madhya Pradesh is among six states in India contributing up to 65% of malaria incidence in the country. Malaria is endemic in 18 districts of the State, of which 4 districts account for 25% of malaria cases (the districts of Mandla, Dindori, Jhabua and Dhar). All four districts are predominately tribal. Though reported deaths from malaria are relatively few (in 2008 there were 53 reported deaths), the actual numbers are widely acknowledged to be substantially higher. The disease is a major cause of anaemia – an estimated 20% of women of reproductive age are anaemic as a result of malaria in India. This is of particular concern since anaemia in pregnancy accounts for a high proportion of maternal mortality and morbidity, spontaneous abortion, preterm births and intrauterine fetal deaths (Kulkarni et al., 2007 and ICMR, 2007).

In this scenario of high burden of disease and poor health, climate change is projected to further worsen the health situation in the State. Malaria incidence is likely to increase as temperatures rise, causing an increase in the transmission window.

In this scenario of high burden of disease and poor health, climate change is projected to further worsen the health situation in the State. Malaria incidence is likely to increase as temperatures rise, causing an increase in the transmission window (see Figure 2). A 2.5°C temperature rise will increase the number of months of open transmission window from 6 months currently to 7–8 months. This will place an increased burden

Figure 2:
Transmission window of malaria in Madhya Pradesh and other states



Source: NATCOM I: MOEF, 2004, p.120

> *The 'India State Hunger Index' concludes that while most Indian states have a 'serious' hunger problem, Madhya Pradesh is the only state in the 'extremely alarming' category.*

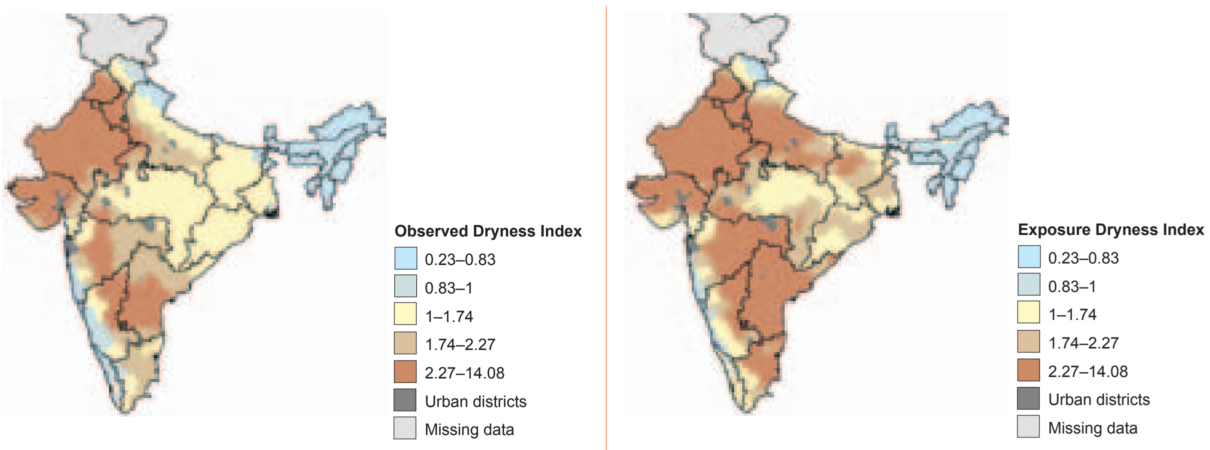
on already over-stretched health systems. However, as temperatures continue to rise by another 1°C the number of months of open transmission window will come back down to 6 months (NATCOM I: MOEF, 2004). Therefore, in Madhya Pradesh initial temperature increases will result in an increased incidence of malaria, but as temperatures continue to rise, incidence levels will begin to decline again.

The number of people afflicted with hunger continues to be large and even growing in Madhya Pradesh. Data from the National Sample Survey Organisation (NSSO, 2008) indicate that expenditure on food per month is the lowest per person in Madhya Pradesh (Rs.263) among the states of India, and there has been a decline of 15% in per capita food consumption. A survey of diet and nutritional status by the National Nutrition Monitoring Bureau (NNMB, 2006) reports that the diets of over two thirds of children under the age of three years are inadequate in terms of calorie, mineral and vitamin content. The 'India State Hunger Index' (Menon et al., 2009) concludes that while most Indian states have a 'serious' hunger problem, Madhya Pradesh is the only state in the 'extremely alarming' category.

Extreme weather conditions have a critical impact on food production and availability. Droughts and floods have been striking India and the world with greater frequency and ferocity. Madhya Pradesh sits in a drought-prone region of the country (see Figure 3). The predicated rise in temperature over the next 50 years will result in increased susceptibility to drought, which in turn will affect crop yields. This implies the need for urgent action to prevent worsening malnutrition by departments other than the Health Department, such as the Rural Development and

Figure 3:

Drought-prone areas: present and projected



The map shows areas prone to drought in India today. The bluish colors indicate areas that get more rain than is evaporated from the heat, while the yellow to brown shades indicate regions where evaporation is greater than precipitation. The browner the color, the drier the region.

The map shows a climate model's estimate of which areas will be prone to drought in a warmer climate in 50 years. More areas than before may become prone to drought.

Source: Schreiner and CICERO, 2004

Agriculture Departments (particularly through measures such as decreased dependency on non-rainfed agriculture and switching to drought-resistant crops). The Department of Women and Child Development can also help mitigate the increasing levels of malnutrition through more effective coverage of the supplementary nutrition programme.

Mitigation and adaptation

It is abundantly clear that action is needed now to mitigate the further impacts of climate change on health and to take adaptive measures to enable the Government of Madhya Pradesh to cope with the present and future impacts. The following immediate steps are required:

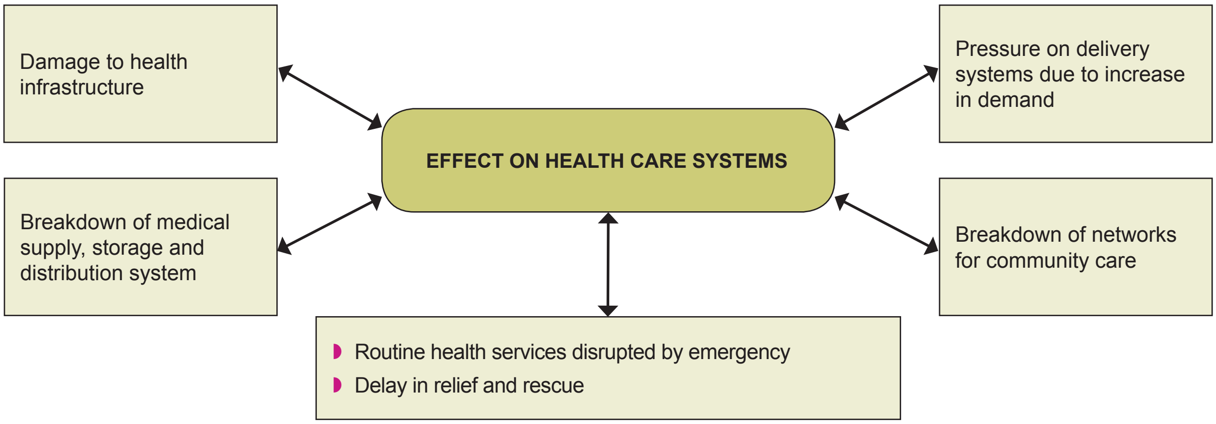
- Sensitisation of policy-makers to climate-related health impacts, emphasising the need for adaptive actions.
- Generation of data to provide better information about the likely impacts, such as more accurate modelling to project the changing incidence of malaria.
- Better convergence and coordinated action with other departments' programmes:
  - Sanitation (Rural Development)
  - Food security (Women and Child Development, Food and Civil Supplies, Rural Development)
  - Safe drinking water (Public Health Engineering Department).
- Strengthening of health systems.

Strengthening health systems

Figure 4 illustrates the impacts that climate change will have on health systems. Adverse weather conditions may damage health facilities, routine health services may be disrupted by the need to provide relief and rescue services during emergencies, and increased pressure on health systems may result in stock-outs of medicines and inability of existing staff to cope with the increased demand.

Figure 4:

Impacts of extreme events on the health-care delivery systems



Source: Wolfe, 2006

Health systems in Madhya Pradesh can be strengthened in several ways to help mitigate climate change and better cope with increasing demands resulting from climate change.

1. **Infrastructure:** Locations for new health facilities should be selected on the basis of vulnerability. Facilities should be constructed with appropriate materials so they are able to withstand heat/flooding as appropriate. Health facilities should use renewable energy sources and plant trees and shrubs in the compound.
2. **Drugs system:** The procurement, distribution and supply chain management systems must be streamlined in view of the impacts of climate change. Drugs should be procured in anticipation of disasters and changing disease patterns (e.g. treatments for diarrhoea, snake-bite, etc.), and drug storage should be decentralised to ensure availability during emergencies.
3. **Infection management and environmental protection:** The Environmental Protection Act (1986) must be implemented, emphasising adherence to standard operating procedures with regards to safe and environmentally friendly hospital waste management.
4. **Data availability and use:** Current vertical systems of reporting (HMIS, IDSP, Hospital MIS, malaria data) should be integrated, and data accuracy verified through triangulation. Weather data must be overlaid with disease data and early warning systems installed.

Conclusion

The imperative for the Government of Madhya Pradesh to take action now to mitigate climate change and adopt adaptive measures is clear and unequivocal.

The impact of climate change on health will be substantial and far-reaching, and will result in even higher burdens of disease in the State of Madhya Pradesh. The imperative for the Government of Madhya Pradesh to take action now to mitigate climate change and adopt adaptive measures is clear and unequivocal. Concerted actions will be required not only by the Health Department but also by the Departments of Rural Development, Women and Child Development, Food and Civil Supplies, Public Health Engineering, and Agriculture, to mitigate the increasing burden of poor health arising due to climate change.

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Climate change and cities in Madhya Pradesh

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Introduction

Global warming and issues related to climate change are now at the forefront of discussions and policy-making at all levels – global, national and local. The science of climate change is better understood now and its implications are already being felt in several parts of the world. According to the IPCC (2007), cities are responsible for 26% of direct greenhouse gas emissions. The concentration of people and industry in cities are a major contributor to carbon dioxide (CO_2) emissions. Urban activities like transport, industrial activities and waste incineration, among others, generate considerable amounts of CO_2.

Climate change and the impacts on cities

There is a very high degree of certainty that as this century proceeds, climate change will have an increasing impact on human society. It is also known that there is a very strong trend towards an increasing proportion of the world's population living in cities (Sharma, 2010). It is estimated that 60% of the world's population will live in cities by 2030

(UN-HABITAT, 2004). Today, around 50% of the world's population lives in cities and they use about 75% of all energy produced. So a majority of the world's energy consumption occurs in the cities. At another level, the impacts of climate change on cities would be profound, threatening infrastructure, livelihoods and economics. Major effects of climate change will be rising sea levels, rising global average temperatures, and changes in precipitation. Major dangers to human populations in cities will probably occur from extreme events such as increased storm surges, submergence due to increasing sea levels, and temperature extremes related to increasing average temperatures.

A broad set of potential climate change impacts has been identified which includes shifts in regional water supplies, increased demand for energy, greater public health threats, increased probability of flooding and ecological changes. Large cities also create what is known as an 'urban heat island' effect whereby the heat given off by the city itself and its effect on airflow patterns, makes the city several degrees warmer at the centre than at its edges. This phenomenon is likely to mean that the inhabitants of cities will be more vulnerable to deaths related to heat stress and poor air quality.

Developing countries like India have low adaptive capacities to withstand the adverse impacts of climate change, due in part to the high dependence of much of their population on climate sensitive sectors like agriculture and forestry, poor infrastructure facilities, weak institutional mechanisms, and lack of financial resources. This puts them at higher risk of suffering the adverse impacts of climate change.

Urban responses to climate change

Climate change is posing dual threats to cities. The impacts associated with rising temperatures, changes in precipitation patterns and rising sea levels will be gradual at a temporal scale, but would also vary spatially and increase the risk of disasters and frequency of extreme weather events. In order to address climate change, mitigation and adaptation have been identified as two responses. Mitigation attempts to slow the process of global climate change by lowering GHG emission levels, whereas adaptation takes practical steps to protect countries and communities from likely damage that will result from the impacts of climate change.

Mitigation attempts to slow the process of global climate change by lowering GHG emission levels, whereas adaptation takes practical steps to protect countries and communities from likely damage that will result from the impacts of climate change.

Mitigation and adaptation when coupled with capacity building and efforts to improve governance have the potential to reduce the vulnerability of urban populations and help build climate resilient cities. In turn, climate resilient cities would have the institutional, structural, social and economic capacity to better withstand the impacts of climate change. Such cities would not only have knowledge of the impacts of climate change that are specific to the city, but would also have an understanding of the responses needed to build resilience.

Cities as a canvas for responses to climate change

Cities represent a concentration of resources and human populations, which gives them a higher capacity to act. There may also be fewer barriers to action at the city level of governance than at the national or global level. Thus, the city may actually prove to be a very effective level of organisation for instigating innovative and replicable responses to climate change impacts.

Management of urban areas and their growth and spatial planning requires the consideration of climate change issues and disaster risk reduction as essential components of urban development. Local governments and their partners

Urban resilience is defined as the ability of cities to tolerate alteration before reorganizing around a new set of structures and processes.

are well suited to managing a changing environment. Towards this end, the need to promote changes in technologies, citizen participation, and urban growth patterns are equally important parts that contribute to global warming and create vulnerability to disasters. Mainstreaming these issues into policy and practice requires the holistic engagement of various stakeholders for risk reduction and resilience building.

Climate resilient cities should develop plans for future development and growth to encourage urban resilience, bearing in mind the climate impacts that the urban systems are likely to face (Prasad et al., 2009). Urban resilience is defined as the ability of cities to tolerate alteration before reorganizing around a new set of structures and processes (Alberti et al., 2003). Tremendous gains are to be had from mainstreaming climate risk reduction into ongoing and planned investment, existing capital stock, associated city planning, governance and management practices.

More frequent or more intense extreme events like cyclones and enhanced storm surges could have devastating impacts on large coastal urban centers including the megacities of Mumbai, and Chennai, important ports like Kandla, and the one million plus cities of Vishakhapatnam, Surat, Bharuch, Bhavnagar and Jamnagar. The areas most vulnerable to sea level rise along the western Indian coast are Khambhat and Kuchh in Gujarat, Mumbai and parts of the Konkan coast, and southern Kerala. On the east coast, significant settlement area is expected to be lost in the deltas of the rivers Ganga, Krishna, Godavari, Cauvery and Mahanadi (Aggarwal et al., 2001). Increased coastal vulnerability is also due to increasing population densities along the coast and in coastal deltas coupled by a greater openness of the Indian economy to trade.

Challenges to integrating allowance for climate change within city governance and management systems

The need to address climate change issues in various sectors including urban development is finding its place in the policy think tanks of various countries and cities. However, if the potential threats and potential impacts of climate change across countries, regions and cities are considered, the task seems immense and the actions taken so far appear so small. When the situation in the developed world is considered, it is the fear of change and the potential reduction in the standard of living that are often heard as justifications for inaction. In the developing world, however, some of the reasons that dominate inaction towards climate change, which is considered a distant threat, are immediate development priorities, lack of infrastructure and finances, the high pace of urbanisation and rapid population growth. Cities like London, Seattle, Singapore and Tokyo have already started to think and act towards addressing climate change. In India, Kolkata, Indore, Gorakhpur and Surat have also started to think and act towards mitigating and adapting to potential climate change impacts.

However, there is a strong need to scale up these interventions, learn from each other and mainstream policies, because of the great risks to urban areas from the threat of climate change. Climate change impacts can wipe out development gains and would significantly reduce the quality of life.

Policy environment in India: urban development

At the central level, urban planning and development is steered through the Ministry of Urban Development and the Ministry of Housing and Urban Poverty Alleviation. The next tiers for development planning are then the State Urban Development Departments and Town and Country Planning Departments at the state level, and municipal bodies and Development Authorities at the individual city level.

Ministries propose various schemes to assist state and city governments to address their urban problems and urban development issues. Today, the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) is the flagship programme of the Ministry of Urban Development (MoUD), which focuses on reform-linked assistance to 65 cities for infrastructure development and providing basic services to urban poor. In order to obtain grant assistance from the Government under the JNNURM, the Government of India makes it conditional upon eligible cities to formulate a medium-term City Development Plan (CDP), which is essentially a policy and investment plan.

The CDPs are vision documents that address city's future growth and development. The investment and policy plan under the CDPs aim to bridge the infrastructure gaps and focus on the reforms required to sustain these investments, with little emphasis on environmental sustainability and addressing climate change issues.

In addition to the JNNURM, the Government has initiated the Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT), which aims to improve infrastructure in urban areas that are not covered under the JNNURM. 'Rajiv Awas Yojana' (RAY) is a government scheme for the urban poor, which envisages a slum-free India and encourages states and union territories to tackle the problem of slums in a definitive manner.

In spite of these government programmes and schemes, what is missing is a comprehensive policy framework that addresses environmental, social and economic sustainability, and that includes climate change adaptation and mitigation issues.

The Model Laws and the Urban Development Plans Formulation and Implementation (UDPFI) guidelines used for master planning for cities do not have a climate change adaptation or mitigation component built into them. However, the National Action Plan for Climate Change (NAPCC) recognised it as one of eight missions. The National Sustainable Habitat Mission under NAPCC focuses on steering urban development towards a more sustainable, 'green' pathway. In order to implement the NAPCC, all states are now preparing their action plans on climate change, which is an excellent opportunity to include local issues.

Climate change action in India: past and present

Since 1998, India has undertaken national assessments of climate change risks and impacts, and adaptation and mitigation options, though there are few examples of local level adaptation actions or policy interventions. However, the NAPCC has opened up entry points for mainstreaming climate change issues (PMCCC, undated). This will be further strengthened as states prepare action plans on climate change addressing local issues. Also, various international agencies (such as the World Bank, the International Council for Local Environmental Initiatives (now known as ICLEI–Local Government for Sustainability), the World Wide Fund for Nature (WWF), the Asian Cities Climate Change Research Network (ACCCRN) and the Urban Climate Change Research Network (UCCRN)) have started pilot projects in some Indian cities.

Climate change and cities in Madhya Pradesh

In Madhya Pradesh, there are 26 cities with a population of more than 100,000 (Census 2001), including the capital Bhopal. The State is undergoing considerable change in terms of urban and economic growth, with a population of 60.4 million (Census 2001). Despite its reputation as a largely rural state, Madhya Pradesh has a large and growing urban population. The estimated urban population is 16.1 million, 27% of the total, very similar to the all India proportion of 28%. In line with expected trends in India, urbanisation in Madhya Pradesh is expected to intensify over the coming decades. The urban population is likely to exceed 25 million by the year 2021. The State is also the third poorest in terms of the population living below the poverty line. This calls for a robust urban development policy for the State that not only links economic growth to a better quality of life, but also targets disaster risk reduction and building resilience of cities to the impacts of climate change.

Madhya Pradesh was one of the foremost states in India to implement the 74th Amendment Act that allowed decentralisation to reach down to local bodies in urban areas. The State also recognises the need and importance of action towards climate change impacts, and hence has established a Climate Change Cell within the Environmental Planning and Coordination Organisation (EPCO).

One of the larger cities in the State, Indore, is amongst three cities in India and one of the ten in Asia that has undergone a complete vulnerability analysis for climate change impacts and has produced a city resilience plan. This initiative is part of the Asian Cities Climate Change Resilience Network (ACCCRN) initiative of the Rockefeller Foundation (2012).

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The Clean Development Mechanism (CDM) and opportunities in the energy sector for mitigating climate change

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Introduction

The global concern for reducing emissions of greenhouse gases (GHG), especially CO_2, is likely to put pressure on the Indian power system to adopt improved generation technologies. Although India does not have GHG reduction targets, it has actively taken steps to address climate change issues. It is estimated that the 'green energy' projects undertaken by the Indian power sector will generate more than 400 million Certified Emission Reductions (CERs) by 2012. Mitigation options for CO_2 reduction that have been taken up include GHG emission reduction in the power sector through adoption of co-generation, combined cycle clean coal technologies, and coal beneficiation. These are important because CO_2 emissions per unit of electricity generated are relatively high in India, as a large proportion of power comes from small, old and relatively inefficient generating units which constitute at least 50% of the total national installed capacity of more than 170,000 MW.

A major thrust towards CO_2 reduction in the long term and on a sustainable basis will come from the adoption of advanced technologies of power generation. These include supercritical/ultra-supercritical power cycles, integrated gasification combined cycles (IGCC) and fluidised bed combustion/gasification technologies, amongst others. In addition to clean coal technologies, the 21st Century may see accelerated growth without sacrificing the interests of nature. The issue therefore is not whether energy production for the nation should be increased, it is rather how to ensure national energy security without sacrificing human and environmental interests. Given the projected growth in world population and energy demand particularly in rapidly developing economies such as India and China, one of the most challenging issues facing the international community this century is how to simultaneously attain energy security, economic growth, poverty mitigation and environmental protection. Currently, fossil fuels (coal, oil and natural gas) supply over 85% of the world's commercial energy needs, 65% of the world's electricity and 97% of energy for transportation. For countries like India and China where coal is the main source for their power generation, the production and use of fossil fuels contribute 64% of the anthropogenic (man-made) GHG emissions. Worldwide, fossil fuel power generation currently accounts for more than one third of global annual CO_2 emissions.

...one of the most challenging issues...is how to simultaneously attain energy security, economic growth, poverty mitigation and environmental protection.

The Clean Development Mechanism

The Clean Development Mechanism (CDM) is contained in Article 12 of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). It is a market mechanism that allows governments or private entities in Annex I (developed) countries to implement emission reduction projects in non-Annex I (developing) countries, and receive credit in the form of Certified Emission Reductions (CERs). The CDM strives to promote sustainable development in developing countries while helping developed countries meet their targets for reducing carbon emissions. The CDM provides a mechanism for developing countries to contribute to the objectives of the UNFCCC by assisting non-Annex I countries to acquire improved technologies and assist their sustainable development, while also assisting Annex I parties to fulfil their emission reduction obligations under the Kyoto Protocol.

All CDM projects must result in a net GHG reduction, through improvements in energy efficiency, increased generation of renewable energy, or carbon sequestration through afforestation and reforestation.

Typical CDM projects fall into the following categories, each indicating their estimated CDM potential in India:
- Renewable energy including biomass (51.0%).
- Fuel switching (in industry, transport, residential sectors, etc.) (5.6%).
- Solid waste management (1.6%).
- Advanced coal-based power generation technologies such as IGCC (7.0%).
- Industrial process improvement (5.2%).
- Demand-side management and improvements in energy efficiency (29.1%).
- Forestry (0.5%).

Types of CDM projects

Carbon credits are sold to entities in Annex-I countries, like power utilities who have emission reduction targets to achieve, and they find it cheaper to buy offsetting certificates rather than making efforts in their own country. The following are projects which are being applied for under the CDM and which have valuable potential.

Energy efficiency projects

- Increasing building efficiency following the concept of ‘green building’, e.g. the Technopolis Building, Kolkata.
- Increasing commercial/industrial energy efficiency, and the renovation and modernisation of old power plants.
- Fuel switching, from more carbon intensive fuels to less carbon intensive fuels.
- Re-powering, upgrading instrumentation, controls, and/or equipment.

Transport projects

- Improvements in vehicle fuel efficiency by the introduction of new technologies.
- Changes in vehicles and fuel type, e.g. switching to electric cars, fuel cell vehicles or use of compressed natural gas (CNG) or biofuels.
- Switching transport mode, e.g. changing to less carbon intensive means of transport such as public transport, e.g. the Metro in Delhi.
- Reducing the frequency of transport activities.

Methane recovery projects

- Animal waste methane recovery and utilisation.
- Installing anaerobic digesters and utilising methane to produce energy.
- Coal mine methane recovery.
- Collection and utilisation of fugitive methane from coal mining.
- Capture of biogas.

- Landfill methane recovery and utilisation.
- Capture and utilisation of fugitive gas from gas pipelines.
- Methane collection and utilisation from sewage/industrial waste treatment facilities.

Changes to industrial processes
- Any industrial process change resulting in the reduction of any category of greenhouse gas emissions.

Co-generation project
- Use of waste heat from electricity generation, e.g. exhaust from gas turbines used for industrial purposes or heating.

Agricultural sector projects
- Improvements in energy efficiency or switching to less carbon intensive energy sources for water pumps for irrigation.
- Reductions in methane emissions in rice cultivation.
- Reducing animal waste or using animal waste for energy generation (see also under methane recovery).
- Any other changes in agricultural practices resulting in reductions in any category of greenhouse gas emissions.

The points in favour of India regarding CDM projects include:
- High potential for carbon credits.
- Potential to capture 10% of the global CDM market.
- Annual estimated revenues range from US$10 million to US$330 million.
- A wide spectrum of projects of different sizes.
- Vast technically-skilled human resources.
- A strong industrial base.
- Dynamic, transparent and rapid processing by the Indian National CDM Authority (NCDMA) for host country approval.
- Baseline CO_2 emissions from the power sector are already in place.

Sector-wise CDM potential in India

With the Indian electricity market now open to foreign investments, its impact in the context of climate change and India's role in promoting CDM for sustainable development becomes all the more important. Industrialised countries following their commitment for emission reductions under the Kyoto Protocol can utilise renewable energy opportunities in India to meet their targets. Although there are varying estimates of CDM potential and projected financial flows to India, potential financial investments are expected in several sectors.

Potential areas, options and projects and the potential benefits of CDM activities are presented in Tables 1 and 2.

Green power technologies and greenhouse gas reduction

Green power technologies such as circulated fluidised bed combustion (CFBC) and integrated gasification combined cycles (IGCC) have large national mitigation potential in terms of thousands of tonnes of CO_2 per annum for mega power generation. Some of the technologies mentioned above have high CO_2 abatement costs while others have low costs, further quantified in Table 3, both for renewable energy and for green power generation technologies.

Table 1: **Expected carbon emission reductions and CDM flows by sector**

Sector		Expected carbon emission reductions (MT/year)	CDM flow (million €/year)
Renewable energy		60	600
Coal-based IGCC power plant		5	50
Agricultural-energy efficiency		18	180
T&D loss reduction		32	320
Industrial energy efficiency	Caustic soda	0.1	1.2
	Cement	1.1	11
	Aluminium	Very high (yet to be assessed)	—
Municipal solid waste management		Very high (yet to be assessed)	—

Note: €10 per tonne of CO_2 (€1 = Rs.72)

Table 2: **Potential CDM projects targeted to meet national mitigation targets**

GHG mitigation option	Abatement cost range	National mitigation potential ('000 tonnes of CO_2)
Mega-power generation		
Renovation and modernisation	High	8,579
Circulated fluidised bed combustion (CFBC)	Low	8,166
Integrated gasification combined cycle (IGCC)	High	14,610
Renewable energy		
Wind power (grid-connected)	High	526
Wind-based water pumps	Medium	<1
Solar thermal power (grid-connected)	High	300
Industrial efficiency		
Iron and steel dry coke quenching	Low	950
Pulp and paper	Medium	904
Replacement of industrial motors	Medium	36

- Technologies like co-generation and combined cycle are found to be most effective in terms of mitigation cost per tonne of CO_2.
- Integrated gasification combined cycle (IGCC) and supercritical power plants are considered at par with each other regarding cost effectiveness per tonne of, though cost of abatement of GHGs is higher in the case of IGCC technology.
- Green power technologies like IGCC and CFBC have high national CO_2 mitigation potential.
- Regarding renewable energy, biomass and small hydro projects are the favoured choice, followed by properly designed wind farms.

Table 3: **Cost of various carbon dioxide (CO_2) mitigation options in India**

Technology	Greenhouse gas emission reduction (kg/kWh)	Investment cost (US$/kW)	Cost-effectiveness (US$/tonne of CO_2)
Green power generation			
Cogeneration	1.50	900	10
Combined cycle	0.96	818	54
Inter-cooled steam-injected gas turbine	0.76	947	77
Pressurised fluidised bed combustion	0.18	1894	503
Integrated gasification combined cycle	0.23	1578	340
Pulverised coal super-critical boilers	0.18	1202	342
Coal washing	0.13	11	179
Circulated fluidised bed combustion	0.20	1000	250
Renewable energy for power			
Small hydro	1.30	1950	88
Wind farms	1.30	1405	257
Biomass	1.60	710	102
Solar thermal	1.30	3730	592
Solar PV (photovoltaic)	1.60	5952	541

Source: ADB, 1998

Greenhouse gas mitigation through CO_2 sequestration

For mitigation of GHGs, it is imperative to develop technologies for low-carbon-based power generation, together with techniques to capture CO_2 being released into atmosphere and store it. For this purpose, CO_2 needs to be compressed, prior to storage and transportation. After separating and compressing CO_2 from combustion stack gases, liquid CO_2 can be transported and discharged into the bottom of the ocean, stored in geological formations, stored in the form of dry ice, fixed by lakes of algae, or converted to benign solid materials or fuels through biological or chemical processes. Sequestration of CO_2 could be modified or suitably altered to encompass production of multipurpose fuels like hydrogen, methane and bio-diesel.

A pilot project sponsored by the Department of Science and Technology, Government of India, is taken up at the Rajiv Gandhi Technology University (RGPV) for the purpose. This consists of a pilot plant being developed at RGPV for the capture of CO_2 and conversion into hydrogen for fuel cell applications, methane for methane-based turbines for power generation, and bio-diesel through the algae route. The systems being incorporated include CO_2 sequestration systems, catalytic flash reduction of CO_2 using charcoal from gasifiers, production of methane using the hydro gasification of biomass process, capture of CO_2 using solar flux, and CO_2 as an input for algae culture which can then be used for biodiesel production. The pilot plant promises to be the future of clean energies.

Conclusions

The 11th and 12th Five Year Plans (2007–2012 and 2012–2017, respectively) will witness the introduction of more green power technologies for mega power production. This will occur through energy efficient and environmentally benign super-critical and IGCC technologies, and more renewable energy technologies for rural and remote areas.

India's national power policy will witness a strong linkage between energy plans and environmental protection. More investments must be made in research and innovations in basic low-carbon energy technologies, energy farming and biofuel development. Green power technologies need a major stimulus in the Indian power sector, and once these projects are taken up along with CDM flows, these would become self-sustaining, ensuring a bright future for humankind.

Besides an integrated sustainable energy framework outlined above, India would also have to give due importance to energy security by reducing energy imports and energy requirements through demand-side management such as the adoption of energy efficient technologies and energy conservation measures.

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Reflection of adaptation to climate change through natural resources management in Madhya Pradesh

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Introduction

Humanity is facing a number of challenges at the beginning of the 21st Century. Scientific evidence implicates greenhouse gas emissions in changing the global climate. Poverty persists around the world, and is worsening in many regions. Biodiversity loss continues, especially in tropical forests. These interconnected problems often reinforce one another, undermining the environment and sustainable community livelihoods (CCBA, 2005). Climate change, in terms of changes in rainfall patterns and increases in temperature, is expected to have significant impacts on water, agriculture and forestry. Scientific evidence about the seriousness of the climate threat to agriculture is now unambiguous, although the exact magnitude is uncertain because of the complex interactions and feedback processes in the ecosystem and in the economy. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Solomon et al., 2007) projected for India an acceleration of warming above that observed in the 20th Century, in addition to a decrease in precipitation and an increase in the occurrence of extreme weather events. The climate change debate is now characterised by political debates over the existence and severity of human-induced climate change and by ongoing negotiations on how to limit greenhouse gas concentrations in the atmosphere. This has resulted in societies and governments focusing on adaptation.

The IPCC defines adaptation as "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects". The capacity to adapt is a function of access to wealth, scientific and technical knowledge, information, skills, infrastructure, institutions and equity, and therefore varies among regions and socioeconomic groups.

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This paper focuses on the traditional coping practices adopted by communities in Madhya Pradesh in the face of climatic stress in general, and drought in particular. Two villages in the Rajgarh District of Madhya Pradesh – Nalajhiri and Banskho – were studied.

Research methods and study area

Madhya Pradesh State has diverse agro-climatic zones. The impact of climate change is felt more strongly in western zones. Rajgarh District was selected based on meteorological evidence including the average climatic variations over the last five years, especially rainfall and its deviation from normal levels, number of drought years, biophysical characteristics like gross irrigated area versus gross cropped area, percentage of forest cover, and socioeconomic conditions, including health, education and income, based on data in the 'Third Human Development Report Madhya Pradesh 2002' (GOMP, 2002). In the Biaora *Tehsil* (administrative division), two villages – Nalajhiri, near the forest, and Banskho, 5 km from forest – were selected for the study. One in five households (20%) were selected in each village, using stratified sampling at the village level to ensure a representative sample. The tools used included participatory resource mapping, household questionnaires, semi-structured interviews, observation of tree/forest-related coping strategies, and a drought timeline. Focus group discussions (FGDs) were organised for landless, scheduled castes (SC) and scheduled tribes (ST), small-scale and marginal farmers, women's groups and *panchayat* members.

Rajgarh District extends between 23°27'12" and 24°17'20" N Latitude and 76°11'15" and 77°14' E Longitude. The total geographical area of the district is 6,154 km^2. It is 145 km from Bhopal. According to the 2001 Census, the district population was 1,254,085 and population density was 204 per km^2. The literacy rate of the district was 54% in 2001. The employment rate was 50% in 2001 and the rural employment rate was 53.7%; the share of the primary sector in 1991 was 82.4%. With the Green Revolution placing a focus on agriculture, the cereals per capita grown in the district increased to 227.8 kg in 1998. Significant changes in agriculture and land-use patterns have taken place over the past 30 years. The gross irrigated area is 169.5 hectares. The net sown area compared to total geographical area increased to 67.3% in 1998. The forest area was 3% and per capita forest area in the district is 0.009 ha. The monsoon contributes most of the district's rain and the average amount of rainfall declined steadily between 2004 and 2008.

…the probable climatic stress would have greater negative impact on poorer households and forest-dependent communities, as they have the weakest capacity to adapt to changes in climatic conditions.

The village of Nalajhiri is situated at a distance of 64 km from Rajgarh. The average annual precipitation of the village is approximately 1,085 mm. The village has 168 households representing different caste groups: 30–35 Brahmin households, 30–35 SC households and about 100 ST households (mostly *Bhil*). The total population of the village is 585. Most households (55%) are joint families and 40% of households are nuclear families. Most of the houses are *kuccha*. The literacy in the village is 63%. The total geographical area of the village is 415.24 ha, of which 80.97 ha is forest, 34.70 ha is grazing land, 57.84 ha is government fallow, 45.08 ha is uncultivable wasteland and 196.64 ha is cultivable land. Agriculture and animal husbandry are the main occupations in the village. About 28 households work in agriculture and 29 households provide agricultural labour, while 56 households are involved in labour in other sectors and the village has one carpenter. The upper castes are the large-scale farmers. The majority of the villagers fall into the group of landless, small-scale and marginal farmers. Those that are landless mostly depend on wage labour and sharecropping. The major crops grown in the *Kharif* season are *jowar* (sorghum), *bajra* (millet) and maize on dry land, and soybeans, *tuar* (pulses) vegetables and groundnuts on irrigated land. The crops grown in *Rabi* season are wheat, channa (chickpeas), garlic, onions and coriander, among others. The forest is mixed deciduous type. The major problem faced in the forest is encroachment, demand for wood for fuel, and grazing, which have led to degradation of the forest. The total cattle population of the village is 342. The village has a primary school, community hall and an *Ajivika Bhavan*. A road of 1 km length has been made under the District Poverty Initiative Programme (DPIP). The major climatic stresses faced are drought, irregular rainfall and hailstorms.

Banskho is a forest village, 12 km away from Suthaliya town. It is a *panchayat* village having a primary school. It has 150 households of the *Bhilala* community (ST). Most of the villagers are illiterate. The primary health centre is at Suthaliya. The main occupations are agriculture and labourer, and average landholding is about 1 acre. Maize and *jowar* are grown in the *Kharif* season. The average production is 4–5 quintal in a normal year. Being a tribal village, most of the villagers are landless, marginal, small-scale farmers, while only a few are medium and large-scale farmers. The majority of villagers are living below the poverty line (BPL) and possess a job card provided under the National Rural Employment Guarantee Act (NREGA). The agricultural productivity depends on rain and few use well water for irrigating their land. The region once had a rich forest, which is now degraded due to biotic factors. The village well dries up in the extreme dry seasons. The water level has fallen to 200 feet. When the well is dry, drinking water is fetched from more than 3 km away. Annual rainfall in the district has continuously decreased, resulting in crop failures, which leads to a shortage of cattle fodder, resulting in turn in the abandonment or sale of the cattle. Because of water scarcity, hygiene and sanitation is a major problem, resulting in skin and diarrhoeal diseases.

Results

The meteorological records of the Rajgarh District show that precipitation decreased between 2004 and 2008. This resulted in scarcity of water, such that wells and ponds dried up. This immediately impacted drinking water availability, forcing villagers to travel long distances to fetch water. The water scarcity also had an impact on agriculture, which is the backbone of the village economy. The perceptions of villagers in Nalajhiri and Banskho are reported in this section.

Community perception of the causes for changes in agriculture

Approximately 78% of respondents in Nalajhiri Village said that climate change is felt and the main indicators according to them are change in rainfall pattern and availability of water for irrigation (Figure 1a). In Banskho Village, the majority think that the market for cash crops is the major cause for the changes in the agriculture sector, followed by rainfall and availability of water (Figure 1b).

About 60% of the residents of both villages stated that they use traditional knowledge to predict the rainfall and it is essential for sustained livelihood. With regards to knowledge of the weather from modern systems, the villagers depend on radio reports and information from the Forest Department.

Community perceptions of changes in climate

In Nalajhiri about 37% feel that climate has changed totally and 16% feel that there is partial change in the climate. Among the people of Banskho, only 9% feel that climate change has taken place either totally or partially.

According to the villagers of Nalajhiri, the most noticable effect of climate change is drought (74%), followed by changing rainfall patterns (Figure 2a). In Banskho village, the main effect of climate change is considered to be the changing rainfall (64%), while drought (36%) is the second most important factor (Figure 2b).

This shows that the community members rely on natural indicators to interpret the changes taking place in the weather and climate, with reference to the factors most closely related to their livelihood planning and activities.

Perception of impact on resources

Most villagers in Nalajhiri notice an impact of climate change on agriculture, but even more notice the impact on the availability of non-timber forest products (NTFP) (Figure 3). Another significant impact is on groundwater, whose extraction for livelihood and other needs has intensified in the past few years with the help of technology but without a proper strategy for replenishing it.

Figure 1:

Perceived causes for the changes in agriculture, (a) Nalajhiri and (b) Banshko

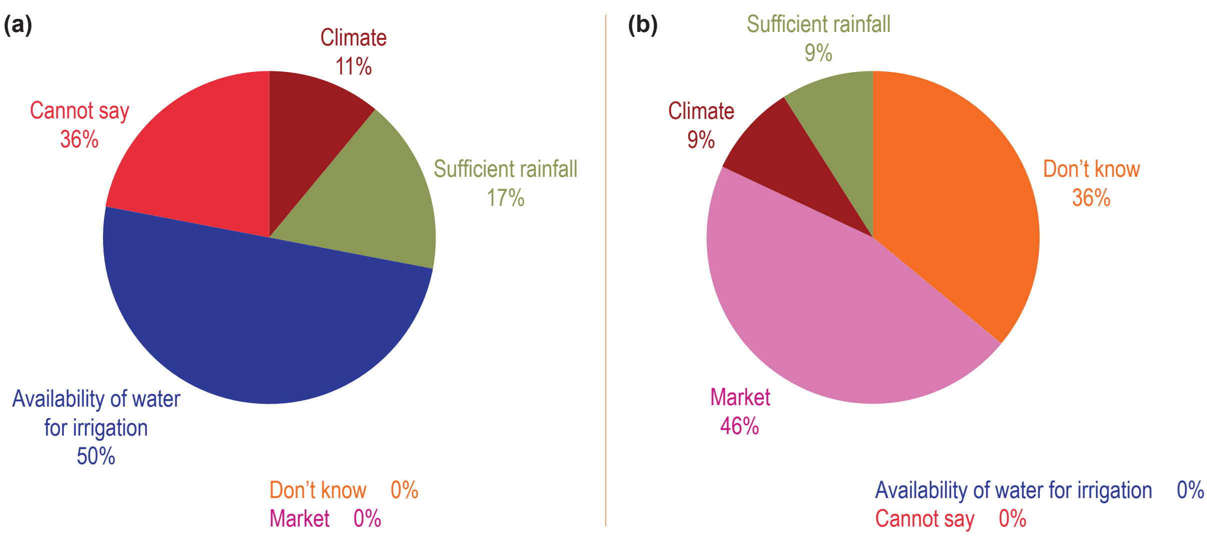


Figure 2:

Perceived effects of climate change, (a) Nalajhiri and (b) Banshko

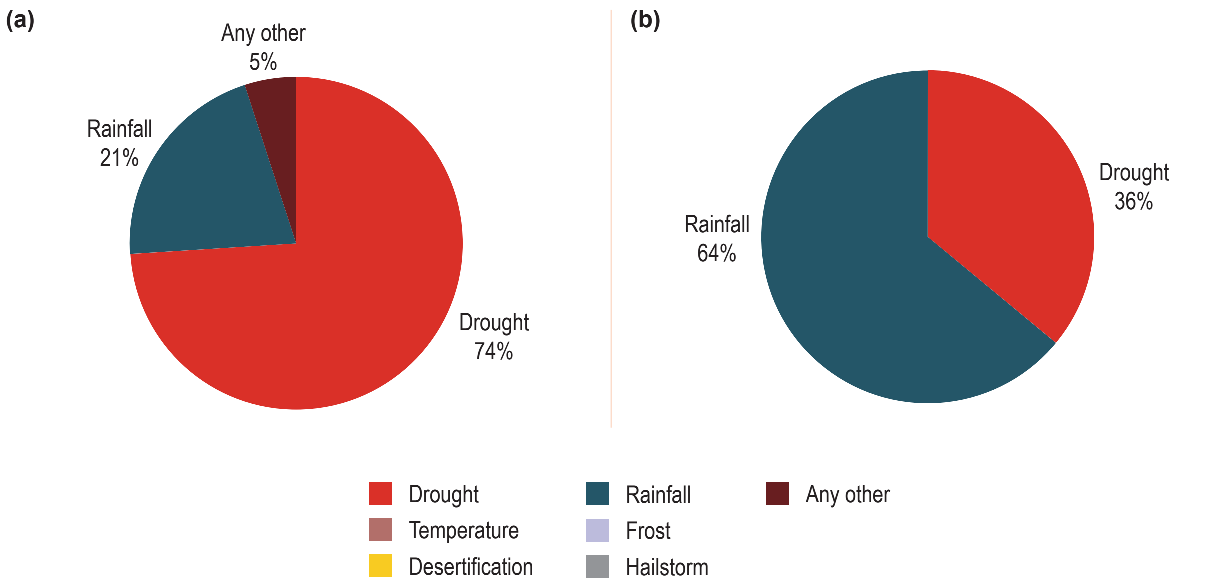
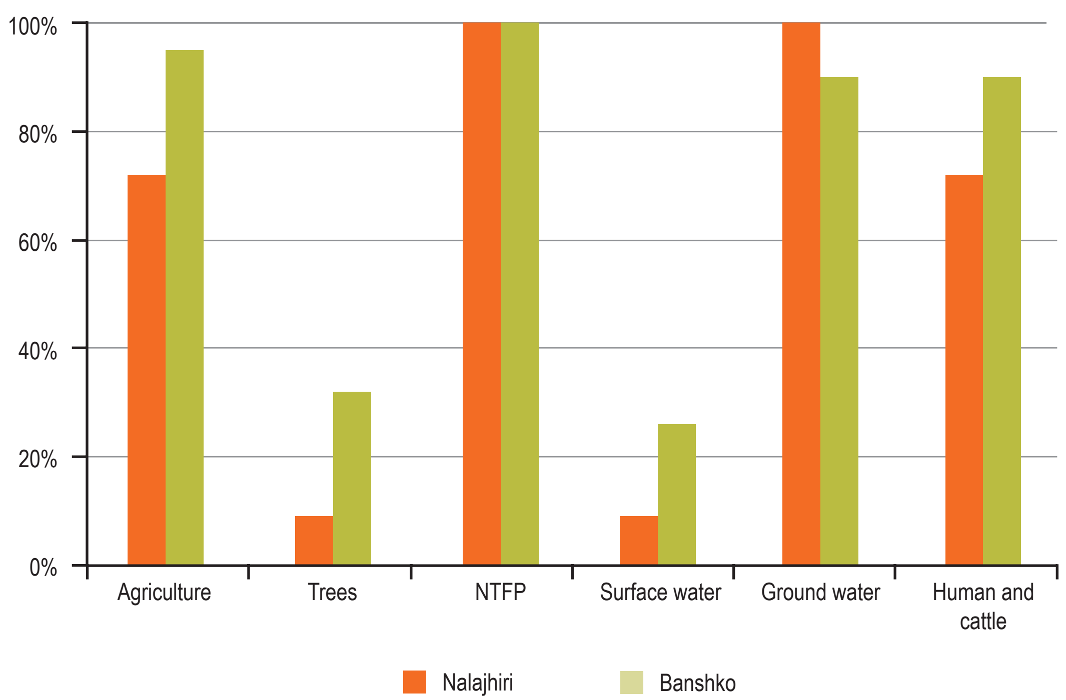


Figure 3:

Perceptions of impact on natural resources in Nalajhiri and Banshko



In Banskho village, the major impact of climate change was percevied to be on availability of NTFP for forest and commons, followed by agriculture. Next significant impact was on groundwater, whose extraction for livelihood and other needs has intensified in the past few years with the help of technology, but without a proper strategy for replenishing it. Here the impact on cattle and human population is also discernable.

Vulnerability due to climate change

According to Nalajhiri villagers, the main factors of climate change that make them feel vulnerable are drought, extreme heat or increase in temperature, and decrease in rainfall (Figure 4a). The prolonged shortage of rainfall is considered to be main problem. Meanwhile, high winds, hailstorms, frost and sandstorms are considered to be 'low' and 'medium' level causes of vulnerability. With reference to the past 15 years, about 90% of villagers feel that annual precipitation has decreased, and all consider that average temperature has increased. About 59% felt that agricultural production had gone down in the past 15 years.

According to Banskho villagers, the main factors of climate change that make them feel vulnerable are drought, extreme heat or increase in temperature, decrease in rainfall and prolonged shortage of rainfall (Figure 4b). As in Nalajhiri, high winds, hailstorms, frost and sandstorms are considered to be 'low' or 'medium' level problems. with reference to the past 15 years, all the villagers felt that annual precipitation has decreased and the average temperature has increased. About 36% felt that agricultural production had decreased in the past 15 years.

Figure 4:

Climatic factors responsible for vulnerability, (a) Nalajhiri and (b) Banskho

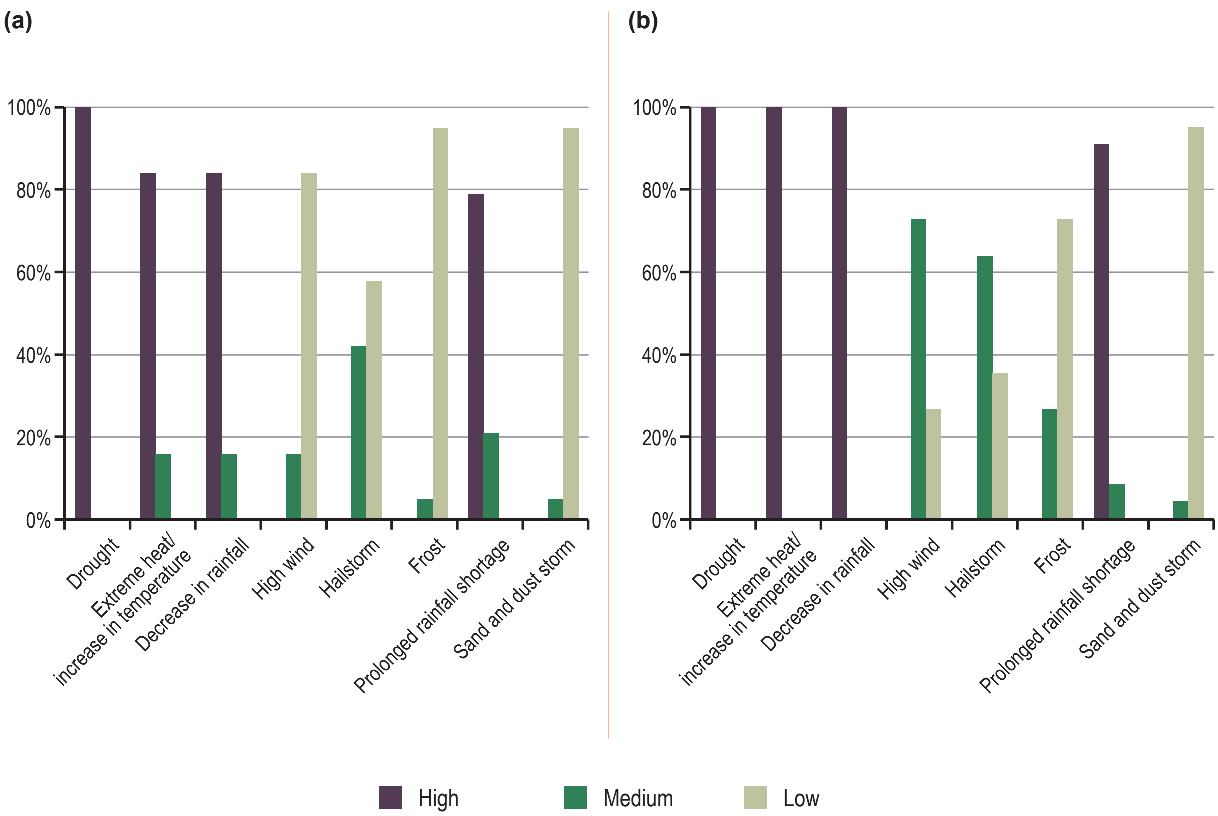
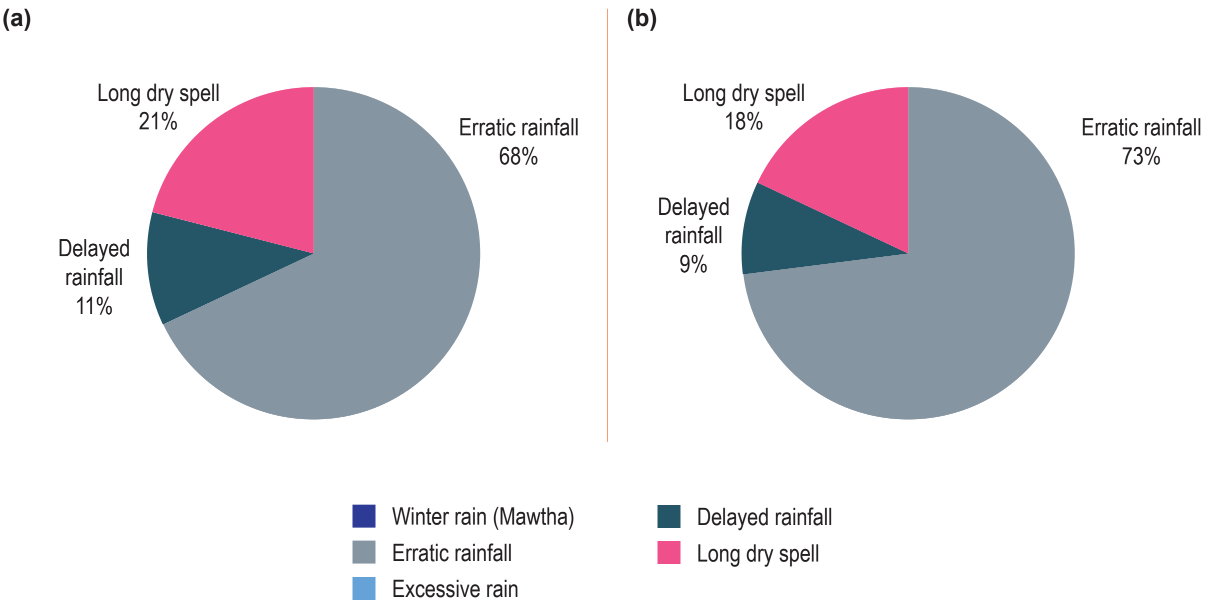


Figure 5:
Vulnerability with regard to precipitation, (a) Nalajhiri and (b) Banskho



Regarding changes in precipitation, in Nalajhiri the majority of villagers (68%) considered that erratic rainfall was the main cause of increasing community vulnerability, followed by long dry spells (21%) and delayed rainfall (11%) (Figure 5).

Similarly, the villagers of Banskho considered that erratic rainfall (73%) was the main cause of increased community vulnerability, followed by long dry spells (18%) and delayed rainfall (9%).

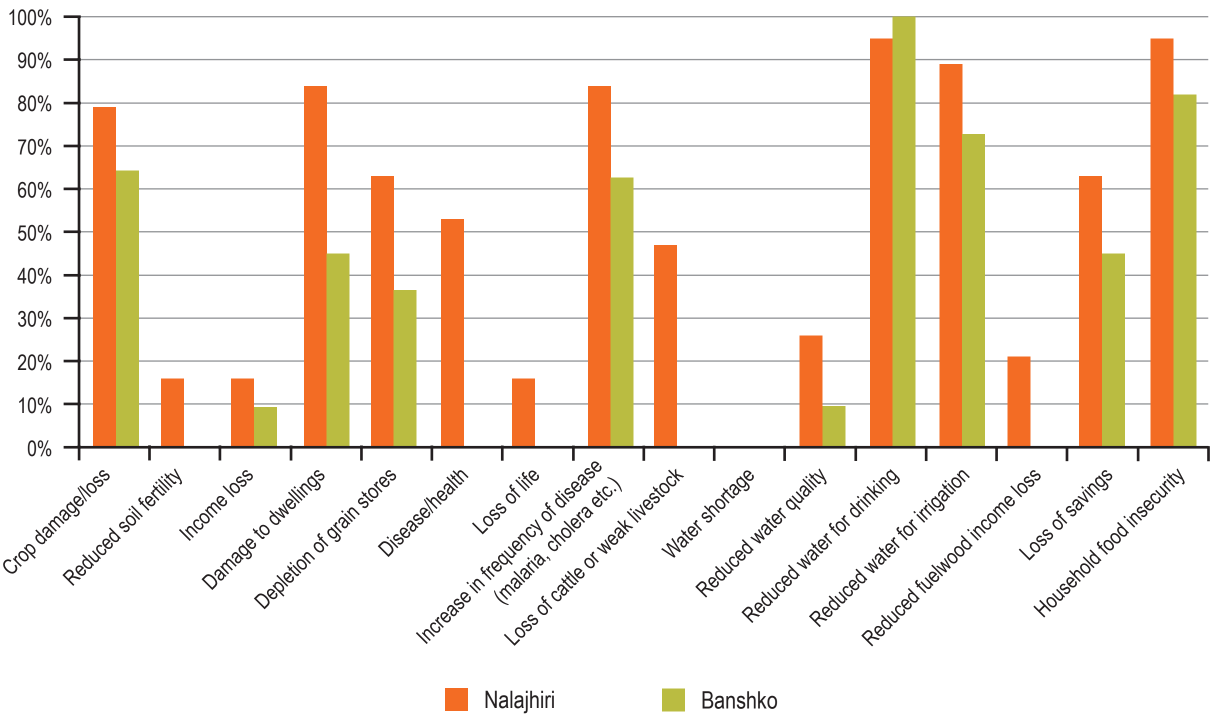
Impacts of climatic stress

According to villagers of Nalajhiri, the main impacts of climatic stress are crop loss (reported by 80%), damage to dwellings (84%), reduced water for drinking (95%), reduced water for irrigation (89%), household food insecurity (95%), and increase in frequency of diseases like malaria and cholera (84%) (Figure 6). Some medium-level stress factors include depletion of grains, reduced fuelwood, loss of soil fertility and income loss.

According to the villagers of Banskho, the major impacts of climatic stress are crop loss (reported by 63%), reduction in water for irrigation (100%), household food insecurity (82%), and increase in the frequency of diseases like malaria and cholera (63%) (Figure 6). As in Nalajhiri, some medium-level stress factors are depletion of grains, reduced fuelwood, loss of soil fertility and income loss.

Traditional community knowledge was used as a risk management strategy by the Banskho villagers. The people of the older generation are good at predicting the onset of the monsoons, based on their experience and learning from earlier generations. The farmers use their knowledge and experience to predict the monsoon and accordingly plan agricultural activities for the coming season. This helped in efficient spending on inputs (e.g. seed) and appropriate timing of the tillage activities.

Figure 6:
Main perceived impacts of climate stress in Nalajhiri and Banskho



Coping mechanisms and adaptation strategies

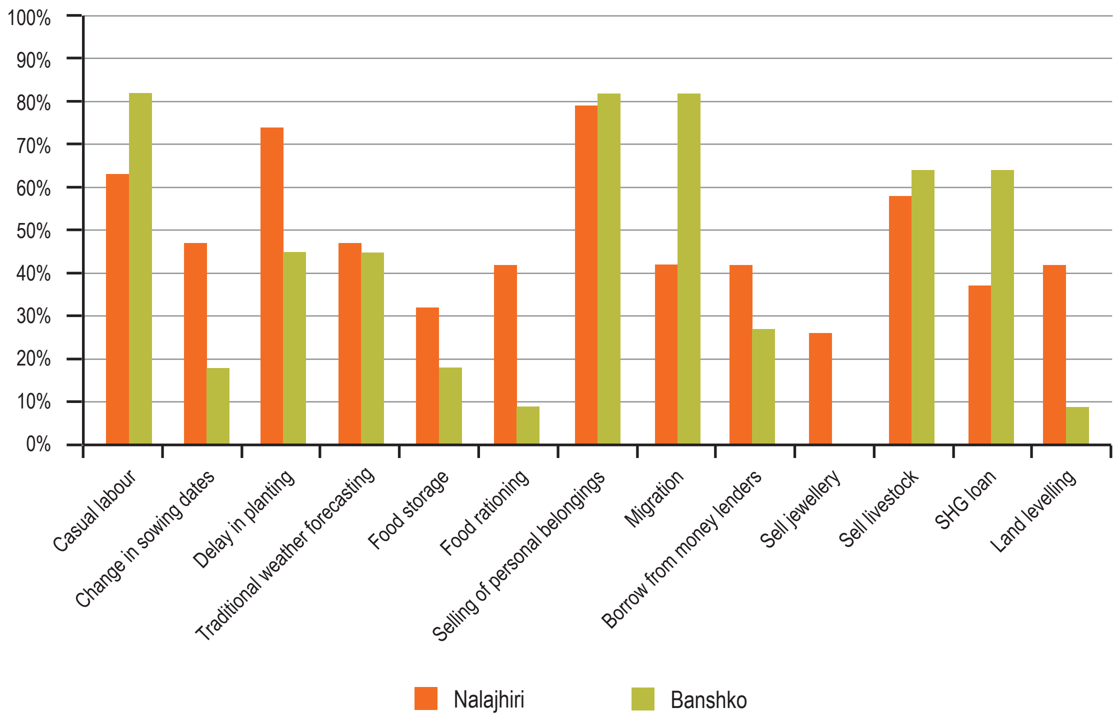
In Nalajhiri, the villagers' main coping mechanisms and adaptation strategies in response to climatic changes include working as casual labour after suffering crop loss due to drought (mentioned by over 60%), delaying planting activity (over 70%) and selling personal belongings (almost 80%) and livestock (almost 60%) (Figure 7). Other common adaptive strategies in response to climate distress included changing sowing dates, using traditional weather forecasting, storing and rationing food, migration, borrowing money from money lenders, and selling of jewellery. Self-help group (SHG) loaning and land levelling are strategies adapted due to government intervention programmes.

In Banskho village, assessment of the community coping mechanisms and adaptation strategies used in response to climatic changes showed that the villagers consider that working as casual labour, selling personal belongings and migration are the most immediate responses to suffering crop loss due to drought (each mentioned by over 80%) (Figure 7). Other strategies commonly adopted by villagers include walking long distances for water, selling livestock, delaying the planting activity, and use of traditional weather forecasting. Less common coping mechanisms used by villagers in Banskho include storing and rationing food, changing sowing dates, borrowing money from money lenders, and land levelling.

Community responses to drought

One community response to drought was in the form of distress migration. Villagers used their skills as labourers to earn money in response to the vulnerability created by drought, which was caused by climatic stress. Another

Figure 7:
Adaptation strategies in Nalajhiri and Banskho



common strategy adopted by the villagers was borrowing from money lenders at high interest rates and under harsh terms of repayment. Selling their cattle was another coping mechanism. In both villages, the majority of those who migrated were landless, marginal and small-scale farmers. The duration of migration ranged from a minimum of 40 days to a maximum of 180 days for both villages. The main reported cause for migration was drought. The duration of migration in Banskho ranges from a minimum of 50 days to a maximum of 180 days.

Discussion

Government intervention to support the community

In 1991, a village pond was constructed by the Irrigation Department, and two or three villages (including Nalajhiri) benefited from irrigation facilities. Out of 850 *bigha*, 450 received irrigation, which provided water for *Rabi* season. This had made possible the cultivation of cash crops like soybeans and oilseed. With better crop production, availability of fodder for livestock increased and some households took to dairy production and are selling milk in the nearby town. In 2001, District Poverty Initiative Programme (DPIP) activities were started by the Government of Madhya Pradesh. The DPIP strategy was to develop community strength through self-help groups (SHGs). SHGs were formed for various activities: sewing, horticulture, dairy, goat rearing, etc. Women's SHGs were formed to provide support to each other through loaning small grants by rotation, to meet their needs

Women's SHGs were formed to provide support to each other through loaning small grants by rotation, to meet their needs with dignity.

Government policies should be aimed at helping communities to cope with current climatic variability. The role of local institutions is to strengthen capacities.

with dignity. Common land and water resources were provided for development and management. Jodha (1996) stated that about 55% of livelihood needs of the poor in villages are met from common land. The activities undertaken during the drought season included land levelling, well deepening and well digging.

In 1998, the Rajgarh Forest Division initiated a village forest protection committee (FPC) under a joint forest management (JFM) programme. A total of 440 ha was allocated to the village FPC for protection and management of its usufruct needs like fuelwood, fodder and non-timber forest products (NTFP). The area was managed under a micro-plan developed by the FPC, which details work to be done and development initiatives of the Government. The protection of the area was done through patrolling. The Forest Department helped in extending the electricity supply, provided support to the village temple and constructed a culvert and a primary school. This was done in lieu of community support and contribution in forest management. The Forest Department started activities for regeneration of degraded forest (RDF) in 300 ha and another area of 50 ha was converted into a plantation with the support of irrigation facilities. The Forest Department also started some livelihood generation activities, like woodcraft work, which were undertaken by most of the villagers.

Government support in coping with vulnerability

The JFM effort resulted in the revival of the biodiversity of the area; trees have grown to the height of 10–30 feet. Grass production increased and the committee received Rs.8,000 from selling grass in one year. These efforts indirectly resulted in an increase in the water level in the well due to the slowed/reduced run-off caused by the improved ground cover leading to increased groundwater. The Forest Department carried out training and awareness-raising activities. Other support included vermicomposting and the use of organic fertiliser. The non-governmental organisation working in the block helped in conducting training on vermicomposting. The Government initiatives helped to increase water availability in the villages, thus reducing the water stress. The levelling of fields helped farmers in better agriculture output and reduction in soil loss due to erosion. The agricultural fields were provided with field bunding, which helped in retention of water for a longer duration in the field, resulting in better productivity. The assured irrigation enhanced cropping intensity and led to better productivity. The distress migration decreased as the opportunity for agriculture and other wage labour activities became available within the village. The support from the Forest Department also helped to increase the availability of labour opportunities in the village.

This shows that the role of government programmes is very important in enhancing adaptive capacities of vulnerable communities. Government policies should be aimed at helping communities to cope with current climatic variability. The role of local institutions is to strengthen capacities. Government policies should aim to integrate adaptation in planning (e.g. crop insurance, seed banks, alternative employment options, access to inputs and markets) and give more financial support for research and development and for dissemination of information (e.g. tolerant species, fertilisers, resource-conserving technologies and water management).

Conclusion

The adaption of humans to climate change is a natural process of selection of coping strategies. However, human activity over the last few centuries has hastened the process of climate change, making it important for the present generation to take remedial measures. It was found that the forest is an important support system. NTFPs can provide a supplementary source of income along with agriculture. The vulnerabilities faced are recurring drought, increase in temperature, delayed rain and shortening of rain days. The immediate responses are to take work as casual labourers and to migrate in search of work. The micro-level adaptation strategies reported are changing the cropping pattern, delaying the sowing period and diversifying into other livelihood sectors. Government intervention through the JFM programme helped in forest improvement. This effort resulted in recharging of the village well. The strategy of using the SHG model of invention led to the community taking loans from SHGs instead of from money lenders. It has also provided some non-farm-sector livelihood. The role of government is important and its policies should aim to reduce human vulnerability and facilitate sustainable adaptation as it strengthens the coping power of communities.

Acknowledgements

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Climate change and rural development strategy in Madhya Pradesh

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Introduction

Scientists have made it clear that climate change is happening, and that it is due to emissions of greenhouse gases produced largely by industrialised countries. Those likely to be worst affected are the world's poorest countries, especially poor and marginalised communities within these countries.

Climate change refers to short-, medium- and long-term changes in weather patterns and temperature that are predicted to happen, or are already happening as a result of anthropogenic emissions of greenhouse gases such as carbon dioxide. These changes include a higher frequency of extreme weather events, such as droughts and floods, as well as greater unpredictability and variability in the seasons and in rainfall. Overlying this increased variability are expected longer-term changes, such as temperature and sea level rises, and lower (or higher) rainfall.

The words 'climate change' buzz around the globe like wind whispering in everyone's faces. This is a serious concern for the world community and could become a bottleneck issue for sustainable development. This issue of climate change becomes more hazardous when it crosses paths with the challenges of poverty alleviation and rural development.

Climate change and poor communities

Many poor communities are heavily dependent on natural resources for their livelihoods. Smallholder farmers have much experience of adapting to their complex, diverse, and risk-prone environments. However, farming is now becoming even more difficult and risky because of greater unpredictability in the timing of rainy seasons and the pattern of rain within seasons, making it more difficult to decide when to cultivate, sow and harvest, and needing more resources to seize the right time for planting, and to maintain crops and animals through dry spells. Heat stress, lack of water at crucial times, and pests and diseases are serious problems that climate change appears to be exacerbating. These all interact with ongoing pressures on land, soil and water resources that would exist regardless of climate change (Jennings and McGrath, 2009).

This issue of climate change becomes more hazardous when it crosses paths with the challenges of poverty alleviation and rural development.

Vulnerability to climate change is not just a function of geography, or dependence on natural resources; it also has social, economic and political dimensions that influence how climate change affects different groups (Action Aid International, 2005). Poor people rarely have insurance to cover loss of property due to storms or cyclones. They cannot pay for the health care required when climate change induced outbreaks of malaria and other diseases occur. They have few alternative livelihood options when their only cow drowns in a flood, or drought kills their maize crop for the year – and they do not have the political clout to ask why their country's early warning system did not warn them of likely flooding. Climate change will also have psychological and cultural effects; for example, season-related beliefs and traditions are now being undermined by climate change (Jennings and McGrath, 2009).

Climate change and the context of poverty

Poverty alleviation has been made the top priority among the Millennium Development Goals, with a target to halve, by 2015, the proportion of people living below the national poverty line. In India, where 70% of the population lives in rural areas, and where a major portion of the people live below the national poverty line, rural development initiatives are major instruments to eradicate poverty. Climate change may jeopardise the path of development. According to the National Action Plan on Climate Change (GOI, 2009), “Climate change may alter the distribution and quality of natural resources and adversely affect the livelihood of [India’s] people. With an economy closely tied to its natural resource base and climate-sensitive sectors such as agriculture, water and forestry, India may face a major threat because of the projected change in climate”. The situation may deteriorate most in states like Madhya Pradesh.

Situational analysis of Madhya Pradesh

Madhya Pradesh is a predominantly rural state and most of its population is dependent on agriculture and natural resource use for sustenance. While the contribution of agriculture to the State’s domestic product (SDP) is less than 30%, nearly two thirds of its population depend on agriculture and related activities for their livelihoods (IGIDR, 2009). Madhya Pradesh has 52,117 villages, which are home to 73.5% of the population. The vast majority (71.48%) of Madhya Pradesh’s working population is employed in agriculture, as cultivators and agricultural labourers, compared to 57.10% for India overall. The health situation of Madhya Pradesh is very poor, with life expectancy at birth standing at 59 years for males and 58 years for females (corresponding to the period 2001–2006) – the lowest among all major states in India. The infant mortality rate (IMR) of Madhya Pradesh in 2004 was the highest among all states, estimated at 79 per 1,000 live births (84 rural; 56 urban), compared to the national IMR of 58. The maternal mortality ratio (MMR) data released by India’s Registrar General for the period 2007–2009 show the MMR of Madhya Pradesh as 269 per 100,000 live births, a significant improvement from 335 in 2004–2006, but still substantially worse than the national average of 212 (GOI, 2011).

...season-related beliefs and traditions are now being undermined by climate change.

A high poverty rate, especially a high rural poverty rate, combined with a low economic growth rate, and an even slower agriculture sector growth rate, does not augur well for Madhya Pradesh in the near future. The prospect of increased growth exceeding 6–7% at constant prices and climbing up to 8% over a sustained period of time is critical for the State. However, this seems to be a daunting task given the present scenario. Stagnation in agriculture, a slow rate of investments in industry, and growing but not accelerating growth in the service industries are the major challenges for the State at present. Considering the long-term trend in SDP figures, agriculture sector growth in Madhya Pradesh has been nearly stagnant. Between the periods of 1993–1994 and 2005–2006, while the State’s overall income grew by 61% at constant prices, the agriculture domestic product remained essentially the same, with growth of just 1%, and the contribution of agriculture to the State’s income fell from 40% 12 years ago to 25% today. What is also worrying is that even in the last five years or so, manufacturing (both registered and unregistered) has actually been declining. The ‘boom’ in construction, transport (including railways), trade, hotels and restaurants, communications, banking and other financial services, and fisheries seems to be pulling the State up from an otherwise poor performance in some core sectors (GOMP, 2007).

Observed changes in climate and weather events

Some changes have been observed in climate parameters in India. 'India's Initial National Communication to the UNFCCC' (known as 'NATCOM 1', GOI, 2004) has consolidated some of these. According to NATCOM 1, at the national level an increase of 0.4°C has been observed in the surface air temperature over the past century. A warming trend has been observed along the west coast, in central India, the interior peninsula, and north-eastern India. However, cooling trends have been observed in north-western India and parts of south India. While the observed monsoon rainfall at the national level does not show any significant trend, regional monsoon variations have been recorded. A trend of increasing monsoon seasonal rainfall has been found along the west coast, in northern Andhra Pradesh, and in north-western India (10–12% above normal levels, over the last 100 years) while a trend of decreasing monsoon seasonal rainfall has been observed over eastern Madhya Pradesh, north-eastern India, and some parts of Gujarat and Kerala (6–8% below normal levels, over the last 100 years).

The context of vulnerability

Crop productivity is sensitive to climate change, since it varies with the amount of monsoon rainfall and temperature changes within a season. Studies, including one by the Indian Agriculture Research Institute (IARI), have predicted greater losses in the *Rabi* season crop. Every 1°C rise in temperature reduces wheat production by 4–5 million tonnes in India. Small changes in temperature and rainfall have significant effects on the quality of fruits, vegetables, tea, coffee, aromatic and medicinal plants, and basmati rice. Pathogens and insect populations are strongly dependent on temperature and humidity, and change in these parameters may change their population dynamics. Other impacts on agriculture and related sectors include lower yields from dairy cattle and decline in fish breeding, migration, and harvests. Global reports predict a loss of 10–40% in crop production by 2100 (GOI, 2009:16). In this context, Madhya Pradesh is particularly vulnerable to climate change events. The vulnerability of the State is further deepened when we consider of the plight of the ethnic groups living there.

According to the Indira Gandhi Institute of Development Research (IGIDR, 2009), in Madhya Pradesh (as in most other parts of India) tribal communities are the poorest among all social groups. In rural areas, 58.6% of the tribal population was found to be poor, compared to 42.8% of the scheduled caste (SC) population. The incidence of poverty among scheduled tribes and scheduled castes in Madhya Pradesh is significantly higher than at the national level. The livelihoods of most of these marginalised groups are based on forest and agricultural resources. The conditions of the natural resources governed by these communities are also comparatively poor. So changes in the climatic pattern could exert negative impact on them, causing further deterioration in their present standard of living.

Whereas men view the forest more in terms of commercial potential, women see it as a resource for basic domestic needs.

There is a need to view climate change under the lens of gender also. Due to gender divisions, women are more connected with nature in their roles of providing for basic domestic needs. In developing countries, women have always had a close relationship with the trees and the forest. Traditionally, women gathered products from trees and other plants, products that provide them with the basic 'three Fs' – fuel, food and fodder – as well as serving a variety of other uses. Whereas men view the forest more in terms of commercial potential, women see it as a resource for basic domestic needs. These gender-based divisions further lead to a disproportionate impact of climate change on men and women. Acknowledging the relatively disadvantaged position of women in the process of development, it is important to put focus on the impacts of climate change on women in Madhya Pradesh.

Furthermore, Madhya Pradesh has a relatively poor economy and a fairly slow pace of growth in terms of the SDP, as previously mentioned. In 2007–2008, the per capita Net State Domestic Product (NSDP) in Madhya Pradesh was Rs.13,299, which was only approximately 55% of the national figure. During the period between 1999–2000 and 2007–2008, the per capita NSDP grew 0.8% per annum as compared to 4.85% at the national level (IGIDR, 2009). Adverse climatic conditions, like recurrent drought, water shortages and monsoon failures, are a bottleneck for agricultural production and will ultimately have an adverse impact on the progress of rural development in Madhya Pradesh.

Rural development programmes and climate change

The basic objectives of rural development programmes have been alleviation of poverty and unemployment through (i) creating basic social and economic infrastructure, (ii) promoting self-employment for the rural poor, and (iii) providing wage employment to marginal farmers and landless labourers so as to discourage seasonal and permanent migration to urban areas. Indian states with poor economies, like Madhya Pradesh, are continuously making efforts to arrest poverty and hunger by implementing programmes from the Central or State Government. The major programmes include the Madhya Pradesh Rural Livelihoods Programme, the National Rural Employment Guarantee Programme, the SGSY (Swarnajayanti Gram Swarojgar Yojana) and the District Poverty Initiative Programme (DPIP). Most effort is applied to the programme for strengthening the livelihoods of the rural poor. But it is important to address climate change as an integral part of this programme.

Strategies to facilitate rural development for coping with climate change

The former Prime Minister, the late Shrimati Indira Gandhi, once stated: “poverty is the worst polluter”. It is recognised that development and poverty eradication will be the best form of adaptation to climate change (GOI, 2009:13). Emphasising this fact, the Government of Madhya Pradesh needs to address the issues of poverty under the ongoing development programmes to fight climate change. The proposal to make a State Action Plan on Climate Change (SAPCC) is a good initiative in this regard. The SAPCC proposes to review the climate-related sectoral initiatives and the sectoral and regional issues related to climate change, and also to prepare strategies and action plans for the same.

It is recognised that development and poverty eradication will be the best form of adaptation to climate change.

An agriculture-based economy like that of Madhya Pradesh needs to give more weight to climate-resilient agricultural development, by strengthening the natural resources sector through integrated natural resource development activities. The ongoing watershed development programme under the Rajiv Gandhi Watershed Mission (RGWM) and the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) could be good opportunities for developing water harvesting infrastructure and for developing soil quality by arresting soil degradation.

Even with better crops, better soil conservation, better planting patterns and better weather forecasts, all of which are needed, there will still be regional calamities. To ensure that food is always available, the global food market will have to be more resilient than it is now (The Economist, 2010). In this context, it is important to put special focus on food security in rural areas.

Community-based adaptation (CBA)

Poor communities already struggle to cope with the existing challenges of poverty and climate shocks, but climate change could push many beyond their ability to cope or even survive. It is vital that these communities are helped to adapt.

Community-based adaptation to climate change is a community-led process, based on community priorities, needs, knowledge and capacities, and this process should empower people to plan for and cope with the impacts of climate change.

Although climate change is an integrated part of the daily challenges of the local people, they may not have identified or defined climate change as a problem. Nevertheless, most of these problems are indeed linked to climate change. Therefore, community-based planning for adaptation is required. Community-based adaptation (CBA) to climate change is a community-led process, based on community priorities, needs, knowledge and capacities, and this process should empower people to plan for and cope with the impacts of climate change.

CBA needs to start with communities' expressed needs and perceptions, and needs to encompass poverty reduction and livelihood benefits as well as reducing vulnerability to climate change and related disasters. In practice, CBA projects look very like 'development as usual' and it is difficult to distinguish the additional adaptation components. For example, in a drought year, we cannot divide water storage measures undertaken by local communities into those initiated as a response to 'normal' climate variability, and those initiated as a response to climate change. However, the difference is that CBA work attempts to factor in the potential impact of climate change on livelihoods and vulnerability to disasters by using local and scientific knowledge of climate change and its likely effects.

CBA could be initiated in Madhya Pradesh by first identifying communities that are most vulnerable to climate change, or these communities may themselves come forward to ask for assistance. CBA work needs to incorporate information on climate change and its impacts into planning processes. This includes:

- Scientific information, such as long-term predictions from climate change models, seasonal forecasts, and information on trends based on data collected at nearby weather stations; and
- Local knowledge about trends and changes experienced by communities at a local level and strategies these communities have used in the past to cope with similar shocks or gradual climatic changes.

If development gains are to be sustained in the future, all disaster risk reduction and development work should take into account the impacts of climate change. An important strength of this strategy is that it recognises both indigenous and external scientific knowledge as resources upon which to build successful local strategies for vulnerability reduction.

Conclusion

The Government of Madhya Pradesh could place more emphasis on community-based planning and adaptation strategies for rural development programmes, which may lead to reduction of poverty and ensure sustainable development as community ownership is enhanced. The Government can facilitate this process by reorienting and sensitising the implementing staff and it can also incorporate adaptation strategies into all policies that promote development.

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Climate change and gender in Madhya Pradesh

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Introduction

Climate change may seem to be gender neutral because it is largely understood through scientific studies that forecast changes in the physical parameters of climate – rainfall and temperature variation, water stress, and the upward movement of the tree-line in forests – or the increasingly unpredictable nature of natural disasters like droughts.

Ordinary people understand climate change in terms of the impact of changing weather patterns on the economic and social parameters of their lives and livelihoods. A man's primary role is to earn and provide for the family. A woman's role is also to provide for the family, in addition to the responsibilities of collecting water, fuelwood and fodder for their homes, and nurturing and caring for family members. This is where the vulnerability of men and women to climate change impacts differs. This is also why policies and programmes driving climate change

...women are less likely to have the education, resources, authority and opportunities needed to adapt to climate change. Addressing women's needs and concerns often implies doing things differently.

adaptation need to have a gender lens in order to ensure that adaptation interventions benefit the lives and work of both women and men.

The words 'gender' and 'women' are often used interchangeably even though 'gender' refers to both men and women. While 'man' and 'woman' refer to biological differences in sex, 'gender' refers to the social differences between male and female identities. These gender differences are governed by the sociocultural norms in a society. Thus, 'adding women' to existing programmes and schemes may still not benefit both women and men because of the existing gender divide, which generally means that women are less likely to have the education, resources, authority and opportunities needed to adapt to climate change. Addressing women's needs and concerns often implies doing things differently. And as a basis for more effective action, adaptation plans, programmes or schemes must be designed and implemented based on gender-differentiated baseline data, assessments and research.

The Madhya Pradesh SAPCC has made a start by providing for (a) preparation and implementation of gender-centric Local Action Plans on Adaptation (LAPAs) through Panchayati Raj Institutions (PRIs); and (b) gender-centric participatory assessments for monitoring and evaluation.

Better implementation of gender-responsive components of existing programmes (like Joint Forest Management and Agricultural Technology Management Agency (ATMA)) and designing more gender-responsive adaptation programmes, especially in areas like energy and rural and urban transport, will go a long way towards integrating gender into climate change adaptation programmes across livelihoods, infrastructure, public services and governance.

Gender-responsive adaptation to climate change

Are gender-disaggregated data critical?

While most vulnerability studies focus on the physical parameters of climate, the Madhya Pradesh SAPCC adds value to these assessments by including selected socioeconomic parameters, such as sex-ratio, literacy rates, percentage of households with access to safe drinking water, sanitation and electricity, percentage of land holdings below one hectare, crop diversity, milk production per capita, and number of available varieties of non-timber forest products (NTFP). The Madhya Pradesh SAPCC recognises that "some of the(se) indictors...determine the adaptive capacity of populations".

The above indicators vary by geographic location – e.g. by district and by rural/urban area – and are expressed quantitatively, in terms of numbers of different levels of schools, health centres and power generation stations, proportions of workers employed in primary, secondary and tertiary sectors of the economy, and proportions of households with access to safe drinking water, sanitation or ownership of consumer goods (e.g. radios, televisions and telephones), among others.

These indicators also vary for men and women, who do not benefit equally from infrastructure, land and public services. These indicators, when seen through a gender lens, reveal how men and women are differently vulnerable to climate change impacts. The gender divide also shows how men and women have different capacities to adapt to climate change. A gender lens can be used by asking questions like: How many women own and control assets

Box 1:

Planning for differing health impacts

The Madhya Pradesh SAPCC recognises the following WHO-identified areas of climate-sensitive health impacts: (a) availability of food, (b) safe drinking water, (c) a decent home that provides protection against disasters, (d) a reasonable income, and (e) good social and community relations.

Gender disaggregated data are key to designing and implementing the envisaged health disaster management plan in a state where:

- 42% of women are malnourished
- only 2 in 5 women receive antenatal care
- 71% of pregnant women receive the recommended two does of tetanus toxoid vaccine
- only 14% of rural families have a drinking water source within their homes (50% within half a kilometre and 36% further away, mostly obtained from handpumps or tube wells).

Health disaster management plans will be more gender-responsive if they are based on gender-disaggregated baseline data, research and assessments. Similarly, gender-responsive programmatic interventions should include targeted awareness-raising and knowledge-building for women, membership of women in decision-making groups, promotion of gender-appropriate income-generation avenues and provision of safe drinking water and sanitation within (or very near to) the home.

like land and livestock? How many women have control over their own or their family's income? How many women earn their livelihoods through NTFPs and what control do they have within the value chain? How many girls attend school (and is this related to the occurrence of drought and desertification)? and, How many women access health centres (and how will this behaviour be affected by the anticipated impacts of climate change on public health)?

Recognising the gender divide in rural and urban Madhya Pradesh

Life expectancy in Madhya Pradesh continues to be the lowest in the country. Natural calamities like drought, floods and hailstorms are common in Madhya Pradesh, contributing to mortality rates. Several global studies (by UNDP, IUCN and Oxfam, among others) have shown that many more women and girls die during natural disasters than men and boys, for various gender-related reasons, and also that recurring disasters lower women's life expectancy more than men's. In the aftermath of a disaster women are also more likely to be victims of domestic and sexual violence.

These disasters also affect productivity of the climate-sensitive agrarian economy, which is the mainstay of 70% of the population in the State. Interestingly, over half (53%) of agricultural labourers are women. The percentage of women cultivators is also high at 38%. The State has one of the country's largest tribal populations, forming 20% of the State's population, and they are dependent on forests for their livelihoods and survival. Most NTFPs are collected by women. Similarly, much of the horticulture and fisheries work is done by women. It is important to note that women's labour and the burden on their time is increasing due to the impacts of climate change. For example, women have to repeatedly sow seeds when rains fail or repeatedly do weeding as more weeds mushroom in higher temperatures. Women's labour has also increased due to labour-intensive adaptation interventions like organic farming.

Box 2:
Land rights for women farmers

Madhya Pradesh is one of the very few states that have promoted giving land titles to women. Less than 6.5% of women farmers legally own land although they contribute up to 70% of the agricultural work (IGSSS, 2008).

A policy push for land rights for women will help women farmers take stronger decisions regarding their farming practices in the face of climate vagaries.

The Madhya Pradesh SAPCC envisages adaptation strategies that promote soil and water conservation measures, dry-land agriculture and horticulture, cropping systems suited to different agro-climatic zones, information management systems with weather forecasting, preparation of forest management plans, water management practices, availability of adequate feed, fodder and water for livestock during floods/droughts, creation of fish seed banks and capacity building on climate-resilient agriculture and forestry, among others. Given the high proportion of women workers in agriculture and related activities, gender-responsive adaptation interventions that view women as active agents of change will help the State economy adapt better to climate change. The Madhya Pradesh SAPCC already highlights "projects which are aiming to enhance women's income through adoption of low input costs and effective technologies in watershed development" and climate-resilient strategies in the fishery sector that will help provide "food and nutritional security in particular to women and the girl child".

Low carbon interventions in cities can benefit from incorporating women's needs into planning and implementation.

Madhya Pradesh's urban population is slated to grow by a whopping 56% between 2011 and 2026, with a steady rise in slum dwellers. The Madhya Pradesh SAPCC envisages a three-pronged urban management approach comprising environmental protection, economic growth and social equity – all beginning from the initial planning stage. Low-carbon housing, transport, water supply, waste management and energy-use coupled with good governance have been identified in the SAPCC as key components of climate-resilient urban planning and growth. A major challenge will be addressing urban poverty, which is growing faster than rural poverty.

Like rural women, do urban women (and men too) have different requirements? Do low-carbon growth interventions affect them differently? Yes. For instance, women prioritise houses with airy and naturally-lit kitchen areas, provision of adequate and safe water and sanitation, sanitised household garbage removal systems, well-lit access roads, good public transport and neighbourhood education and health services. Low carbon interventions in cities can benefit from incorporating women's needs into planning and implementation. Adequate participation of women in urban decision-making institutions and structures can help cities become more productive, sustainable and safe for both women and men.

Conclusion

Recognising and empowering women is the key to good adaptation. Adaptation measures succeed where women – especially resource-poor and socially marginalised women – are empowered through programmes and schemes to understand climate change, to speak up, to take decisions and engage in adaptation practices. These interventions succeed best when they are backed by adequate resources for both genders. Key components of gender empowerment in the context of climate change adaptation include:

- collection of gender-disaggregated data for all programmes and schemes that contribute to climate change adaptation
- asset-creation for women, including land titles, livestock ownership, leases on forest land, biogas facilities and water tanks, so that women can take decisions regarding optimum and efficient use of these resources in the face of climate change
- promotion and support for women's income-generating activities, including kitchen gardens, poultry and other small livestock, NTFPs, inland fishing, horticulture, small enterprises like manufacturing vermicompost and other bio-inputs as well as other products such as brooms, mats, puffed-rice, etc.
- reduction of women's labour and workload, through research and development and use of women-friendly technology
- equal participation of women as informed decision-makers in mainstream institutions in order to shape laws, policies and programmes that improve their lives and livelihoods
- earmarking public resources towards gender budgeting in proportion to the number of women engaged in specific sectors, especially agriculture and related sectors, for adaptation
- building awareness and capacity among women, especially poor and marginalised women, in rural and urban areas, on climate change adaptation in all sectors.

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Understanding climate change adaptation in view of poverty alleviation and sustainable development initiatives in Madhya Pradesh: Perspectives from a research study

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Introduction

Climate change is not only a major global environmental problem but also an important development concern. Climate change has the potential to harm societies and ecosystems. In particular, agriculture, forestry, water resources, human health, and natural ecosystems will need to adapt to a changing climate or face a trend of decline. Poor and rural communities are heavily dependent on ecosystem services and therefore are most severely affected by deteriorating environmental conditions and factors limiting their access to natural resources. The circumstances of poverty weigh heavily on each of the three major dimensions of vulnerability: exposure (to a threat or perturbation), sensitivity (the degree of harm as a result of that threat), and resilience (the ability to recover from harm). In these vulnerable conditions, livelihoods become less secure, health risks increase, and the ability to participate in income-generating opportunities is further restricted.

A dynamic agricultural sector enables successful livelihood diversification. Strong agricultural growth enables people to make choices about their livelihood strategies from a position of strength rather than one of weakness or desperation. It can boost economic growth and the quality of that growth would benefit the poor. The predominant characteristic of Madhya Pradesh is that it is essentially a rural state with a substantial population living below the poverty line. Most residents of the State are dependent on natural resources for their survival.

A dynamic agricultural sector enables successful livelihood diversification.

In Madhya Pradesh, the majority of the population depends on climate-sensitive sectors such as agriculture and forestry – sectors that play a vital role in anti-poverty initiatives. Agriculture in Madhya Pradesh is mostly rainfed and the major challenges include soil erosion due to rolling topography, the practice of keeping land fallow during *kharif* and taking only one crop in *rabi*, the existence of large areas of cultivable wasteland and fallow land, a high proportion of low-value crops with low productivity, and low consumption of fertilisers.

In order to understand how farmers in western Madhya Pradesh make strategic decisions in response to seasonal variations in climatic, market and other factors, and how the various programmes at the district level can be integrated to address the agenda of climate change adaptation, a rapid study based on the analysis of existing climate change adaptation practices and inter-linkages with sustainable livelihoods and poverty was undertaken. The study was conducted between January and April 2008 in two development blocks of Ujjain District.

For this study, we relied mainly on discussions with a variety of stakeholders. Most of the insights and ideas gathered were further refined, validated and debated within these intellectual discourses. The recommendations and conclusions presented here represent the outcome of this dialogue process.

Methods

The semi-arid region of Madhya Pradesh consists of 11 western districts that do not have good forest cover in comparison with the central and eastern parts of the State. Districts in the western and north-western parts of the State are considered to be susceptible to desertification. This region has traditionally been a drought-prone area. Ujjain is one of these western districts and was selected for study based on its ecological profile, forest cover, poverty levels, ongoing rural development programmes, socio-political environment, density of the scheduled caste (SC) population, and connectivity. Input from the district administration was also taken into account in selecting the blocks and study villages within the district.

The scope of study was confined to the investigation and analysis of farmers' perceptions of climate change and agricultural practices in four villages of two development blocks. The geographical scope of the field survey was limited to these four villages whereas the policy-related discussions were held at the district level. The scope of the discussions was confined to the agriculture sector only, including the impact of climate change on agriculture. Preliminary assessment of the linkages between various developmental sectors and climate change was also carried out through content analysis of existing policies and programmes. Major gaps were identified in order to inform subsequent plans and discussions on climate change adaptation.

To assess farmers' perceptions and identify background determinants, a questionnaire-based survey and focus group discussions were implemented. For the field-level survey, multistage systematic sampling was used. Out of the seven development blocks in Ujjain District, two blocks, namely, Ujjain and Badnagar, were selected based on climate-related indicators including drought, excessive rains and overexploitation of groundwater. The 'snowball' method of sampling was adopted to contact respondents.

The survey used a structured questionnaire comprising both open-ended and closed questions. To assess the perceptions of other stakeholders in the sector, the study also involved one-to-one interaction with representatives of departments, agencies and NGOs involved in agriculture extension and rural development activities. Primary data were generated through the field-level survey, discussions and interviews, whereas secondary information was collected from a variety of sources.

Limitations of the study

There may be gaps in the coverage of economic and policy issues as this was beyond the scope of the study. The study is based on the information collected from the survey and there may be information gaps as well as under- or overestimation regarding the perceptions of the farmers, due to ignorance or bias in the information provided by the respondents.

Results and discussion

The problems arising from climate change and climate variability in rural areas of Madhya Pradesh are manifested in terms of land degradation, water scarcity, constrained livelihoods and associated socioeconomic issues. The strategy for managing these problems can be based on the following two cornerstones.

1. An integrated eco-regional approach to climate change adaptation and observation of how impacts can be made via technological breakthroughs can ensure the sustainability of the natural resources that are required to address the heterogeneous nature of poverty.
2. A 'mission mode' approach can bring a fair degree of convergence among all the sectoral departments and their schemes.

The field observations, discussions with district authorities, and analysis of the findings indicate that in this district climate change does not necessitate the use of different or new strategies but requires sound policies on socioeconomic development. The concerns related to climate change cannot be treated separately from other development concerns; rather, they must be integrated into efforts for poverty reduction and sustainable development in order to achieve significant and lasting results.

Current development strategies, however, usually tend to overlook the risks of climate change, which seem distant compared to immediate policy-making priorities. Climate change either has to be shown to be a compelling threat that overshadows other policy demands, or it has to be integrated into the routine decision-making frameworks of government organisations.

The study results indicate that farmers' decisions are influenced by a host of socioeconomic factors that include household characteristics, household resources and assets, access to information and availability of social services. Farm-level decision-making happens fairly quickly, usually influenced by seasonal climatic variations, the local agricultural cycle and other factors. Appropriate adaptation efforts are important for farmers to achieve their farming objectives, including food and livelihood security.

The study also looked at the interrelationship between changing climate conditions and poverty. Analysis was done to assess the farmers' perceptions about long-term changes in temperatures and rainfall patterns. The survey results suggest that farmers are aware that the region is getting warmer and drier with increased frequency of droughts and changes in the timing of the rains. Observations of temperature and precipitation changes over time also confirm the perceptions of the farmers. An important question is whether government departments and farmers are prepared to adjust their management practices to ensure that they make efficient use of the available rainfall and water resources.

Farmers identified the lack of forecast information on climate change, inadequate supply of inputs like fertilisers, erratic power supply and inadequate availability of high-quality certified seeds as key barriers. Addressing these issues could significantly help farmers to adjust their agricultural practices.

Important adaptation options being used by farmers include varietal changes, intercropping, diversification of crops, changes in the dates of sowing and harvesting, increased use of irrigation, increased use of water and soil conservation techniques, and diversification from agriculture to horticulture and floriculture. Some small-scale and marginal farmers are also switching to non-farm activities to improve their livelihoods. Growing a number of different crops in the same field (about 66% of farmers combine horticulture and floriculture with agriculture) minimises the risk of complete crop failure, as different crops are affected differently by climate events.

It is important to understand that these adaptation measures should not be used independently but in combination, such that they are complementary to each other. For instance, use of irrigation technologies needs to be accompanied by crop management practices. Supporting farmers in increasing these adaptation measures through providing the

necessary resources – such as credit, information and training – can significantly increase farmers' capacity and sustain high productivity levels, even under changing climatic conditions.

The study confirms that implementation of efficient extension services and capacity building programmes like Agricultural Technology Management Agency (ATMA), as well as farming experience, mixed crop and livestock farms, and perceptions of climate change are some of the important factors to be considered when reviewing farm-level adaptation options. Designing policies that aim to improve these factors for marginal and small-scale farmers may significantly improve their adaptive capacity.

Government policies need to support research and development activities that will result in appropriate technologies to help farmers adapt to climate change. Government responsibilities are usually implemented through deliberate policy measures to enhance the adaptive capacity of agricultural systems. Examples of these policy measures include drought-resistant crop technologies, improved climate information forecasting and dissemination, and promotion of farm-level adaptation measures, such as the use of efficient irrigation technologies.

Policy recommendations

Though increasingly sensitive to environmental concerns, the Government of India has still not completely integrated these concerns (including climate change) into its planning processes. Sectoral and development plans have so far not paid adequate attention to the close links among various sectors such as forestry, agriculture, water, fisheries, health and education.

Two types of policy interventions are suggested with a view to integrating climate change concerns in the development process.

1. Reorient policies and practices that already integrate current climate variability (e.g. rainwater harvesting, water conservation and disaster management practices).
2. Fill policy gaps to address current climate variability while also enhancing the resilience of the poor to the expected increases in vulnerability due to climate change.

Other policy recommendations emerging from the study include the following:

- Strengthen capacities for influencing policy-makers with regards to integrating global environmental concerns in state projects, programmes and policies.
- Demonstrate technologies (including traditional technologies) and innovative approaches to address linkages between environmental issues and developmental challenges.
- Build partnerships among Panchayati Raj Institutions (PRIs), women's groups, civil society organisations and government agencies to develop, test and disseminate innovative, gender-equitable and community-managed approaches to sustainable livelihoods and environmentally sustainable natural resource management.
- Pilot test models for employment creation and poverty eradication, and make them competitive in a climate of globalisation and economic liberalisation.
- Create platforms for exploration of issues such as management of common property resources by a range of actors, including those who are not usually involved with these concerns.
- Build capacity of PRIs in rural areas, including through support to the national initiative.
- Support PRIs for environmental planning and programming at the local level.
- Build capacity for district and village-level planning, including developing databases and enhancing technical expertise in the use of information and communication technologies.

Conclusions

Although the concept of sustainable development has received much attention, unfortunately this has only been at the philosophical level and it remains a low priority for many governments. When states like Madhya Pradesh are referred to as 'rich states with poor people' it suggests that rapid exploitation of natural resources is the only way to overcome poverty and backwardness.

Despite the growing realisation about the fragile linkages between poverty and environment at the policy-making level, these linkages are seldom appreciated at the field level, primarily because of lack of awareness. Thus, economic development activities continue to adversely impact the environment.

As the 12th Five Year Plan (Government of India) commences, the country is at a turning point. We are compelled to depart from certain straitjacketed norms and formulate new approaches based on implementation experiences, thereby leading to the realisation of the vision of poverty eradication.

Sector-specific strategic development organisations can spearhead efforts to achieve shared visions and goals for climate change adaptation, sustainable livelihoods and poverty alleviation. While sector-specific institutional infrastructure, policies and legal frameworks are relatively robust in Madhya Pradesh, the relevant departments will need to gear up to address the emerging demands of climate change adaptation and sustainable development.

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