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Climate Change and its Implications on Agriculture and Food Security: A Case of Madhya Pradesh, India

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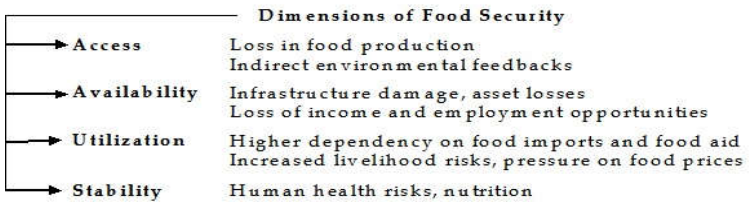
Abstract
The Global Hunger Index places Madhya Pradesh between Chad and Ethiopia in its list of the world's worst malnutrition ratings in 2008. The condition is worsening further with the spectra of a drought due to the capricious monsoon and insufficient rains during the sowing season from many years in different regions in the state because of climate change. A recent report estimated that 37% deaths registered between 0 to 4 years in Madhya Pradesh were due to chronic hunger and malnutrition. Its effects, especially on rural communities are particularly adverse because food security is directly related to agriculture production. There is steep decline in agriculture output and severe shortage of food in rural areas. Unfortunately, not much improvement is visible on the ground even after the commencement of many government schemes. The present study adds to the understanding of the impact of climate change on agriculture and food security in Madhya Pradesh and listing of adaptation and mitigation strategies to make agriculture sustainable on the face of global warming and improve livelihoods of farmers in the study area.

Key words: *Climate change, food security, mitigation, adaptation.*

Introduction

Climate change is a long-term shift in the climate of a specific location, region or planet. The shift is measured by changes in features associated with average weather, such as temperature, wind patterns and precipitation. Climate change is not a new phenomenon in the world. Though, it is a natural process but in some cases human activities are also responsible for this. There are many examples across countries where increase in the possibilities of climate change due to growing population, rapid urbanization, higher industrialization, use of modern technology, innovation, higher economic development, transport, building construction, reduction in forest area etc. are observed (Ahmad *et al.*, 2011). In mid, high latitude and higher income countries climate change has positive impact on agricultural production or crop yield, and on the other hand, lower-latitude and lower income countries experience a negative effect on agricultural production. On the other hand, developing countries are most vulnerable compared to developed countries. There are many reasons which increase the vulnerabilities for developing countries like low level of technological progress, lack of resources to mitigate the adverse effect of climate change on agriculture; and due to their greater dependence on agriculture for livelihood of large populations (Nath and Behera, 2011). This would increase the severity of disparities in cereal yields between developed and developing countries (Fischer *et al.*, 2005).

Thus it's adversely affects the food security in all countries through agriculture production. It affects to food security is in four dimensions, food availability, food accessibility, food utilization and food system stability. It will also have an impact on human health, livelihood assets and food production and distribution channels (FAO, 2008).



Due to rising global population size, climate change will challenge agricultural production and food security which will affect about 200 million people and their families worldwide who live by fishing and aquaculture (Greg *et al.,* 2011).

In India, Gross Domestic Product (GDP) may decrease up to 6.2% and agriculture production may decrease up to 24% by 2080 due to climate change (Zhai and Zhuang, 2009; and Zhai *et al.,* 2009). High variation in environmental factors such as temperature, rainfall and others get affect to crop growth negatively and certain crops get positively affected due to change in these environmental factors. Thus change in climatic variables may have positive and negative impact on agricultural productivity and food security situation in the economy (Greg *et al.*, 2011). Agriculture is very crucial sector that may reduce poverty in several ways (Goswami *et al.*, 2010; and Salami, 2011) like increase in crop productivity directly create more employment

opportunities and improve the level of food security. Adverse implications for agricultural productivity may increase incidence of more poverty, which in turn is closely associated with hunger (Ramasamy and Moorthy, 2012). Thus agricultural productivity is an important part of food security which is an integral part of poverty eradication and hunger. With its vast expanse, geographical features and varying climate conditions, different parts of the Madhya Pradesh State have been perennially prone to drought conditions.

Climate change- Current Scenario and Future Projections

The state has been identified as one of the most vulnerable states in India from impacts of climate change (GoMP, 2012) According to the Madhya Pradesh State Action Plan on Climate Change (MP-SAPCC) the average monsoon rainfall data from 1961 to 2002 shows a declining trend of rainfall with an inter-annual variability. While the average surface daily maximum and minimum temperatures, in the period 2030s is projected to rise by 1.8 to 2.0°C and 2.0°C to 2.4°C respectively throughout Madhya Pradesh. The eastern half of the state is expected to experience more warming than the western half. As per Vulnerability and Risk Assessment Study on Madhya Pradesh released by GIZ's programme under the collaborative project of ministry of environment and forests (MoEF) , 12 districts of Madhya Pradesh are most vulnerable to climate change. The 12 most vulnerable districts are Dindori, Anuppur, Shahdol, Ashoknagar, Tikamgarh, Umaria, Singrauli, Sidhi, Morena, Alirajpur, Panna and Bhind, while Bhopal, Indore, Hoshangabad and Gwalior. The most of the districts with high vulnerability are located in the east and north of Madhya Pradesh, except Alirajpur which is in south west. All these areas are facing general problems related to decline in soil fertility and ground water levels and other climate related factors like droughts, excess rainfall, frost and hailstorm are causing significant year to year variation in production and productivity. These districts have comparatively low adaptive capacity, show higher sensitivity and exposure to climate change with respect to the other districts.

In 2007-08, Eastern Madhya Pradesh was severely hit by dry monsoon, 39 districts were declared drought affected and most of them belonged to Bundelkhand region. In 2008-09, droughts has moved towards western Madhya Pradesh and 21 districts have already scanned as scarcity district (districts where rainfall deficit between -20% to -59%), among them seven districts (Chindwara, Dewas, Harda, Hoshangabad, Sehore, Khargone and Panna), have received deficit of 40% of their average rainfall. District wise historical rainfall data analysis for the state showed divergent trends. Trend analysis of daily rainfall data from 1961-2002 indicated a general declining pattern in all agro-climatic zones (MP SAPCC, 2012). However in the recent analysis carried out by All India Co-ordinated research project on agro meteorology at CRIDA (VUM Rao, unpublished) using IMD data (1971-2012), there was no significant trend in annual rainfall in majority districts. However districts in the central and north east part show a marked decreasing trend.

Table 1: District Wise Percentage Deviation of the Rainfall

District	2011	2012	2013	2014
Alirajpur	-18	15	64	10
Anuppur	11	-19	-19	-14
Ashoknagar	53	-6	46	-20
Balaghat	-12	-18	3	-30
Barwani	-12	-26	42	12
Betul	-10	64	69	5
Bhind	20	2	39	-44
Bhopal	27	13	27	-27
Burhanpur	2	35	71	34
Chhatarpur	12	-18	29	-46
Chhindwada	25	12	38	-22
Damoh	25	-2	61	-37
Datia	-1	13	26	-29
Dewas	16	26	40	-38
Dhar	-4	-10	39	-16
Dindori	16	-13	-7	-20
Guna	83	-21	62	-15
Gwalior	7	3	9	-29
Harda	1	52	62	8
Hoshangabad	4	30	51	-22
Indore	22	20	75	-16
Jabalpur	23	13	75	-25
Jhabua	30	36	60	-3
Katni	-28	-3	20	-28
Khandwa	27	34	66	38
Khargone	1	-3	23	6
Mandla	20	2	28	-15
Mandsaur	38	15	35	-5
Morena.	1	16	34	-39
Narsinghpur	2	-6	49	-24
Neemuch	53	7	51	10
Panna	6	-2	34	-39

Raisen	27	-7	33	-22
Rajgarh	82	10	63	7
Ratlam	44	14	43	-37
Rewa	15	22	31	-36
Sagar	20	-19	69	-33
Satna	8	-4	20	-36
Sehore	9	23	29	-23
Seoni	11	-8	43	-30
Shahdol	12	-13	-18	-30
Shajapur	47	2	46	-22
Sheopurkala	48	1	16	-18
Shivpuri	18	20	58	-4
Sidhi	68	37	11	-17
Singroli	74	61	-2	-30
Tikamgarh	35	-8	30	-19
Ujjain	31	18	40	-31
Umaria	24	-37	-9	-37
Vidisha	39	-5	53	-14
Average	**20**	**7**	**36**	**-19**

*Source: https://data.gov.in/catalog/annual-**rainfall-madhya-pradesh***

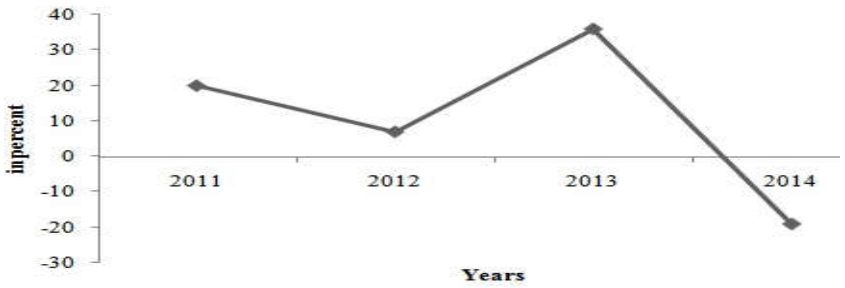


Fig. 1. Average deviation of rainfall in Madhya Pradesh

Table 1 presents the district wise and figure 1 presents the percentage as well as average deviation of the rainfall calculated on the basis of long term normal rainfall in Madhya Pradesh between 2011- 2014. In 2014, out of total 50 districts in only 9 districts rainfall is above normal while in 41 districts it is less than normal. In Chhaterpur district percentage deviation of the rainfall is -46 followed by Bind (-44), Panna (-39), Morena (-39) Umaria (-37) Damoh (-37). This trend shows that Madhya Pradesh is becoming a drought prone geo-cultural region.

Agricultural Growth in Madhya Pradesh

Madhya Pradesh is a primarily an agricultural state and 78 percent of the workforce is directly engaged in Agriculture. The agriculture and allied services contribute about 44 percent share of the state economy. But the growth rates have never been steady it has always fluctuated wildly. A comparison of GDP and Agriculture growth shows that growth rates have dropped down sharply in the years when agriculture has suffered.

Table 2 : Growth of Agriculture in Madhya Pradesh

Year	GDP	Agri. Growth
2000-01	-6.9	-26.2
2001-02	7.1	23.5
2002-03	-3.9	-18.5
2003-04	11.4	36.7
2004-05	3.0	-4.3
2005-06	5.3	7.5
2006-07	9.2	2.0
2007-08	4.6	-1.8
2008-09	12.3	NA
2009-10	10.5	NA
2010-11	8.1	-
Average Growth 1994-02	4.7	3.8 (1996-04)
Average Growth since 04	7.6	0.8
Imp. Over the periods (%)	2.9	-

Source: http://planningcommission.nic.in/data/datatable/0904/tab_103.pdf

During 2000-05, GDP shrunk twice. Over 1994-02, Madhya Pradesh grew at 4.7%, which improved to 7.6% for the period 2004-12 (table 1). The agriculture growth rates have dropped from 3.8% over 1996-04 to 0.8% since 2004. The majority of farmers are smallholders and many of them already find it difficult to make ends meet. In October 2008, the India States Hunger Index was released by the International Food Policy Research Institute (IFPRI) and its partner organizations in the Global Hunger Index 2008 project. For the first time, India's states had been disaggregated from the national index. The Madhya Pradesh In the 'extremely alarming' category where the availability of food grain per person has plummeted over the last 20 years - it is only just over 60% of what it used to be. In 1981-82, the per capita availability of coarse cereals in Madhya Pradesh, from the state's own harvest, was 82.3 kg per year. In 2006-07, that figure had dropped to 27.8 kg per capita and continues to do so because agriculture faces major challenges related to climate change and climate variability and the production is always very prone to the adversities of nature. Overall the impact of climate change is increasingly pronounced because of a predominantly agrarian economy and considerable poverty (Hedger and Vaideeswaran, 2010).

Climate Change and Its Impact on Agriculture

Many districts of Madhya Pradesh have been facing a drought situation repeatedly every year. During 2007-08, 39 out of 50 districts (165 Tehsils and one cluster) of Madhya Pradesh have been declared as drought affected. The State has faced drought in the nine out of last ten years. Though irrigated area has increased substantially in the State, yet production in almost 70% agriculture area remains highly dependent on rainfall. At present around 7 districts highly affected from drought. The drought has shattered the villagers' hope of earning a dignified living in the past few years and this year also they were not having any choice except for rain. Increase in the state's population has been accompanied by an increase in the need for food, but the per capita food production is going down. The situation during 2007-2013 can be clearly seen in Table 2 and 3.

Table 3: Situation of Major Rabi Crops

Year	Area (Lakh ha.)	Production (Lakh MT)	Productivity (Kg/ha)
2007-08	34.16	22.47	658
2008-09 *	36.72	32.21	877
2009-10* *	37.94	36.29	957
2010-11 * **	39.01	25.70	659
2011-12	35.17	31.90	907
2012-13 ***	40.39	43.80	1084

Source: http://nfsm.gov.in/NFSMPP.aspx

* *Drought affected 41 districts.*

** *Drought affected 38 districts*

** * *Drought affected 37 districts & frost affected 46 districts.*

***** *Hail storm affected 37 districts & frost affected 20 districts*

Table 4: Scenario of Total Pulses

Year	Area (Lakh ha.)	Production (Lakh MT)	Productivity (Kg/ha)
2007-08	43.98	26.74	608
2008-09 *	46.37	37.10	800
2009-10* *	47.95	41.34	862
2010-11 * **	52.09	30.29	581
2011-12	47.59	37.18	781
2012-13***	53.23	50.41	947

Source: http://nfsm.gov.in/NFSMPP.aspx

* *Drought affected 41 districts.*

** *Drought affected 38 districts*

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The main oil seeds i.e. Soybean and mustard saw the worst decline at 5.92 lakh MT in 2013-14 from the high of 9.95 lakh MT in 2012-13. Soybean production, in which MP has a lion's share, was less by 43.91 per cent. Rabi is the main cropping season but due to consecutive drought in the State. In year 2015, the south-west monsoon arrived with a bang (in June-July) and western part of state receives almost 47 per cent surplus rainfall. While the eastern part recorded a 17 per cent shortfall, it was still within manageable limits. By mid-August, the state had exceeded its sowing target of 104 lakh hectares (lh) for all Kharif crops (including soyabean, paddy, maize, urad, arhar/tur and cotton) by more than 15 lakh hectares.

The rains, however, played truant in the second half of the monsoon season. The deficit during August-September amounted to 31 per cent in west and 40 per cent for east. It was only towards the second week of October that the full impact of the late-season drought sank in. The woes of farmers have, however, been compounded by poor rains in the post-monsoon period (October-November), leaving very little residual soil moisture for Rabi sowing operations too.

In the normal course, sowing of wheat should have been completed by November 15, but it stretch beyond mid-December. Moreover, many farmers, whose Kharif crop have failed or yields impacted by drought, may not even have the money to buy

seeds or fertilizers to undertake Rabi plantings. The impacts of excess/deficit rainfall and warmer temperatures vary depending on the crop and season. The climatic change affect agriculture in several ways such as quantity and quality of crops in terms of productivity, growth rates, photosynthesis and transpiration rates, moisture availability etc. A generalized mechanism by which climate change crash key crops are given in below-

Table 5: Sowing Progress due to Drought in Rabi Season in Madhya Pradesh (Lakh Hectares)

Crop	2015	2014	2013
Wheat	0.55	10.88	21.57
Pulses	1.20	3.45	29.84
Gram	0.64	3.06	23.53
Masur	0.17	0.18	5.46
Matar	0.13	0.16	2.37
Mustard	0.37	5.13	6.24

Source: Gatwal, 2015

Table 6: Nature of Impact of Climate Change on Selected Crops

Crop	Nature of Impact
Rice	Water shortage in rainfed rice during *Kharif* due to long dry spells. Pollination and grain filling in transplanted rice to be affected due to high temperature.
Wheat	Negative impacts of higher minimum temperature on grain filling duration and grain size leading to reduced yields.
Soyabeans	High temperature during *Kharif* to increase water demand by crop canopy. Heavy rainfall events to cause water logging and yield reduction.
Red gram	Heavy rainfall events during *Kharif* to cause water logging and impact yields.
Bengal gram	Higher minimum temperatures up to 1.5 to 2.0 0C may have beneficial effects in the short term, but greater warming in long run may impact reproduction and seed development.
Horticultural crops	Unseasonal rains, hailstorms and frost whose frequency is likely to increase may cause physical damage impact quality of produce and increase the incidence of pests and diseases.

The Cultivators and agricultural labourer in numerous villages are suffering from acute distress due to the prolonged drought conditions in the state over the long period State government has promulgated 46 out of 50 districts as drought affected due to the heavy crop loss to the farmers. Madhya Pradesh is considered to be the top Soyabean producer of the country and the largest supplier of Wheat after Punjab, but after the second consecutive drought year the figures of these gains are been wiped off.

The flow chart (fig. 2) given below focuses on the drought impacts to agricultural and non-agricultural sectors and the negative impacts on end-users. Drought impacts on the economy, societies and the environment moving through time from the top to the bottom of the chart. Drought produces a complex web of impacts that spans many sectors of the economy and reaches well beyond the area experiencing physical drought. Many economic impacts occur in agriculture and related sectors, because of the reliance of these sectors on surface and groundwater supplies. In addition to losses in yields in both, crop and livestock production, drought is associated with insect infestations, plant disease, and wind erosion. Income loss is another indicator used in assessing the impacts of drought. Reduced income for farmers has a ripple effect. Retailers and others who provide goods and services to farmers face reduced business. This leads to unemployment, increased credit risk for financial institutions, capital shortfalls, and eventual loss of tax revenue for local, state, and federal governments. Prices for food, energy, and other products increase as supplies are reduced. In some cases, local shortages of certain goods result in importing these goods from outside the drought-stricken region.

Migration is the major social impact occurs in the drought affected areas in the state especially in Bundelkhand region. Empty, locked houses are a common sight in the villages. Given the tough conditions, the rural poor are plunged into the crisis every year and are not left with any other option but to migrate to other States in search of work. Every year a large number of such distress migrants reach Delhi and other metropolitan areas where an organized chain of labor contractors and middlemen lure them with employment at promising wages.

The study, *"Climate Change in Madhya Pradesh: Indicators, Impacts, and Adaptation,"* done jointly by faculty member Veemal Mishra of IIT-Gandhinagar and Amit Garg of IIM-Ahmadabad says that Madhya Pradesh is likely to see 1-1.2 degree Celsius rise in temperature by 2045, bringing more droughts that will pose *"enormous" pressure on agriculture, water resources, infrastructure and energy sectors. The projected future climate may lead to more frequent, severe, and wide-spread droughts during the monsoons season. The frequency of hot days, hot nights, and heat waves is projected to increase in the state. Further, as per present report this rise in temperature is much beyond the target set by 194 countries as per the Paris Climate Agreement to keep global temperature rise below 2 degree Celsius by the end of the century from pre-industrial level. But here we have temperatures breaching the target much quickly, which is a cause of concern."*

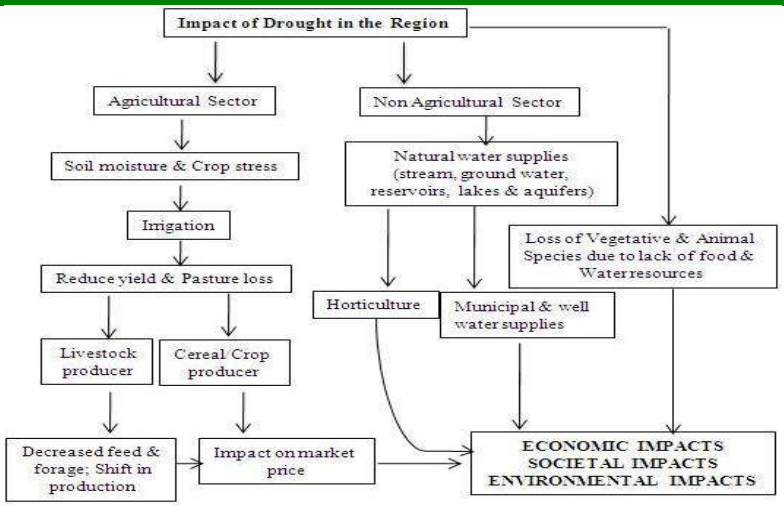

Fig. 2. Drought impacts to agricultural and non-agricultural sectors *(Adapted with modification from Ding et al. (2010); Kellner and Niyogi (2014)*

Adaptation strategies for Sustainable Agriculture

Adaptation in the context of climate change refers to 'adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structure to moderate potential damages or to benefit from opportunities associated with climate change' (Smit B. et al. 2001). Adaptation in developing countries is critical for stable economic and social development and involves adjustments at all levels. At the community level it involves building resilience through the adoption of appropriate technology, making the most of traditional knowledge and diversifying livelihoods to cope with climatic stress. Coping strategies and traditional knowledge need to be complemented by favorable policies and interventions at the local, state and national level. Thus, climate change adaptation needs to be mainstreamed in planning processes including budgets and policies in order to ensure climate resilient development.

Climate change poses serious threats to productivity and sustainability of the rice-wheat and other cereals-based cropping systems, the backbone of food security of India. The impacts of climate change are complex and no single strategy will address the issue adequately. A combination technology and policy related interventions are required (Venkateswarlu and Shankar, 2009). Considering the natural resources, cropping systems and the projected climate scenario for the state, the following strategies are important.

- Providing timely and micro level weather forecast to farmers along with appropriate agro advisories.
- Evolving crop varieties tolerant to multiple abiotic stresses (eg. heat, drought, submergence etc.), through coordinated research efforts by public and private sector.
- Water management is the most crucial part of climate change adaptation in the state. Efficient use of irrigation water and *in situ* and *ex-situ* rain water harvesting are critical in irrigated and rainfed agriculture, respectively.
- Promoting conservation agriculture and other practices to build soil organic carbon.
- Formulate state specific weather based insurance policies and encourage farmers for wider adoption of such products for minimizing losses during extreme events like heavy rainfall, floods, hailstorm, heat wave, cold wave, frost etc.
- Integrate climate change adaptation as a key component in all the development plans at state level for agriculture sector. In other words, while any new policy is formulated regarding the utilization of natural resources, energy use, and providing inputs to farmers etc. its impact on climate change adaptation should be critically examined.

Conclusion

However, while the impact of climate change on the life and livelihood of the people needs to be recognized and assessed, a note of caution is also needed. In recent decades large-scale ecological ruin has also been caused by indiscriminate cutting of natural forests, ruthless mining operations, chemical-intensive agricultural technologies and excessive extraction of ground water. It is very important to check these local causes of ecological ruin and their harmful impacts. Those responsible for such damage should not be allowed to take cover behind climate change (in the sense of attributing all ecological damage to climate change, so as to divert attention from their misdeeds). Any planning for sustainable development of the region has to include reduction of all these causes of ecological ruin and checking the activities of those responsible for this ruin. The watershed management approach is beneficial for the development of climate-resilient agriculture because in watershed development framework water and energy-efficient systems and integrated / mixed tree-based farming and livestock development were integrated in maximum synergy. These hold the key to enhancing the capability of the farming community to adjust and adapt. It ensures dietary diversity and food security. The promotion of alternate non-farm livelihoods for small-holder producers reduces the burden on agriculture and the natural resource base of being the only sources of income.

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