

RESEARCH PAPER

Adaptation Measures to Combat Climate Change Impacts on Agriculture: An Empirical Investigation in the Chambal Basin

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Abstract: This study is based on the empirical investigation of the climate change adaptation measures adopted by the farmers in the Chambal basin. The adaptation measures were analysed after investigating the nature and impact of climate change in the region. Four representative districts were selected using control sampling. A representative sample of farmers was selected through stratified snowball sampling technique. Descriptive statistics and case study methods were used for results and analysis. Detailed irrigation profiles of the farmers were traced. The moisture index was calculated based on secondary data. A sampling survey method of investigation was used in the study. This paper also presents the context of maladaptation of monoculture in the region and severe groundwater depletion associated with this practice. The study directs policy to strengthen water-harvesting measures in the region to facilitate the adaptation measures for coping with the effects of climate change on agriculture.

Keywords: Climate Change, Agriculture, Adaptation, Water Harvesting, Maladaptation

1. INTRODUCTION

A consistent shift in the weather of a region over a long period is termed as climate change. It includes many variables like temperature, rainfall, rate of evaporation, wet day frequency, etc. The Bruntland Report states that

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climate change was identified as a crucial problem bearing on our survival long back (WCED 1987). According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007), large scale variations in average temperatures and precipitation in the coming decades will have a significant impact on ecosystems, related livelihood options, and overall human well-being. Agriculture as a managed ecosystem gets affected by climate change most significantly. Productivity, crop-duration and even selection of crops to be grown in a region depend upon temperature coupled with duration and spatial distribution of rainfall. Hence, changes in average climatic conditions along with the occurrence of extreme climatic events will have a significant impact on the agricultural sector, which, in turn, may have critical implications for food security. However, the effects in different regions around the globe will differ significantly. Consequently, region-based research on the interactions between climate change and agricultural performance has gained momentum. Climate change adaptation and mitigation, therefore, is now an important area of research in social sciences as well as physical sciences.

The real challenge of climate change is to minimize its risks through adaptations, which is a process of adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate or avoid harmful activities and exploit beneficial opportunities. These adaptations have to take place at all levels from changes in global systems to changes at national and regional levels through adaptations made by local communities and individuals. The development of adaptation strategies needs to recognise the appropriate mix of actions at different levels. Agriculture is one of the most important sectors to be severely impacted by climate change and thus an inquiry into the adaptation measures in this sector in relation to climate change is a must. It is all the more significant to be carried out on a regional basis as the regional climate has peculiarities that govern crop selection and irrigation management at the most basic level. This study is an attempt to fulfil this objective in the Chambal basin, which has faced significant changes in climatic and cropping patterns in the decades following the construction of Gandhi Sagar Dam on the Chambal river.

2. NATURE OF CLIMATE CHANGE, ITS IMPACT ON AGRICULTURE, PERCEIVING THE CHANGE, AND ADAPTATIONS MADE: A REVIEW OF LITERATURE

2.1. An Assessment of Risk and Vulnerability due to Climate Change

In some natural systems, human intervention may facilitate adjustment to the expected climate and its effects (IPCC 1996). In human systems, adaptation seeks to moderate or avoid harmful activities and exploit beneficial opportunities. Adaptations take place at all levels from changes in global systems to changes at national and regional levels through changed practices of local communities and individuals. The development of adaptation strategies needs to recognise the appropriate mix of actions at different levels. Agriculture is inherently sensitive to climatic conditions and is among the most vulnerable sectors to the risks and impacts of global climate change (Parry and Carter 1989; Reilly and Schimmelpfening 1999). Studies show that without adaptation, climate change is generally problematic for agricultural production and agricultural economies and communities; but with adaptation, the vulnerability can be reduced and there are numerous opportunities to be realised (Rosenzweig and Hillel 1995; Mendelsohn 1998).

Studies on climate change trends have already shown that climate variation is a reality for India but its impact on society as well as its social and economic consequences are yet to be fully understood. Also, there is neither a consensus on the definition of vulnerability to climate change nor a full, regionally nuanced mapping of impacts of variables available. It is only when we have a better understanding of what constitutes vulnerability to climate change and what are its region-specific impact, that we can determine proper adaptation strategies. In this context, one study has found that the states of Bihar, Rajasthan, Gujarat, Punjab, Haryana, Madhya Pradesh, Maharashtra, Andhra Pradesh, and Karnataka have the lowest adaptive capacity (O'Brien *et al.* 2004). The areas of greatest climate-sensitivity are Rajasthan, Madhya Pradesh and Uttar Pradesh using current climatological data. To identify and assess crop adaptation, there is a pressing requirement for more observational field studies to achieve detailed knowledge about how crops respond to climate change. In another study, it was found that a 2°C temperature rise and 7 per centages increase in rainfall would lead to an almost 8 per cent loss in farm net revenue (Kumar and Parikh 2001). The regional differences are significantly large with northern and central Indian districts along with coastal districts bearing a relatively large impact. It has been observed that during the past 25 years, significant changes in climate are observed over different regions

of the country (Sinha, Singh and Rai 1998). For example, many parts of northern India show an increase in minimum temperature by about 1°C in the *rabi* cropping season. However, mean temperatures are misleading as some of the individual regions could exhibit a large variation with a larger impact on *rabi* production.

2.2 Exploring Perceptions about Climate Change in Agricultural Systems

As the impacts of climate change on agriculture are severe, it is important to take appropriate actions to minimise the losses. The foremost requirement for taking an action is to accurately assess the nature of change in the climatic events. In this context, existing research suggests that the formation of environmental perceptions is most of the time a local phenomenon rather than a global phenomenon (Magistro and Roncoli 2001). It is usually associated with personal experiences about changes in temperature, precipitation and observation of crop-responses to the environment. In developing countries ‘farm surveys’ and ‘focus group discussions’ are the preferred mode of research in identifying farmers’ perceptions of climate change and the factors that shape them. A study on climate change in the Western Himalayas of India (Vedwan and Rhoades 2001) compared farmers’ perceptions with ‘locally idealised traditional weather cycles’. Several studies indicate that socio-economic and demographic factors are most important in determining farmers’ perceptions. In a survey-based study of the Sekyedumase district in the Ashanti region in Ghana, 180 farmers were queried about their perceptions of changing climate in terms of changes in temperature, rainfall and area covered by vegetation in the past 20 years (Fosu-Mensah, Vlek and MacCarthy 2012). They were also queried about their major adaptations to climate change and the barriers they faced. Household characteristics, years of farming experience, size of landholdings and their access to extension services along with credit services were major explanatory variables. Age of the head of the farming household, which is usually a proxy for the farmer’s experience, was found to be one of the most important factors in shaping the perceptions about climate change (Diggs 1991). Extensive field-based studies of African small-holding farming systems have shown that the level of formal education of farmers is positively associated with their ability to perceive correctly climate-related changes (Mustapha, Sanda and Shehu 2012). Access to banking services and information about climate change through extension-services plays an important role in enhancing farmers’ understanding of climate change and appropriate adaptation measures (Maddison 2007). Farmers with a higher level of income were also found to be more perceptive of changes in climate (Semenza *et al.* 2008). Finally, a

cross-sectional analysis of farmers in Kyuso district in Kenya, Africa, found that joint family households were less perceptive of climate change as such families are more inclined to engage in non-farm activities as well (Ndambiri *et al.* 2012). A comprehensive strategy that seeks to improve food security in the context of climate change may include a set of coordinated measures related to agricultural extension, crop diversification, integrated water and pest management, and agricultural information services. Some of these measures may have to do with climatic changes and others with economic development. Indeed, studies indicate that farmers perceive that the climate is changing and also adapt to reduce the negative impacts of climate change (Thomas *et al.* 2007; Ishaya and Abaje 2008; Mertz *et al.* 2009). Studies further show that the perception or awareness of climate change (Semenza *et al.* 2008; Akter and Bennett 2011) and taking adaptive measures (Maddison 2007; Hassan and Nhemachena 2008) are influenced by different socio-economic and environmental factors.

Adaptation to climate change is a two-step process; the first step requires the farmers to perceive a change in climate and the second step requires them to act through adaptation (Maddison 2007). Studies of perceptions of climate change, both in developing (Vedwan and Rhoades 2001; Hegeback *et al.* 2005; Thomas *et al.* 2007; Ishaya and Abaje 2008; Gbetibouou 2009; Mertz *et al.* 2009) and developed (Diggs 1991; Leiserowitz 2006; Semenza *et al.* 2008; Akter and Bennett 2011) nations show that the majority of population have already perceived climate change and they are adapting to it in various manners (Falco, Veronesi and Yesuf 2011). There are different ways of adapting to climate change in agriculture (Bradshaw, Dolan and Smit 2004; Kurukulasuriya *et al.* 2004; Mertz *et al.* 2009) and different factors affect the use of any of these adaptation methods (Deressa *et al.* 2009). For instance, it has been shown that better access to markets, extension and credit services, technology, farm assets (labour, land and capital) and information about adaptation to climate change, including technological and institutional methods, affect adaptation to climate change (Hassan and Nhemachena 2008). Changing cropping calendars and pattern will be the immediate best available option with available crop varieties to adapt to the climate change impact (Rathore and Stigler 2007). The options like introducing new cropping sequences, late or early maturing crop varieties depending on the available growing season, conserving soil moisture through appropriate tillage practices and efficient water harvesting techniques are also important. Developing heat and drought-tolerant crop varieties, by utilizing genetic resources that may be better adapted to new climatic and atmospheric conditions, should be the long-term strategy. Genetic manipulation may also help to exploit the beneficial effects of

increased CO₂ on crop growth and water use (Rosenzweig and Hillel 1995). One of the promising approaches would be gene pyramiding to enhance the adaptation capacity of plants to climate change inputs (Mangala 2007).

2.3. Adaptation Strategies

Adaptations to climate change impacts are not new phenomena. Natural and socio-economic systems have been continuously and autonomously adapting to a changing environment throughout history. Adaptation to climate change and variability (including extreme events) at national and local levels is regarded as a pragmatic strategy to strengthen capacity to lessen the magnitude of climate change impacts that are already occurring and could increase gradually (or suddenly) and may be irreversible. Adaptation can be anticipatory, where systems adjust before the initial impacts take place, or it can be reactive, where change is introduced in response to the onset of the impacts. Climate change adaptations in agricultural practices often have synergy with sustainable development policies and may explicitly influence social, economic and environmental aspects of sustainability. Many adaptations have co-benefits (improved efficiency, reduced costs, environmental co-benefits) as well as trade-offs (e.g. increasing other forms of pollution) and balancing these effects will be necessary for successful implementation of climate change adaptation and mitigation in the agricultural sector (IPCC 2014).

Farmers generally adapt swiftly to avert their agricultural production losses. In India, adaptations in farm practices (changing the sowing dates, adopting different crop varieties and improving water supply) have been seen to reduce the adverse impacts of climate change (Kumar and Parikh 2001). Adaptation measures could be simple ones like shifting planting calendars or changing crops, or more costly ones like investing in protective infrastructures such as damming rivers to provide assured water supply for irrigation. Farm-level resource management innovations such as the development of irrigated drainage systems, land contouring, reservoirs and recharge areas, and alternative tillage systems are also used to minimise the impact of climate change on agriculture (Easterling 1996). A comprehensive strategy that seeks to improve food security in the context of climate change may include a set of coordinated measures related to agricultural extension, crop diversification, integrated water and pest management, and agricultural information services. Some of these measures may have to do with climatic changes and others with economic development. Studies have indeed indicated that farmers perceive that the climate is changing and also adapt to reduce the negative impacts of climate change (Thomas *et al.* 2007; Ishaya and Abaje 2008; Mertz *et al.* 2009). From United Nations Framework

Convention on Climate Change (UNFCCC 1992) to India's National Communications (MoEF 2004) river basin specific impacts of various climate change scenarios and vulnerability to droughts and floods have been estimated at the catchment, sub-catchment and watershed levels, as well as for administrative units such as districts.

While such exercises are useful given the multiple pressures that act on water resources, integrated watershed modelling might be more appropriate. A pathbreaking study examined the current adaptation strategies of stakeholders in the Cauvery delta of Tamil Nadu and argued that the responses to climatic and non-climatic pressures have largely been ad hoc and hence could be inadequate and unsustainable in the long term (Janakarajan 2010). Finally, in context to efficient natural resource management, conservation agriculture offers resource-poor farmers a set of possible options to cope with and adapt to climate change (Thomas *et al.* 2007). Improved water management will represent the key adaptation strategy in both irrigated and dryland agriculture. Emphasis will also be given to crop production systems located in delta regions to sustain high production potential under sea-level rise (Wassmann and Dobermann 2007). Based on fieldwork in Andhra Pradesh and Rajasthan, effective ways to make farmers more adaptive to climate change were suggested (MSSRF 2008). The recommendations include specific changes in traditional water management practices such as *barren* in Rajasthan, establishing small farm networks that enable farmers to share knowledge on-farm management practices, utilising weather data from simple meteorological stations operated by farmers and use of some new farming techniques such as systems of rice-intensification.

2.4. Costs and Limits of Adaptation

There is an array of factors that limit adaptations by ecosystems, communities and individuals. There are cost considerations and threshold limits that may primarily be categorised in four sets – ecological, physical, economic and technological (Adger *et al.* 2009). A farmer may practically abandon farming due to limits to adaptation with respect to water resources. It is, thus, especially important to understand social limits to adaptation because this may put the responsibility on governance to work proactively for mitigation strategies. If the capacity to adapt is considered unlimited, a key rationale for reducing greenhouse gases is weakened (Dow *et al.* 2013). A linked consideration, where adaptation is well within the limit, is 'willingness to adapt', which is influenced by individual characteristics and perceptions about climate change impacts (Pannell *et al.* 2006). Finally, the barriers to adaptations are the obstacles which can be overcome by

concerted effort, creative management or changed thinking (Moser and Ekstrom 2010). However, adaptation is not an easy process. Any failed decision in adaptation, with respect to objective, results in ‘maladaptation’. The problem of increasing vulnerability from action taken for adaptation is termed as ‘maladaptation’ (Barnett and O’Neill 2010). Maladaptation also occurs when the negative impacts caused by adaptation are as serious as the climate change adaptation being avoided (Scheraga and Grambsch 1998). This may put whole systems at risk and may lead to its breakdown, and thus needs to be analysed in every adaptation situation.

3. ABOUT THE STUDY AREA

The study area considered here is the catchment area of Chambal river in the state of Madhya Pradesh – the entire geographical area drained by the river and its tributaries and characterized by all run-off being conveyed to the same outlet. It is also known as catchment basin, drainage area or drainage basin. Chambal river, a principal tributary of Yamuna, originates in the Vindhyan ranges near Mhow in Indore district of Madhya Pradesh. The river flows through the states of Madhya Pradesh, Rajasthan and Uttar Pradesh. The basin is roughly rectangular, with a maximum length of 560 km in the northeast-southwest direction. Broadly, its catchment area is termed as Malwa Region. It is located in the south-western part of the Madhya Pradesh and generally slopes towards the North. It is spread across 45,628 square km. The catchment mainly covers the districts of Indore, Dewas, Ujjain, Dhar, Mandsaur, Ratlam, Neemuch and Shajapur. Rainfed farming of grains, pulses (moong, black gram and pigeon pea) and groundnut is a traditional practice. In the *rabi* season, wheat and gram are cultivated mostly under irrigated condition. The natural vegetation comprises of tropical dry and moist deciduous forests. However, rich farmers grow rice, wheat and gram and, sometimes cotton using irrigation facilities.

The catchment area of the Chambal river shows severe effects of climate change. This area was once known for its good climate and abundant food, water and employment opportunities (in the folk idiom it is defined as *pag roti dag neer*). It is now facing severe water shortage and extreme weather conditions (Gupta and Kawadia 2003). Agriculture is primarily rainfed and the region does not have adequate mechanism to use surface water for agriculture. As a result, farmers are forced to exploit ground water for the domestic as well as for agricultural purposes. No proper facilities to recharge groundwater are developed. As water withdrawal from the ground is much more than the recharge (Gupta, Kawadia and Attari 2007), it has

created conditions of deforestation and desertification in the area. The area thus presents a good case study for climate change adaptation practices.

4. OBJECTIVES OF THE STUDY

- 1) To understand the nature of climate change and its impact on agriculture in the Chambal river catchment area.
- 2) To present an overview of the adaptation measures in the area.
- 3) To discuss maladaptations and its implications for the region.
- 4) To direct policy for strengthening specific adaptations.

5. RESEARCH METHODOLOGY

The study has followed the sample survey method of investigation. Of the eight districts in the Chambal catchment, Indore, Dewas, Mandasaur and Neemuch districts were selected in controlled sampling following expert advice. These four districts provided adequate representation of different agro-climatic and farming systems in the study region. A representative sample of 470 farmers was finally selected from 28 villages of these districts through stratified snowball sampling techniques in the agricultural year 2014-2015. The farm household survey was conducted in two steps, a field pre-test and actual data collection. As indicated above, the study made use of controlled sampling — only those agricultural households were surveyed that got subsidy from the Government for rainwater harvesting specifically to overcome the shortage of water due to climate change. Enumerators conversant with local language and traditions in the study area were engaged to conduct the field survey. Each survey schedule had 70 questions. A farm household was the unit of analysis. Moisture index was calculated based on centennial data of precipitation and potential evapotranspiration (India Water Portal 2016) to determine the ‘aridity’ status of all the districts in the study area. A seven-year moving average was used to smoothen the fluctuations. Linear regression was used to find the equation and trend line. The study also made use of descriptive statistics and case study method for analysis and presentation of results.

6. RESULTS AND ANALYSIS

6.1. Nature of Climate Change in the Chambal Basin

6.1.1. Precipitation and Moisture Index

Agriculture in Madhya Pradesh has remained rainfed and will continue to be so for the next few decades. The state is dependent on rainfall for its water requirements. The total rainfall in the state varies from 60 cms, over the extreme north and western parts, to 120 cms over the central, eastern and southern parts of the state. Therefore, significant climatic aberrations or changes will have a certain impact on the agricultural output of the state. Global warming and shift in precipitation zones would cause drought, exposing the vulnerability of the countries affected. Monitoring the occurrence of droughts is helpful in various disciplines like administration, planning, agriculture and hydrology to take remedial measures. Drought is a period of drier than normal conditions that result in water-related problems. Agricultural drought occurs when soil moisture and rainfall are inadequate during the growing season to support healthy crop maturity and cause extreme crop stress and wilt. The drylands of the world are increasingly subject to desertification due to climate change and recurrent droughts. It is thus extremely important to analyse the trend of climate change in the Malwa region of Madhya Pradesh and to know whether it is being significantly encroached by desert from the neighbouring state of Rajasthan. For this, the study makes use of Moisture Index/ Drought Index/ Aridity Index (Thornthwaite and Mather 1955). The aim is to analyse the phenomenon of drought occurrence, or gradual desertification, in the catchment area of Chambal river basin, that is, the eight districts of Indore, Dewas, Dhar, Shajapur, Ujjain, Mandsaur, Ratlam and Neemuch. The study further attempts to empirically investigate whether these districts have experienced climate change over a century. Then a time-series based linkage was tried to be established between climate change pattern and drought occurrence. For climate change analysis, moisture index was calculated based on the centurial data of precipitation and potential evapotranspiration (India Water Portal 2016). Computation of Moisture Index or MI (Thornthwaite and Mather 1955) was simplified using annual average data (Krishnan 1992) as

$$MI = [(P-PE)/PE]*100$$

where;

P = Precipitation;

PE = Potential Evapotranspiration

The values of the index correspond to the humidity or aridity in an area. If value of the index is positive, it indicates humid atmospheric conditions; negative index value represents dry climate conditions. Table 1 depicts corresponding moisture index and the climate zone of the eight districts.

Table 1: Moisture index value per zone

Value of moisture index	Climate zone
< - 66.7	Arid
- 66.7 to - 33.3	Semi-arid
- 33.3 to 0	Dry sub-humid
0 to +20	Moist sub-humid
+ 20.1 to 99.9	Humid
100 and More	Per-humid

Source: Thornthwaite and Mather (1955)

Moisture is thus most inadequate in arid zones followed by semi-arid and dry sub-humid regions. From moist and sub-humid zones onwards, the moisture is adequate for normal crop production. The eight districts of Chambal basin have been categorised into their prevailing climate zone on the basis of average moisture index obtained

from the climate data spanning almost over a century (table 2). The trend is also identified with the help of regression equation and trend line (figure 1). As per Thornthwaite moisture index calculation six of the eight districts fall in the arid zone, the remaining two are semi-arid. There has been no significant change in the moisture index trend for the districts as per the centurial climate data. Only the Dhar district is depicting a significant increasing trend in the moisture index. This means that currently the district is under 'arid' zone but gradually it will move in the 'semi-arid' zone. Apart from Dhar, there are two more districts in the semi-arid zone, namely Mandsaur and Shajapur. One can conclude that no efforts have been made to shift the area from arid to semi-arid or humid zones.

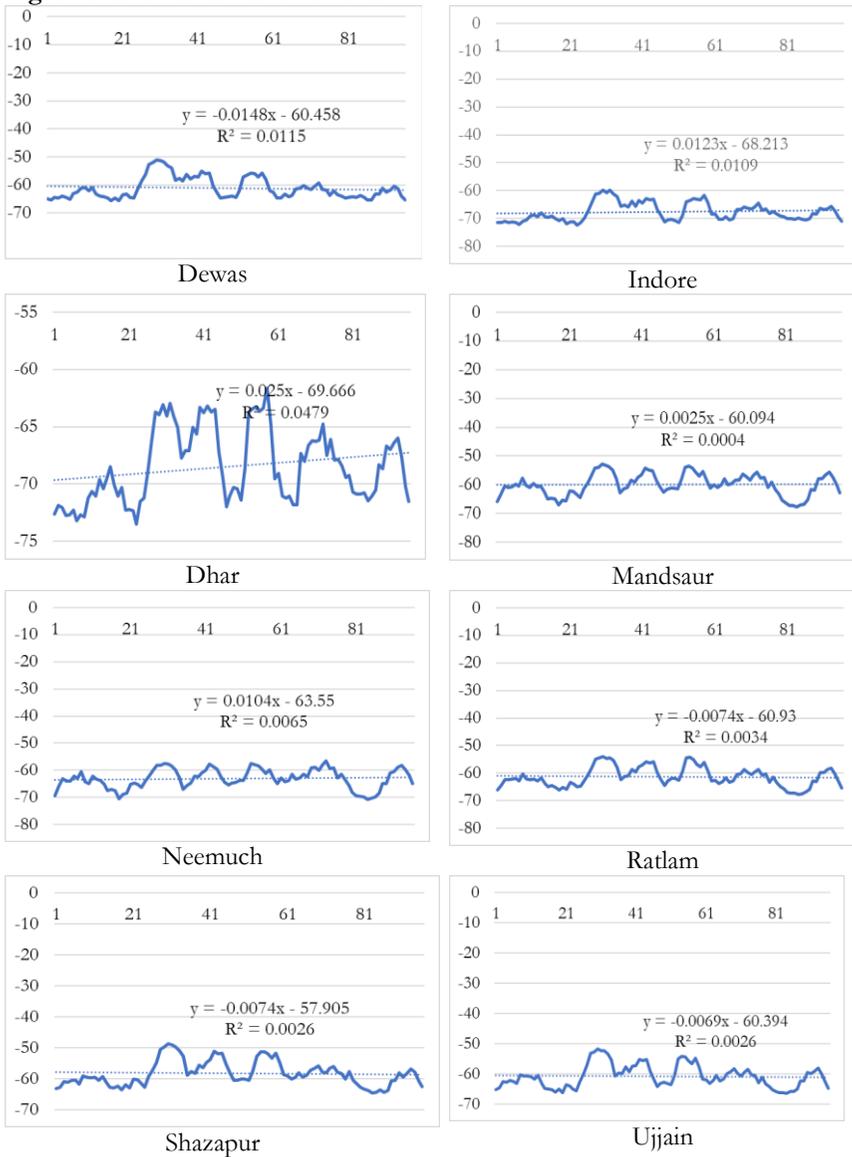
Table 2: District categorisation as per moisture index

District	Value of average moisture index	Climate zone	Nature of trend
Indore	-67.61	Arid	No Change
Dewas	-61.18	Arid	No Change
Dhar	-68.45	Arid	Increasing Trend*
Mandsaur	-59.97	Semi-arid	No Change
Neemuch	-63.05	Arid	No Change
Ratlam	-61.29	Arid	No Change
Shajapur	-58.26	Semi-arid	No Change
Ujjain	-60.73	Arid	No Change

Source: Authors

Note: * denotes that results are significant at 5% level of significance

Figure 1: Moisture index of all districts



Source: Authors

Note: — Moisture index; Linear Trend (moisture) index

6.1.2. Comment on Special Characteristics of Dhar District

As per moisture index, only Dhar district has shown a significant increasing trend. This means that currently the district is under 'arid' zone but gradually it will move in the 'semi-arid' zone. This can be well understood in the backdrop of special focus Dhar has received in the past as a drought-prone district. Integrated Mission for Sustainable Development (IMSD) study was initiated in the year 1987 (Rao, *et al.* 1995) with specific reference to find scientific and lasting solution to mitigate droughts. Droughts have been a recurring feature in Indian agriculture from 1991 to 2000, and also earlier. Thus, some special districts were selected for systematic investigation. A specific study was carried out in the districts of Jhabua and Dhar, in Madhya Pradesh, using Composite Land Development Sites (CLDS) approach for forest and wasteland development and soil and water conservation in 1995 (IMSD 1995). This was followed by specific suggestions and treatments. Further, monitoring was done by Space Application Centre, ISRO, Ahmedabad (Dasgupta, Dhinwa and Rajawat 2015). This was done through visual interpretation and analysis of temporal images of the region from 1991 to 2013. The study had revealed that there is a substantial increase in the area of irrigated agricultural land with increase in number of check dams along with the stream channels. This has helped Dhar district's transition from arid zone towards semi-arid zone. It, thus, becomes clear that for non-arable soil conservation, rainwater harvesting and management of lands for fodder, fruit and fuel-wood production in the watershed perspective are the core strategies for fighting drought in the arid zones of India. As various water harvesting measures were adopted in Dhar district, the result came out in the form increased agricultural productivity. Thus, watershed development programmes were seen to have a positive impact in combating desertification. We, therefore, need to employ more of such techniques in the remaining arid zones to prevent them from getting gradually converted into deserts and to ensure food-security.

6.1.3. Temperature and Pattern of Precipitation

If sufficient water is available, then the temperature is the most important factor determining farm productivity in a region. The higher temperature eventually reduces crop yields, while encouraging weed and pest proliferation. Farmers' responses about a general change in temperature over time were traced. This reflected the change in seasonality, distribution, amount and intensity of temperature over time. As can be seen in table 3, around 78 per cent of farmers in the survey reported an increase in temperature of the study region. Changes in the precipitation patterns

increase the likelihood of crop failures in the short term and production decline in the long term. Agriculture will be adversely affected not only by an increase or decrease in the overall amounts of rainfall but also by shifts in the timing of rainfall. It is thus extremely important that farmers' reporting about the changing trends of precipitation are analysed. In the sample, close to 70 per cent of farmers did not see a major change in precipitation, however, 11 per cent observed a clear decrease (table 4).

6.1.4. Extreme Events

With climate change, extreme weather occurrences have become more common and frequent. Longer and hotter heat waves, greater incidence of droughts, intense precipitation, heavy rains and floods have now become usual occurrences. It is important to know how farmers perceive the occurrence of such events in their regions. They were asked to give their observations of whether the occurrence of a particular climate-event has increased, decreased or has remained constant in terms of its frequency and intensity in their region. The events on which their responses were gathered were drought, flood, hailstorm, heat-waves, cold-waves and frost.

As can be seen in table 5, more than 70 per cent of the surveyed farmers observed that heat waves, frost and cold wave occurrences have increased. About 56 per cent surveyed farmers observed increase in hailstorms. About 47 per cent of the farmers observed increase in droughts. About 70 per cent farmers there had been no significant change in the incidence of floods. Factors affecting farmers' perceptions were also explored. Farmers with a higher educational level, a higher income level and joint family mode of living were able to perceive climatic changes more correctly (Kawadia and Tiwari 2017).

Table 3: The sample distribution of farmers based on their observations about changes in temperature

Response about change in temperature	Number of farmers
(i) Increase	364 (77.47)
(ii) Decrease	62 (13.18)
(iii) No change	29 (6.17)
(iv) No response on temperature	15 (3.18)
Total	470 (100.00)

Note: Figures in the parentheses show percentages.

Table 4: The sample distribution of farmers based on their observations about changes in precipitation

Response about average precipitation	Number of farmers
(i) Increase	10 (2.13)
(ii) Decrease	50 (10.64)
(iii) No change	328 (69.77)
(iv) No response on temperature	82 (17.45)
Total	470 (100.00)

Note: Figures in the parentheses show percentages.

Table 5: The sample distribution of farmers based on their observations about occurrence of extreme events

Major contingency	Number of farmers		
	Increased	Constant	Decreased
Drought	220 (46.81)	95 (20.21)	115 (32.98)
Flood	13 (2.77)	328 (69.78)	129 (27.45)
Hailstorm	264 (56.17)	178 (37.87)	28 (05.96)
Heat waves	350 (74.47)	109 (23.19)	11 (02.34)
Cold waves	330 (70.21)	117 (24.89)	23 (04.89)
Frost	335 (71.28)	104 (22.13)	31 (06.59)
Any other outbreaks	184 (39.15)	284 (60.42)	02 (00.43)

Note: Figures in the parentheses show percentages.

6.2. Impact of Climate Change on the Agricultural System of the Chambal Basin

Crop growth simulation assessments in dryland or rainfed agriculture in tropical stations indicate yield reduction of some crops even with a minimal increase in temperature. If there is also a significant decrease in rainfall, tropical crop yields would be even more adversely affected. Some studies

Table 6: The sample distribution of farmers based on their observations about change in crop yield

Change in crop yield	Number of farmers
(i) No change	10 (2.13)
(ii) Significant increase	50 (10.64)
(iii) Significant decrease	328 (69.78)
(iv) Minor variation	82 (17.45)
Total	470 (100.00)

Note: Figures in the parentheses show percentages.

indicate that climate change would lower incomes of the vulnerable populations and increase the absolute number of people at risk of hunger. Climate change, mainly through increased extremes and temporal/spatial shifts, would worsen food security in some parts of the globe. This study attempts to analyse how farmers of the Malwa region respond to the change in their crop yield due to change in climatic conditions. Our survey found that 70 per cent of farmers reported a significant decrease in farm yield (table 6).

The greatest impact of climate change was observed in case of availability of water, which affects the entire farming community — irrigation systems are affected and so also are the crops dependent on irrigation, while at the same time global warming increases the demand for water in irrigation. As it is important to trace whether farmers have perceived the change in climate correctly or not, farmers were queried on the change in frequency of irrigation required for their crops. As can be seen in table 7, around 60 per

cent of farmers reported greater than marginal increase in the irrigation frequency. Close to 40 per cent farmers in the sample reported 100 per cent

Table 7: Sample distribution of farmers based on their observations about the extent of change in their irrigation frequency

Extent of change in irrigation-frequency	Number of farmers
(i) No change	55 (11.70)
(ii) Marginal	137 (29.14)
(iii) One and a half times	78 (16.60)
(iv) Double	175 (37.23)
(v) More than double	25 (5.32)

Note: Figures in the parentheses show percentages.

Table 8: Sample distribution of farmers on the basis of their observations about increase in pest attack and diseases in crops

Response about increase in pest attack and diseases in crops	Number of farmers
No	129 (27.45)
Yes	341 (72.55)
Total	470 (100)

Note: Figures in the parentheses show percentages.

increase in irrigation frequency over previous values. Climate change also encourages the spread of pests and invasive species and has already increased the geographical range of some diseases. In essence, it is altering the distribution pattern of animal and plant pests and diseases. The change in temperature, moisture and atmospheric gases accelerate growth rates of plants, fungi and insects, which alters the interaction between pests, their natural predators and hosts. In this regard, it is important to trace the farmers' response on whether there is an increase in pest attack and disease outbreak in crops in recent years. The survey found that 73 per cent of farmers confirmed the increase in pest attacks and occurrence of crop diseases due to climate change (table 8).

6.3. Adaptation Strategies in the Chambal Basin

Chambal basin primarily has rain-fed agriculture and groundwater level in the region has been continually on decline. As a result, climate change pressure of increased irrigation requirements on the available water resources has increased manifold. Improved water management is thus one of the most important long-term adaptation as well as protection options that region must pursue. A wide range of adaptation measures have been highlighted in this regard like improving water distribution strategies; changing crop and irrigation schedules; using rainwater more effectively; water recycling and the conjunctive use of groundwater. In this respect some major strategies were identified from the literature. These are: (i) planting trees (ii) soil conservation (iii) different crop varieties (iv) early and

late planting / changing plant dates (v) water harvesting / improved water management.

The farmers were thus queried about their chosen adaptation strategy to protect crop against climate change. Table 9 explains the various adaptation practices used by the farmers of the region. They are not mutually exclusive as farmers are practicing multiple adaptation techniques simultaneously as per their need and suitability.

6.3.1. Water Harvesting / Improved Water Management

Water harvesting was found to be the most popular adaptation strategy followed by the farmers of the Chambal basin. It is adopted by 84 per cent of the sampled farmers. It has specifically become popular since the launch of ambitious schemes like *Khet Talab Yojana* and *Balram Taal Yojana*. Water harvesting can be defined as a range of techniques for collecting rainwater.

Table 9: The sample distribution of farmers based on their adaptation strategies to fight climate change

Adaptation strategies	Number of farmers
Water harvesting	395(84.02)
Irrigation management	272(57.87)
Early and late planting	205(43.62)
Planting trees	119(25.32)
Different crop varieties	114(24.25)
Soil conservation	61(12.98)
No Adaptation	16(3.40)

Note: Figures in the parentheses show per centages.

Water harvesting is economically beneficial for local farmers as it is the only feasible method of farming on degraded land devoid of other means of water for irrigation. It is also significant as a sustained source of irrigation for Rabi crops. Furthermore, it helps significantly in the recharge of groundwater resources of the region, adds greenery and in this way acts as a positive externality towards the overall ecology.

6.3.2. Irrigation Management

Improving the use of irrigation is generally perceived as an effective means of smoothing out yield volatility in rainfed systems. It has the potential to improve agricultural productivity through supplementing rainwater during dry spells and lengthening the growing season (Orindi and Eriksen 2005). Overall, improving the use of irrigation aids in averting the crop losses in areas subjected to recurrent cycle of drought.

Around 58 per cent of the sample farmers used this method to fight climate change (Table 9). The farmers use plastic pipes for transporting water from the reserve to the farm. They also use sprinklers for efficient use of the available water. The government subsidy for proper water management has

played a major role in the adaptation of water harvesting and conservation measures (Orindi and Eriksen 2005).

6.3.3. Early and Late Planting / Changing Plant Dates

Altering the length of the growing period and varying planting and harvesting dates are among the crop management practices used in agriculture (Orindi and Eriksen 2005). This includes early and late planting options as a strategy to fight harmful effects of changing climate. The strategy helps to protect sensitive growth stages of crops by ensuring that these critical stages do not coincide with very harsh climatic conditions such as mid-season droughts. Early and late planting comes third in the sequence of importance among major adaptation strategies. This adaptation is followed by 44 per cent of the farmers surveyed (table 9). The Malwa region is now strictly following soybean-wheat annual crop cycle. As soybean is a Kharif crop and its growth cycle is strictly regulated by rainfall, changes in precipitation cycle certainly change its sowing and harvesting dates for the farmers. For example, many farmers have started opting now for the 95-60 soybean varieties instead of the regular variety of soybean planted earlier. Wheat can be sown only after the harvesting of soybean in Rabi season; therefore, wheat planting dates also change accordingly. Farmers are practicing early sowing date and quicker maturing variety of soybean so that they can use soil moisture following the rainy season for the next crop like wheat, gram, mustard and other crops of Rabi sessions. The monsoon season in the region normally extends up to the end of September or some time to the early October. This provides enough moisture for the cultivation of the next crop. This has not only increased the cropping intensity but made the Malwa the bowl of wheat and soybean.

6.3.4. Plantation

Planting trees or afforestation, in general, provides a particular example of a set of adaptation practices that are intended to enhance productivity in a way that often contributes to climate change mitigation through enhanced carbon sequestration. It also has a role to play in strengthening the system's ability to cope with adverse impacts of changing climate conditions. It also contributes to temperature stabilization in the region. The farmers of the region thus follow tree plantation, particularly along the water harvesting structures. Almost 25 per cent of the sampled farmers undertake tree plantation as a method to avert climate change impact (table 9). This has increased the vegetation cover in the region.

6.3.5. Crop Diversification Varieties

Switching over to varieties that are early maturing and drought tolerant and/or resistant to temperature stresses, the farmers save their crops from rainfall fluctuations as well as add variety (Orindi and Eriksen 2005). There is evidence that growing different crop varieties on the same plot or on different plots reduces the risk of complete crop failure as different crops are affected differently by climate events, and this in turn gives some minimum assured returns for livelihood security. The pattern of crop diversification and its emerging trends in the Malwa region have already been discussed in detail in a previous chapter. In the survey, approximately 24 per cent of the farmers favoured adoption of different crop varieties and 25 per cent support planting of trees on their fields as an essential strategy to ward-off negative impacts of climate change (table 9). Nihaal Singh Tomar from Harnawada village in Dewas district succinctly mentioned that the only way to ensure sustained production in the wake of climate change was to make a pond in the field to capture rainwater and to plant trees in the field.

6.3.6. Soil Conservation

The adoption of practices and technologies that enhance vegetative soil coverage and control soil erosion are crucial to ensuring greater resilience of production systems to increased rainfall events, extended intervals between rainfall events, and potential soil loss from extreme climate events. Improving soil management and conservation techniques assist in restoring the soil while also capturing soil carbon and limiting the oxidation of organic matter in the soil. Soil conservation automatically gets ensured by following all the above-mentioned strategies; however, soil conservation issue was highlighted by only around 13 per cent of the sampled farmers (table 9). Only a minuscule 3 per cent of the farmers said that they were not going for any specific adaptation strategy (table 9). This makes it clear that almost all the farmers of the Chambal basin are aware of the negative impact climate change has on the production trends and taking appropriate mitigative steps.

6.4. Irrigation Profile of the Farmers

The beneficial adaptation in the fight against these problems is to work on optimum irrigation and better rainwater harvesting facilities. In this study, the emphasis was laid on knowing the irrigation profile of the surveyed farmers, that is the sources used for irrigation, for example, tube-well, pond, well, etc. This has been shown in table 10.

A majority of the farmers in the survey sample use pond as their major source of irrigation (65 per cent), followed by well (47 per cent) and tube-well (25 per cent). This shows that importance and usage of ponds has greatly accelerated in recent times and has reduced farmers' dependence on groundwater resources. Thus, rainwater harvesting as an adaptation has lived up to the expectations of the farmer. Farmers from *Harnawada* village in Dewas district emphasise that since the ponds have been constructed in the village on the fields of the farmers, it is symbolic death of the tube-well. Villagers testify decline in the use of tube-wells since the adoption of rainwater harvesting techniques, which, according to the farmers, has helped them significantly in retaining the soil moisture after the rains. This indicates that rainwater harvesting is not only ecologically beneficial but also cost-effective in terms of per unit water consumption.

Table 10: Representation of Irrigation Profile of Farmers

Source of irrigation	Tube-well	Pond	Well
Number of farmers	177	307	219
Total number of source	347	357	317
Average number of source per farmer	1.96	1.16	1.45
Average investment per source (in Rs.)	220288.18	263674.35	385063.09
Average investment per farmer (in Rs.)	441849.71	299003.27	610325
Average water withdrawal/ hour per source	6.81	6.74	4.42
Average water withdrawal/ hour per farmer	13.74	6.81	6.48

Source: Authors

6.5. Tracing Farmers' Responses on Effectiveness of Varied Adaptations (Case Studies)

The farmers of Indore district are the main beneficiaries of recently launched Balram Taal Yojana. Semaliya Raimal and Kampel villages are good examples of excellent work in water harvesting. Yashwant Patel from Semaliya Raimal underlined the importance of the Yojana and its benefits to people when he said that it has helped the villagers in maintaining the stock of water in their fields, enhanced profits significantly, and fulfilled their irrigation needs. Krishnapal Singh Daangi from the same village added that rainwater harvesting has made him self-reliant as it improved his farm production by leaps and bounds. Vishnu Daangi, another farmer, said that as the area sub-soil is full of stones, tubewell-recharge is not good even when the region has abundant rains. In such situations, rainwater harvesting is a blessing. Dilip Patel states that because of water harvesting he has stopped borrowing for agricultural needs as it has made taking two-three

crops in year possible and is thus increasing his total income. Kansingh Daangi, also a farmer, said water harvesting brought him an overall better life as it made it possible for him to make a *pakka* house and send his kids to good schools for education.

In Shadadev, a village adjacent to Semaliya Raimal, farmer Pawan Singh describes the advantages of water harvesting. He says that before they began water harvesting, they were compelled to do irrigation by drawing water directly from Shipra. As it was an illegal practice, farmers were fined Rs. 20,000 to Rs. 25,000. But after farmers started rainwater harvesting, irrigation difficulties are sorted. The farmers' experiences from Kampel village have also been on similar lines. Sunil Nimadia states that rainwater harvesting ensures available water is conserved and it also helps recharge water table. Other villages of Indore district where water harvesting has been carried out substantially are Paaliya, Faraspur, Rawad, Balodatakun, Atawada, Nevary, Matabarodi and Kadwaali Bujurg. Farmers responses from these villages have been on similar lines. They have also reported increased water level, tubewell recharge, less dependence on rainfall, a greater area for crop production, sustained irrigation facility for Rabi crops and last but not the least enhanced socio-economic status with better educational facilities for education for their children.

Arjun Singh from Pedmi village, Indore district, explains that in his area Kumbi, Beed are big Naalas but there is no dam on them. If stop dams are made on them, wastage of water can be minimised. Mahendra Singh Chouhan from Mhowgoan village gives an overview of different adaptation measures by saying that adaptation, in essence, is a long-term process with many benefits. It includes a wide range of measures like those of plantation, construction of ponds, soil conservation, soil testing, save water campaign, etc. These contribute to farming as well as to the environment.

Dewas district is a pioneer in water harvesting activities in the Chambal basin. Tonk Khurd Tehseel is world-famous for the ponds being constructed here under the ambitious Khet Talab or Rewa Sagar Yojana. Jujhaar Singh Tomar from Harnawada village says that there has been a great increase in the yield of wheat and gram in the area along with a substantial increase in green cover since the practice of rainwater harvesting began. He suggests more investment in water harvesting and tree plantations. Forak Singh Tomar from the same village urges that the Government increase subsidy on the construction of pond in the field from Rs. 80,000 to Rs. 200,000. Mansingh Tomar says that there has been a 200 per cent increase in production from his field due to rainwater harvesting. All the farmers say that tree plantation in their fields was the next best

adaptation measure after rainwater harvesting. Sheshnarayan Patel from Gorwa village also stated his production got doubled. Water harvesting is extremely important for water conservation and ecology. Varied types of animals and plants are now noted in the village. Deers are now easily visible in the area. Vishnu from the same village drew attention to soil conservation as a result of water harvesting activities. Uday Singh Khiswi, also from Gorwa, said improved situation encourages him for hard work as water harvesting has made it possible to expect sure returns from farming. He further says that the Government should ban deep tube-wells in the area and encourage construction of ponds instead.

The districts of Mandsaur and Neemuch are in the vicinity of Gandhi Sagar Dam and Retam Barrage. These two districts have seen substantial work in water harvesting and well-recharge activities. Villages of Kachnara, Borkhedi and Haripura were covered in Mandsaur district. Gobar Singh from Kachnara says that rainwater harvested is also used to recharge wells.. Kishan Singh says that well-recharge has helped him get additional income from production of fruits like mangoes, papaya and pomegranate in his fields. Madho Singh Borona from the same village emphasises improved crop yield due to water harvesting. He suggested that water can be transferred from one dam to another by linking them with canals. Earlier the region was continuously under drought. Now, the farmers are prosperous, while earlier they used to work as daily wage labourers. The farmers from Borkhedi also told a similar story. Kamal Singh Shamsawat from the village says his farm production has increased to a great extent as he now gets three crops in a year. Under Kapildhara scheme, 28 wells have been constructed and all farmers have been provided with Kisan Credit Cards. The construction of Retam Barrage in the year 2000 has benefitted the farmers. The water supply is now ensured for a fee charged based on irrigated land in hectare. He also emphasised soil conservation as a major adaptation measure in saving agriculture from the harmful impacts of climate change. Hiralal Ojha and Deepsingh Sattawat also cited the advantage of building dam; they said, they have started sugarcane farming because of it. They have also started cultivating coriander. They also supported soil conservation and plantation of trees. Ramcharan Rewari from Haripura said that water harvesting has considerably increased his basket of production, which now includes wheat, coriander, gram, isabgol, flaxseed, mustard, fenugreek etc. He supported soil conservation and proper soil testing as the major method of adaptation apart from water harvesting and implementation of new and improved methods of irrigation.

Finally, concerning efficacy of various adaptation measures, this study examines the farmers' response in Neemuch district. The villages covered

here included Barlai, Hatunia, and Pipliya Ghota. Rahul Patidar from Barlai says that he has now an orange orchard of his own due to water harvesting. He also favoured plantation of trees as an adaptation measure. Vishnu Prasad Patidar has says that he could grow a variety of crops like orange, garlic, wheat, coriander and fenugreek only because of water harvesting. Shambhulal Patidar said that water harvesting is giving him an annual return of at least four lakh rupees through improved farm productivity. He emphasised organic farming and plantation of trees as an adaptation measure.

In the village of Hatunia, there are around 280 to 300 ponds. Here, tubewells and hand-pumps are not successful. Farmers are engaged in agricultural activities only because of water harvesting. Satyanarayan from this village supports construction of more ponds as well as plantation of trees as the main adaptation measure to sustain in the face of climate change. Villagers from Pipliya Ghota also mainly follow water harvesting, seek enhancement of subsidy for that, plantation of trees and soil conservation as adaptation measures for changing climate.

6.6. Maladaptation: Soybean and Wheat based Monoculture

A 'maladaptation' is a trait that is (or has become) more harmful than helpful, in contrast to an adaptation, which is more helpful than harmful. So, farming practices that though have increased farmers' production and income in the short run but become a severe danger in the long run, if continued unabated, can be effectively called maladaptation. One such maladaptation in the Malwa region is 'monoculture'. Monoculture is the practice of producing a single crop over a long period in a certain area. The practice of monoculture gets usually stimulated by political and economic incentives. Specialisation brings obvious benefits to the economy of scale in terms of higher yields and easier mechanisation techniques; however, there are disadvantages associated with monocultures. Monocultures lead to easier spread of diseases and pests, thereby decreasing resilience to climate change variability that often induces additional stress on plants. Additionally, when the produced crop is negatively affected by changing weather or biophysical conditions, farm income may be severely affected. For these reasons, moving towards diversification reduces the risks of maladaptation (Lin 2011). The Malwa region is a classic text-book example of such kind of monoculture. The area, since 1980s, has become a specialised zone of soybean-wheat annual cycle-based production. Soybean plants usually grow at ambient temperatures between 15°C and 27°C, although temperature below 21°C and above 32 °C may reduce flowering. Temperatures exceeding 40°C (104°F) are detrimental to seed production.

Soybean is adapted to grow in a wide range of soils and climates but requires adequate soil moisture for germination and seedling establishment. Soybean has flourished well in the Malwa region with many growth conditions getting satisfied simultaneously.

The soybean success story caught headlines not only regionally but also at the national level. The Malwa has practically given up on production of crops like maize, sugarcane and especially cotton after soybean success. However, this specialisation has reduced crop-diversification in the region. Also, this monoculture has been sustained by continuous groundwater exploitation. Since the 1980's the Malwa region has become increasingly tube-well dependent to sustain its crop-cycle. During the survey, it was found that villages like Jalodiya-Panth in Depalpur Tehsil of Indore district had as many as 500-600 tube wells with a depth ranging from 250 to 500 feet. The whole region is sustained on irrigation from groundwater resources and in recent times hit severe water shortages, not only for irrigation but also for drinking purposes in the wake of its fast depletion.

Hence, such a crop-cycle suffers a serious threat. The maladaptation thus needs to be balanced by a suitable adaptation that may ensure sustained water supply for irrigation. Besides, soybean-wheat crop cycle has high risks of infestation by widespread pests. Many farmers from the survey corroborated to such incidences. A farmer from Dhaturiya Village in Dewas district said that soybean crop in the district in recent times suffered from severe caterpillar attack and fungal attack. Soybean crop also suffered severely due to the acute shortage of rainfall during the growing stage. This was coupled with a rise in temperatures beyond 32°C, many a time crossing 40°C, severely affecting the crop. Warm temperatures and high humidity are conducive for the fungus that leads to the development of soybean rust. Soybean gets totally destroyed in case of untimely torrential rains; this is known as *jal jaana* in the local language. Thus, both extreme drought conditions with high temperatures as well as torrential excessive rains are harmful to the crop.

7. CONCLUSIONS AND POLICY IMPLICATIONS

As per moisture index, six out of eight districts in the study region lie in the arid zone, clearly indicating a movement towards desertification of the region. Nature of climate change in the Chambal basin was also explored through farmers' observations about change in temperature, precipitation and occurrence of extreme events. Farmers reported an increase in temperature with a clear majority of around 73 per cent. They reported an

increase in the occurrence of heatwaves, cold waves, frost and droughts in the region. The decrease in precipitation was, however, noted by only a few farmers. There were thus indications of increasing aridity in the study-region. The impact of the climatic change was analysed through farmers' responses about changes in crop-yields, the extent of change in irrigation frequency as well as the spread of pest-infestation and disease occurrence in plants. Around 70 per cent of farmers reported a decrease in crop yield, while close to 60 per cent of farmers reported greater than a marginal increase in irrigation-frequency. As much as 40 per cent of the total sampled farmers reported a 100 per cent increase in irrigation frequency. About three-quarters of the total sampled farmers reported an increase in pest attack and disease occurrence in crops.

From the survey responses, the study considers crop diversification, changing plant dates, soil conservation and soil testing, increasing rainwater capture, construction of stop dams on *nalaas*, and tree plantations as the major adaptation strategies farmers perceive as appropriate for rain-fed agriculture. Water harvesting was found to be the most important adaptation measure followed by crop diversification. The case for water harvesting got established by the transition of Dhar district from the arid to the semi-arid zone as per moisture index-based analysis. It also became clear from the survey of the farmers that adaptation measures to climate change cannot be considered in isolation, but relative to the impacts of other exogenous sectoral changes. The issue of 'maladaptation' of soybean-wheat monoculture has accentuated the crisis in the region. This has severely resulted in groundwater depletion in the region and there has been thus overall damage to the ecosystem. Therefore, there are social costs as well as ecological limits to crop-based adaptations in the region. Hence, gross market and institutional failures that make farmers very vulnerable come at the forefront. In short, the key lesson to emerge is that the prioritisation of appropriate adaptation measures needs to be contextual and fit the capacity of local institutional and legal frameworks. Water harvesting measures should be specially strengthened by the policy in the study region to cope with changing climate and its effects on the agricultural sector. Mainstreaming adaptation strategies is thus to be considered as the most important policy intervention.

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