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Resilient Agricultural Practices: A Case Study of Ujjain District, Madhya Pradesh, India

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Abstract

Agriculture is an important sector of the Indian economy as it contributes about 17% of the total GDP and provides employment to over 60% of the population. It contributes almost one-fourth of Gross State Domestic Product of Madhya Pradesh (M.P.) and wihin M.P., Ujjain district contributes significantly with 80% of its total land under agricultural use. Because of its high dependency on agriculture, this district has been considered most vulnerable to climate change. In this research, dominant climatic factors (i.e. rainfall and temperature) and non-climatic factors (i.e. soils and farmer's socio-economic characteristics) influencing the agricultural practices in Ujjain District have been taken into consideration. Temporal analyses of climatic parameters along with analysis of non-climatic components were performed and the outcome showed a relatively high dependency of agriculture sector on climate in Ujjain district. Using projections and model developed by IPSL, there is likely to be a drastic change in the local climate of Ujjain in the coming days. Temperature is expected to rise by about 4°C and rainfall intensity would increase. The current cropping pattern of Ujjain district will not be able to withstand these extreme conditions. In order to adapt to this scenario, this research has proposed alternative cropping practices. An integrated approach of mixed farming and intercropping based on soil type and climatic conditions are also proposed. A set of policies and legislative framework has also been identified to incorporate changes in agricultural practices to make it resilient to climate change.

Introduction

Agriculture being the most primitive occupation of civilized man draws much on its development with the advancement of civilization, starting from shifting cultivation to advanced precision farming (Nistane and Nayan, 2015). In Madhya Pradesh, about 31% of the total population is involved in agricultural practices while 70% of total workers and 65% of the total main-workforce engaged in agriculture (Census, 2011). Around 49% of the total geographical area is under cultivation. Agriculture which is mostly rain-fed in nature along with its multiplier effects contributed about 40% in Gross State Domestic Product of Madhya Pradesh in 2011-12 (SDPMP, 2011-17). Mishra (2014) reported that precipitation has declined while temperature has increased over most parts of India within last few decades, western Madhya Pradesh has witnessed increased in frequency of droughts and reduction in soil moisture for crop growth. In such a case, extreme rainfall patterns and/or variations in rainfall become critical to production. The rain-fed agricultural production system is vulnerable to seasonal variations and irrigation practices which affect the livelihoods of farmers and landless labourers of Ujjain district. Farmers who are unable to adapt to the changing climate, often shift to other livelihoods or remain impoverished.

Background of Study

There is growing acknowledgment that agriculture and food systems need to change, irrespective of climate change. The last time the world faced such pressure to find a permanent solution to world food insecurity was in the 1960s and 1970s when food production and distribution could not keep pace with the growing population (Jones, 2012). The response was the Green Revolution: high-yielding and pest/disease-resistant varieties of seeds, mainly rice and wheat were introduced and their cultivation was supported through subsidies for inputs such as seeds, fertilizers, and irrigation.

The Green Revolution resulted in spectacular achievements, but its longer-term effects are detrimental to the environment. Its focus on mono-cropping and often excessive use of agricultural inputs such as pesticides and fertilizers, which has resulted in poor soil quality, reduction of bio-diversity, pest resistance, pesticide and fertilizer pollution in the environment (soil and groundwater) and human health risks. Overuse of irrigation water has resulted in salinization and/or withdrawal of groundwater beyond its replenishment capacity. These practices were all supported by policies of input subsidies and have led to diminishing returns on further intensification and an excessive burden of subsidies on governments. Besides the stagnation of crop yields, landscapes have been compromised through the overuse of groundwater, the spreading of nutrients and pesticides.

The most important climatic events that affect Indian agricultural practices and are key factors which determine the productivity and yield of agriculture/ crop practiced are heat waves, cold waves, fog, snowfall, floods, droughts, monsoon depressions, cyclones and rise in sea level. While, increased intensity and frequency of storms, drought and flooding, altered hydrological cycles and precipitation variance have implications for future food availability. As the Intensity of these extreme events has been increased due to human activities and natural phenomenon which has led to climate change. It is further predicted that climate change will become a more serious threat in the nearby future.

The Study Area

According to the report published by Stockholm Environment Institute under Indo-UK Climate Change Research Programme (Development Alternatives, 2012), Madhya Pradesh was identified as one of the most vulnerable states to climate change. For this research, Ujjain District was selected as case study district because the district has the highest net sown area in Madhya Pradesh in terms of geographical area (GoMP Climate Change Cell, EPCO, 2012). Ujjain district is considered as one among the most vulnerable districts in Madhya Pradesh (Fig.1). Out of total geographical area (613023 ha) of the district, 80% is under agricultural use while 41% of total agricultural land is irrigated, out of which only 2% is irrigated through proper irrigation facility (Ministry of Water Resources, 2013).The agricultural productivity of Ujjain district is very much affected by regular drought and flood conditions. Generally, drought happens in the month of May, while June to August is months of flash flooding, which happens almost every year (Development Alternatives, 2012).

Methodology

The methodology for assessing impacts of climate change on agricultural practices of Ujjain District is divided into four parts such as, i) selection of climatic and non-climatic parameters, ii) temporal analysis of climatic and non-climatic parameters, iii) selection of model for future climate prediction, and iv) analysing impact of climate change on agricultural practices of Ujjain district.

Selection of Parameters

Climate is the most important dominating factor influencing the suitability of a crop to a particular region. The yield potential of the crop mainly depends on the climate. More than 50% of the variation in crop production is caused by climate change. The most important climatic factors that influence growth, development, and yield of crops are solar radiation, temperature, and rainfall (Agrometeorology: Temperature and Plant Growth, 2017).

Unlike climatic parameters, non-climatic parameters are important in adaptation capacity and mitigation side of the spectrum. These non-climatic parameters such as land use, land degradation, urbanization, Soil Characteristics, pollution affect systems directly and indirectly through their effects on climate while these drivers can operate either independently or in association with one another (Lepers, 2007). These parameters influence the local climate significantly and hence alter the overall climate of the region. Based on the impact of two climatic parameters, viz., temperature and rainfall and two non-climatic parameters, viz., soil characteristics and socio-economic conditions of farmers were taken into consideration in this research.

Temporal Analysis of Climatic Parameters

Temporal analysis of crops practiced within the district shows a continuous shift in cropping from oilseed (Soybean) towards cereal (wheat) which is a result of advances in technology, primarily in irrigation. *Kharif* crops like soybean, maize, and sorghum are 100% rain-fed. As a result, change in rainfall pattern or temperature directly affect productivity and yield of Kharif crop. Problems of low yield and productivity ultimately lead to issues like farmer's suicides, crop failure, etc.

On the other hand, *Rabi* crops, such as wheat and gram are based on irrigation but in case of a change in rainfall, there will be a shortage of water available for irrigation resulting negative impact on the yield of the crops. Rain-fed *Rabi* crops like mustard are the most vulnerable to climate change.

It was identified that 95% of the cultivated area is under mono-cropping or 2 crops of short interval due to dependence on rain for irrigation of the crops. As a result, a major portion of land remains fallow most of the year leading to loss of soil carbon, soil nitrogen, ultimately causing a reduction in soil fertility. Fallow land is also susceptible to soil erosion.

Temporal study of climatic parameters, i.e. temperature and rainfall during the past 114 years shows that both the mean minimum and mean maximum temperatures of Ujjain district have increased by approx. 1.0°C (Fig. 2). The major change in both mean minimum and mean maximum temperatures have been observed from the early 1970s (Fig. 2). Total annual rainfall has reduced by 20 mm since 1900s (Fig. 3) and in the meantime, a total number of rainy days in a year has reduced by 0.5-1 day (Fig. 4).

The peak rainy season has already shifted by almost 2 months from June to August in case of Ujjain district. While the duration of the rainy season has also reduced significantly, a major reduction in the quantum of rain has also occurred between 1980 and 2010 (Sharma, 2016).

Due to the constant rise of temperature and increasing rainfall anomaly, climate change becomes one of the major threat to cultivators, especially marginal cultivators, and small landholding farms as the adaptability of these marginal farmers/ cultivators are very low as compared to large farm holders.

Analysis of Non-Climatic Parameters

Soil analysis shows that the whole district falls under the nitrogen deficit area (Fig. 5). The low level of soil N content reduces soybean yield and quality. Even after such nutrient revival mechanism of soybean, the yield of soybean is less than half of the average global yield. Acidic nature of the soil is another reason for the low soybean yield in the Ujjain district. If available soil nitrogen is low and the soil is acidic in nature, yield and protein content will be low in case of the wheat crop also (Ministry of Agriculture and Forestry, Alberta, 2018). On the other hand, Ujjain block and Ghatiya block have an extreme amount of potassium in the soil (Fig. 5) due to excessive usage of potassium based fertilizers. Ujjain and Ghatiya block have a good amount of phosphorus in soil (Fig. 5) due to the high usage of phosphorus-based fertilizers. However, a high level of phosphorus in the soil doesn't affect the yield in a short time frame but is beneficial in the long time frame (Rosolem & Merlin, 2014).

Farmers' Socio-economic Status

There are 2,32,020 farmers under all classes in Ujjain. Out of which 34% practice Single-crop farming. Among 2,32,020 farmers, 37% of farmers are classified as marginal farmers and another 26% are classified as small farmers, who are primarily dependent on agriculture for income. 80% of the total district land is under agriculture use. The total land area under small farmers is 131035 ha i.e. 26% of the total agricultural area and 21% of the total area of the district (Agricultural Census, 2010-11). The actual productivity of both major crops i.e. Soybean and Wheat are 1350kg/ha (approx) and 3000kg/ha (approx) respectively against the optimum yield of 2000kg/ha and 3500kg/ha respectively.

Selection of Model for Climate Projection

For the purpose of future climatic projection of Ujjain district, IPSL-CM5A-MR model out of 20 available climate prediction models was considered in this research. IPSL-CM5 has been developed by Institute Pierre Simon Laplace (IPSL) and it includes 5 component models representing the Earth System climate and its carbon cycle: LMDz (atmosphere), NEMO (ocean, oceanic biogeochemistry, and sea-ice), ORCHIDEE (continental surfaces and vegetation), and INCA (atmospheric chemistry), coupled through OASIS (Dufresne, *et al*., 2013). This model is a full earth system model with mid-resolution of 1.25° x 2.5° (Misra, *et al* 2016).
Along with the above model, RCP: 8.5 scenarios of projection was considered in this research which has been developed by the MESSAGE modeling team and Integrated Assessment Framework at the International Institute for Applies Systems Analysis (IIASA), Austria.
Within the selected climate prediction model and selected scenario, AgCFSR Dataset has been considered in this research. Agriculture Climate Forecast System Reanalysis (AgCFSR) climate forcing datasets were created as an element of the Agricultural Model Inter comparison and Improvement Project (AgMIP) to provide consistent, daily time series projected till 2100 period with global coverage of climate variables required for agricultural models.

As predicted by model selected and considering the worst case scenario, the mean minimum temperature and mean maximum temperature will increase by 2-3°C (Fig. 6 & 7). In the meantime, the total amount of rainfall in Ujjain district will further increase by 150 mm till 2065 with the anomaly (Fig. 8)and a total number of rainy days in Ujjain district will increase by 10 (Fig. 9).
According to the model, there is a high possibility of having high climate anomaly in the coming future. Therefore, there is a need to adapt to climate change, as current crops cannot withstand these extreme climates and hence need to be changed.

Impact of Future Climate Trends on Current Cropping Practices

A rise in present-day temperature by 3°C under present day CO_2 level, leads to a net decline of 28% in simulated soybean yield (Lal, *et al* 1998). It was further projected that a 40% decline in daily rainfall reduces the soybean yield by about 18% (due to constraints on the availability of water). Similarly, yields of wheat crop will decline to 25-35% (Kumar, *et al* 2014). Even if farmers adjust the time of sowing with use of existing climate-resilient varieties under improved nutrient and irrigation management and with a higher dose of nitrogen fertilizer (25% higher than the dose currently applied by farmers), the wheat production is projected to get reduced by 5% (Kumar, *et al* 2014).
Analyzing the impact of projected climate change scenario, the two major crops practiced within Ujjain district viz soybean (*Kharif*) & wheat (*Rabi*) show negative resilience to climate change with low adaptive capability under the projected climate change.

Results and Discussion

Building Resilience in the Agriculture Sector

The results confirm the negative impact of projected climate on current cropping practices in Ujjain district. Therefore, suggestions about the change in crops along with the cropping cycles under rain-fed conditions (*Kharif* and *Rabi crops*) were made based on the theoretical resilience of crops under projected climate scenario. Considering the uncertain future, non-climatic conditions followed by future consumption patterns and economic growth suggestions have been presented separately for two-time frames (the Year 2020 and 2050).
As per the projected climatic scenario for the year 2020 (Fig. 10 - 11), the temperature will range between 26- 34°C (June-October) in *Kharif* season and will range between 18- 23°C in *Rabi* season (Nov- Feb). Annual rainfall will be 813mm, 90% of which will occur in the rainy season (July- October). Cropping cycle involving soybean (*Kharif crop*) along with pigeon pea (*Rabi crop*) is suggested based on optimum yield capacity of these crops to projected climate. The temperature requirement for optimum yield of soybean is 26.5 to 30°C along with 450 700mm rainfall in growing period (Critchley & Siegert, 1991) while temperature requirement for optimum yield of pigeon pea as *Rabi* crop is 17°C to 22°C. The mean annual rainfall requirement is between 600 to 1400 mm, 80%-90% of which is received during the rainy season (Singh & Oswalt, 1992).
In medium term projected climatic scenario for the year 2050 (Fig. 10 - 11), It has been found that temperature will range

between 28- 35°C(June- October) in *Kharif* season and will range between 19- 25°C in *Rabi* season (Nov- Feb), along with annual rainfall of 965mm of which around 87% received in the rainy season (August- October). Cropping cycle involving mixed farming of green gram with sorghum (*Kharif* crop) along with mixed farming of mustard with chickpea (*Rabi crop*) is suggested based on optimum yield capacity of these crops in the projected climate scenario. As climate requirement for optimum yield of green gram (IITK, 2018), sorghum (IITK, 2018), mustard (Oplinger, 2018) and chickpea (Yadav, 2018) best fits within projected climate scenario providing good drainage conditions. As the majority of farmers fall under a small and marginal group, a low and minor change in crop's yield would make a significant impact on farmers' socio-economic condition.

Policies and Legislative Framework

The above-mentioned suggestions backed by a set of legislative framework and schemes through which the suggested cropping practices can be incorporated into the system will give the desired outcome which would be sustainable in nature. Hon'ble Prime Minister of India has set the goal of doubling farmer's income by 2022-23 compared to 2015-16 level through *THREE YEAR ACTION AGENDA 2017-2020*. To Achieving this goal active participation of state governments is required to bring the necessary changes.

National Seed Policy was launched in 2002 under the *SEED ACT, 1966* to provide intellectual property protection to new varieties of seeds of agricultural crops. Using the act, central government or the respective state government can take preventive measures via distribution of identified crops in order to protect the interest of farmers and encourage conservation of agro-biodiversity; to ensure higher production thereby improving the economic condition of the farmers in the region.

Within M.P., *Madhya Pradesh Organic Farming Policy, 2011* is implemented to capitalize inherent potential by converting weakness and threats of low production agriculture to booming opportunities through organic farming. Agro-ecosystem management and harnessing hypermarkets for premium farm products are also proposed. While doing so, the interests of farmers in remote areas will be kept in mind. The targets of the policy are as follows:

Long Term Targets- achieving renewable environment through agriculture- ecosystem management, implementation of the main schemes such as soil carbon storage and metering, enhancing soil health and biodiversity.

Medium Term Targets-To standardizes agriculture investment and enhances income on investment in the present agricultural system. On the other hand, making agriculture a profitable business by enhancing net income.

Short Term Targets- Developing an appropriate atmosphere for families dependent on small and marginal agriculture economy by developing technology, market security, developing capable, economic, human resources and institutions. Simultaneously, ensuring availability of required quality resources for producing organic products, developing renewable energy sources by utilizing biodegradable resources are also stressed upon. Through this, M.P state government can incorporate the suggested crops in cropping cycles in order to meet targets of this policy.

Role of Panchayat legislations in agriculture is defined through Article 243 G, Eleventh Schedule of Constitution of India. The functions of the Panchayats include agricultural extension, land improvement, implementation of land reform, land consolidation, soil conservation, minor irrigation, water management, and watershed development. Panchayat with a stake of the public, can take appropriate measures in the form of distribution of seeds, monitor the use of fertilizers and implementation of various central and state schemes and policies.

Conclusion

Agriculture is an important part of the economy of Ujjain district. Current agricultural practices of Ujjain district is not resilient to potential climate change. Since Ujjain district is considered as one of the most vulnerable districts in Madhya Pradesh, it is high time to explore agricultural practices which will be resilient to climate change. In this research, two climatic and two non-climatic parameters were identified in the context of Ujjain district. Temporal analysis of those parameters reveals that there is a clear trend of climatic change over the past years. An IPSL based model was used to estimate the future change in climatic condition and the results show a clear indication of climate change in terms of temperature and rainfall. In this paper, resilient cropping practices have been suggested to confront climate change. Due to many reasons, climate-smart agriculture practices have not become popular in the Malwa region of Madhya Pradesh, particularly in Ujjain District. In order to get the desired outcome and for the successful implementation of suggested cropping practices, interventions could be taken at central, state and district levels with the help of an identified legislative framework.

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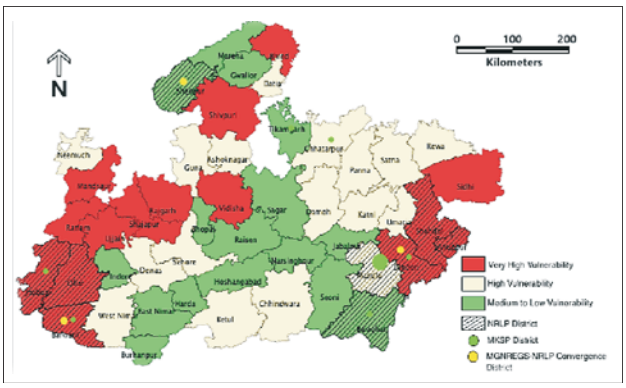

Fig.1: District-wise Vulnerability Map (Madhya Pradesh)

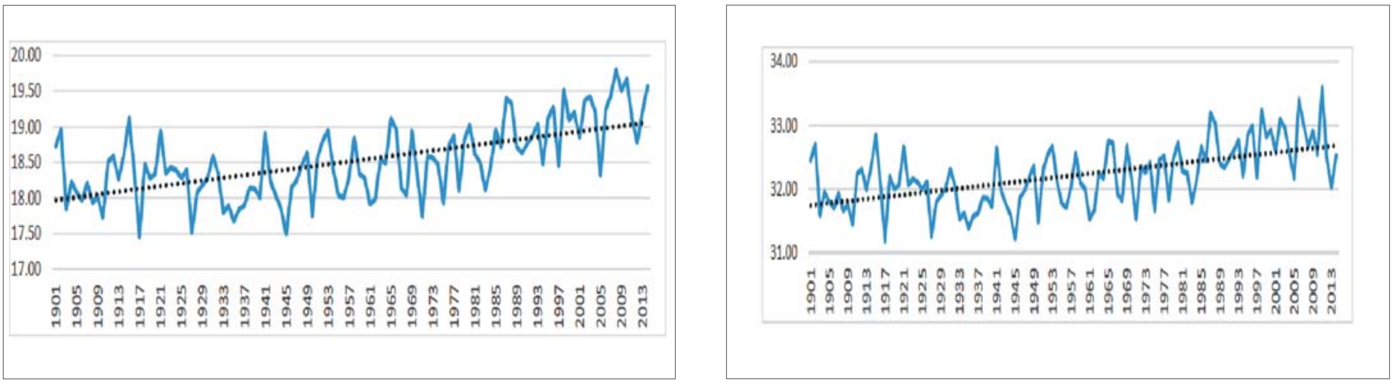

Fig. 2: Trend of Mean Minimum and Maximum Temperature (1901 - 2014)

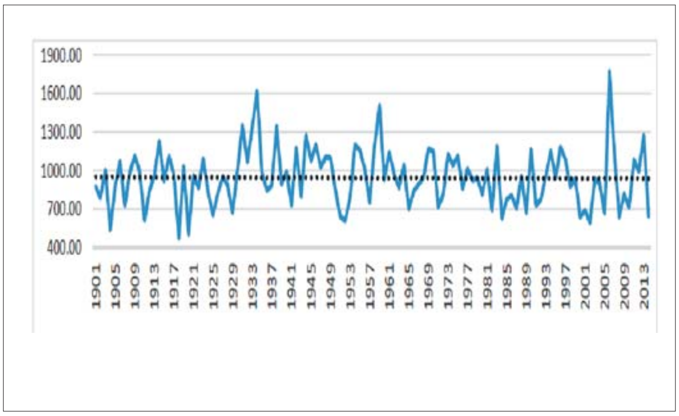

Fig. 3: Trend of Total Annual Rainfall (1901 - 2014)

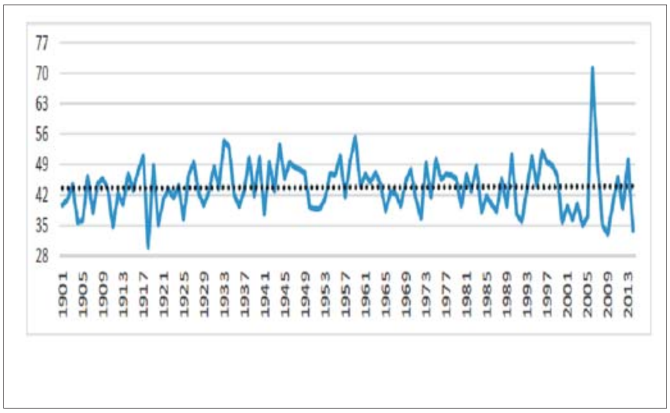

Fig. 4: Trend of Annual No. Of Rainy Days (1901 - 2014)

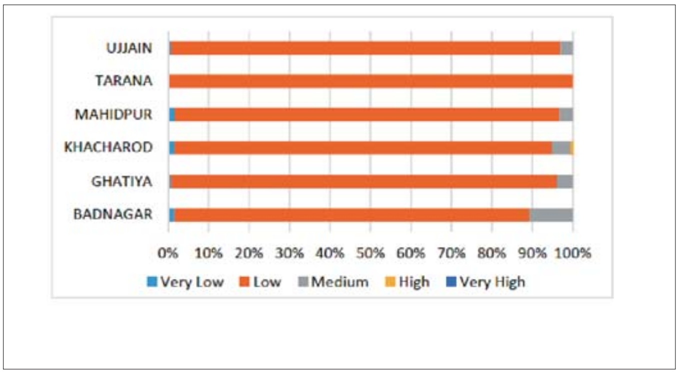

Fig. 5a: Soil Nitrogen Status (Taluka Level)

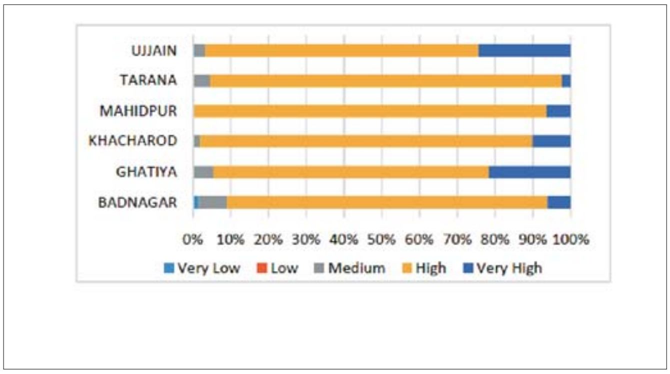

Fig. 5b: Soil Potassium Status (Taluka Level)

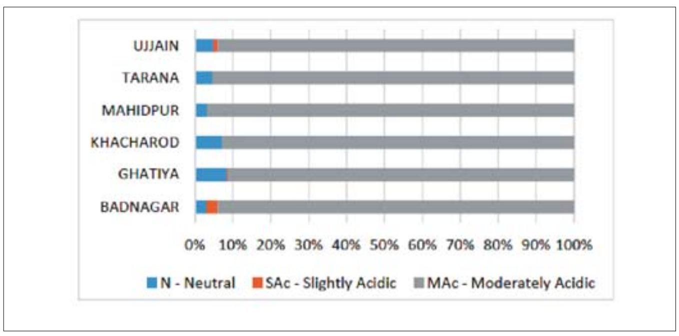

Fig. 5c: Soil pH Level (Taluka Level)

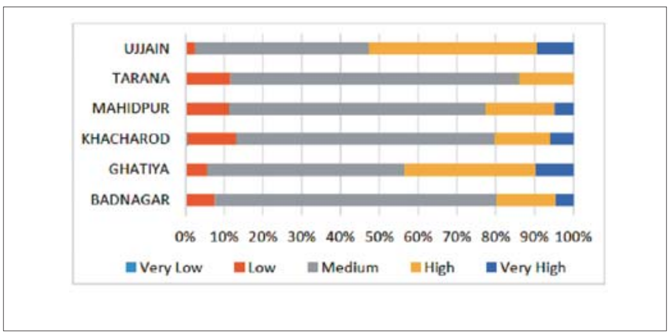

Fig. 5a: Soil Phosphorous (Taluka Level)

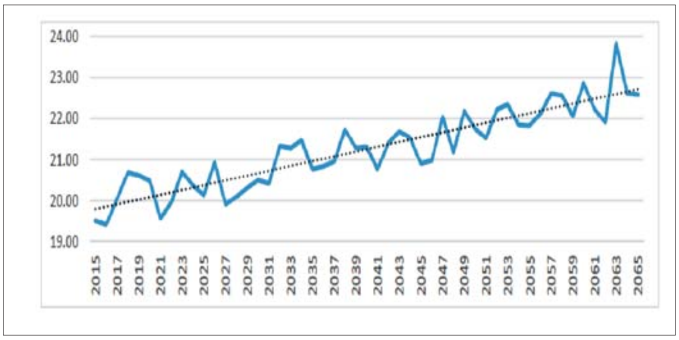

Fig. 6: Trend of Projected Annual Mean Minimum Temperature (2015 - 2065)

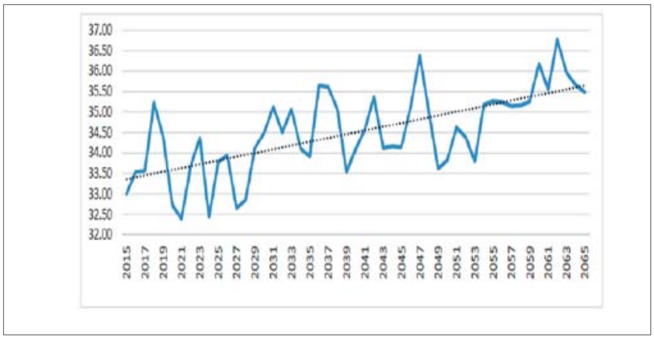

Fig. 7: Trend of Projected Annual Mean Maximum Temperature (2015 - 2065)

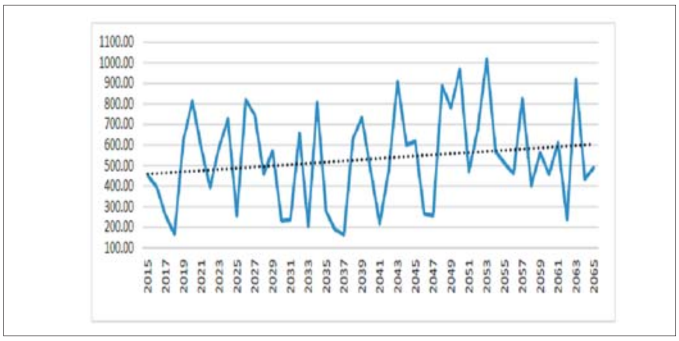

Fig. 8: Trend of Projected Annual Rainfall (2015 - 2065)

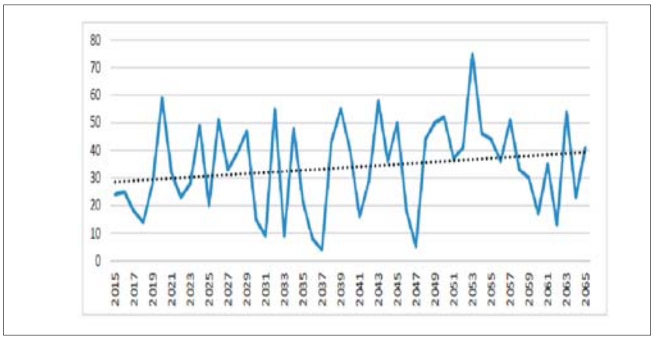

Fig. 9: Trend of Projected Annual No. Of Rainy Days (2015 - 2065)

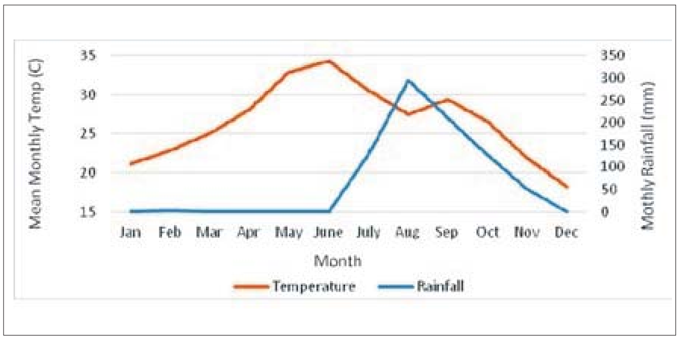

Fig. 10: Projected Scenario of Climate - 2020)

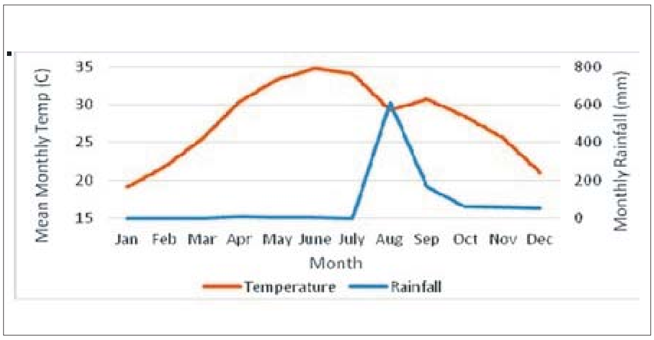

Fig. 11: Projected Scenario of Climate - 2050)

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