Extreme Risks, Vulnerabilities and Community- Based Adaptation in India (EVA)

A PILOT STUDY

Final report on WP2.1

'Impacts of extreme events on dryland ecosystems'

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1 Abstract

The impacts of climate change are manifested across different ecosystems and sectors in various forms. In the case of already water-scarce ecosystems like drylands, climate change and its impacts pose a grave challenge, especially in developing countries. Changes in frequencies and severity of such events increase the vulnerability of communities, primarily of those who are dependent on natural resources for their livelihoods. Therefore, it becomes important to understand how climate change and extreme events like drought impact dryland agro-ecosystems.

The report is based on outcomes from a two-year Indo-Norwegian research and capacity development project, 'Extreme Risks, Vulnerabilities and Community-Based Adaptation in India (EVA): a pilot study' (2012–14). Within the research project the impacts of and vulnerabilities and responses to extreme events on agriculture and water resources are assessed in nine villages in the drought-prone drylands of Jalna District, Maharashtra, India.

In this report, we describe the study area and the historical and projected extremes for the area. As the study area is primarily agrarian, the ecosystem is defined by the cultivated crops and linked natural resources like water. On the basis of secondary data review and analysis and consultations with key stakeholders within the communities as well as with block and district level officers, the historical impacts on the agro-ecosystem and the possible impacts in future due to climate change and other socio-economic and land use changes were identified.

The report is intended for development practitioners, researchers and policy makers interested in climate change and rural development challenges in Maharashtra.

2 Acknowledgements

We extend our gratitude to the entire EVA team and the Royal Norwegian Embassy for their support in the course of this project. Special thanks to both Ms Signe Gilen and Mr Suresh Mathevan for their continuous support and inputs provided in the course of the study. We also thank the Department of Environment, Government of Maharashtra, the district and block officers from Jalna for their generous support and guidance and also for sharing their knowledge and experience with us during this study.

We are especially grateful to the Krishi Vikas Kendra for sharing with us some of the data that we could use effectively for our analysis for this study. We also value the experiences shared by them during the course of the study.

3 Introduction

In this report we present and discuss the outcomes of Work Package 2 (WP2) Assessment of impacts and vulnerabilities in the dryland ecosystem, under the Extreme Risks, Vulnerabilities and Community-Based Adaptation in India (EVA): a pilot project. The overall project has assessed the impacts of and responses to extreme events on agriculture and water resources in nine villages in the drought-prone drylands of Jalna District, Maharashtra, India.

Work Package 2.1 focuses on the assessment of potential impacts of extreme events on the dryland systems. Concentrating on the direct and indirect drivers that govern ecosystem changes, the report gives a background on the extremes that are prevalent in Maharashtra and in the Jalna District. It gives a broad overview about the region where the study area is located, providing a brief profile of the region and of the case study villages. Forthcoming sections highlight the past and future exposure to extremes in Jalna. The report also explores areas that are likely to experience changes in surface runoff, land use and land cover change and changes in cropping patterns.

3.1 Background

Most of the state of Maharashtra lies in the semi-arid belt of India with large parts of central and north-eastern Maharashtra dry and many districts categorized as drought prone. While the state has large urban centres, large contributions to the gross domestic product (GDP) from the manufacturing and services sector, agriculture still constitutes to be a driver of the local economy with as many as 50 million people dependent on agricultural incomes and residing in rural areas.

Rainfall distribution and biodiversity richness across the state is skewed, with the western region of the state well endowed with both, given the presence of the Western Ghats and the Konkan region receiving the highest amount of rainfall about 2000 mm annually (climate normals in the region are quite high) (see Figure 1). Rest of the state receives about 600–700 mm rainfall annually. The state has been divided into nine agro-climatic zones based on rainfall, soil type and the vegetation cover.

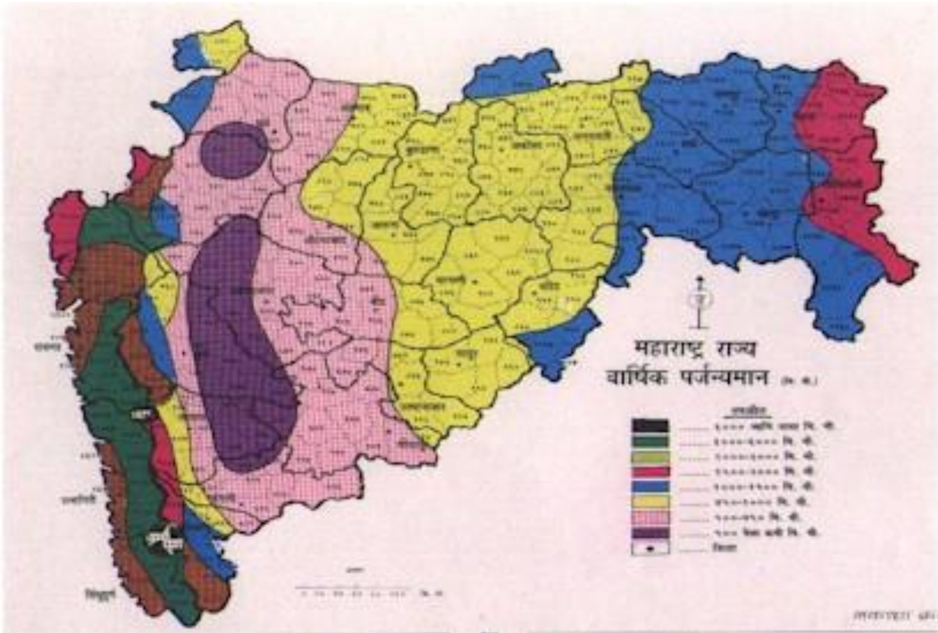


Figure 1: Rainfall distribution across Maharashtra
Source: http://www.mahaagri.gov.in/Maps/Maps/annualRain.jpg

Most parts of Vidharbha and Marathwada are drought prone and get affected by drought very frequently. Observed datasets also show that the rainfall in some of these districts have been showing a declining trend with consequent impacts on the local economy. Records indicate that Jalna District has been observing a decline in rainfall over the last 30–40 years (see EVA WP1 report). Paradoxically, climate projections from EVA WP 1 indicates an increase in rainfall for the region to the tune of some 80–100mm. Extreme wet days are on an increase and therefore, indicative of heavy precipitation events. Also, the region has been experiencing a lot of disturbance due to hail storms during the advent of the summer months. While climate data does not compile the frequency of occurrence of these events, these extreme events have been, and are a concern and have affected the production of crops given the damage done to standing crops. Heavy precipitation events and their timings also have a significant impact on the overall production of the crops. Hence, Jalna as a district has been experiencing varied types of extremes that have had an impact on the overall ecosystem, especially droughts.

In this report, we present and discuss how the climate projections in WP 1 influence dryland ecosystems, studying it in the context of the study area in EVA, i.e., Jalna District of Maharashtra. We have done an assessment through the use of literature and secondary data to understand the impacts of extremes on dryland ecosystems.

3.1.1 Definition and types of drylands

While there is no single definition of the term, drylands are commonly characterized by some degree of water scarcity which leads to reduced primary production from natural resources, resulting from the water deficit caused due to loss of natural moisture input from precipitation through natural processes like evaporation and evapotranspiration (UNEP).[1] The cumulative impacts of loss in primary production not only include reduced production from crops, livestock, forage, but also far-reaching impacts on ecosystem, health, rural livelihoods and human well-being, among others.

The types of drylands can be defined by the degree of water deficit measured by the aridity index (AI) (UNEP, World Atlas on Desertification, UNCCD1992)[1] that is experienced or by the length of growing period for annual crops (FAO, 2000). By both systems, drylands are categorized into four subtypes—dry sub-humid, semi-arid, arid and hyper-arid (hyper-arid is not included in the UNCCD classification) in order of increasing water deficit and increasing number of growing days.

The FAO classification (FAO, 2000) is based on growing periods starting when the net difference in monthly precipitation and monthly evapotranspiration is positive, i.e., monthly precipitation is higher than evapotranspiration. Based on this, areas that have a growing period ranging from 1–59 days are defined as arid regions, areas having a growing period of 60–119 days defined as semi-arid and areas having a growing period of 120–179 days as dry sub-humid regions. Areas where the rainfall never exceeds evapotranspiration are termed as hyperarid. The UNCCD and the World Atlas on Desertification (Middleton and Thomas, 1997) uses AI values from lower than 1 to imply an annual moisture deficit and the drylands are defined as areas with AI less than or equal to 0.65, that is, areas in which annual mean potential evapotranspiration is at least approximately1.5 greater than annual mean precipitation.

Based on the FAO classification, 7% of the world is arid, 20% semi-arid and 18% dry sub-humid drylands, respectively. In total, 45% and 41.3% of the world's area is considered to be drylands, as defined by FAO and UNCCD, respectively.

3.1.2 Drylands in India

Indian agriculture is largely rainfed as drylands in India contribute about 75% of the cultivated acreage. It is assumed that almost 50% of the total acreage will continue to be rainfed even if the full irrigation potential targeted for the country is achieved. Dryland ecosystems are therefore expected to remain a major land class with significant relevance for food production in the country.

Traditionally, low water-requirement crops like coarse food grains, including pearl millets, oilseeds like mustard and ragi, variety of pulses were cultivated in the dryland regions but with more outreach of irrigation infrastructure to these areas, farmers have taken up the cultivation of new and, in some cases, high water consumptive crops like sugarcane and cotton in these areas.

Currently, drylands contribute to 80% of the total production of millets and more than 90% of the total production of pulses and oilseeds in the country. The case study site for the EVA project lies in the drylands of Marathwada in the state of Maharashtra. The Marathwada region is a drought-prone area with recorded incidences of droughts in the past. The region is constituted by eight districts which include Aurangabad, Nanded, Parbhani, Latur, Beed, Hingoli, Jalna and Osmanabad districts of Maharashtra. Out of these, Jalna District was selected as the case study site for the EVA study.

3.2 Profile of case study area

[1] http://www.unep.org/maweb/documents/document.291.aspx.pdf

Jalna is a district in Marathwada in central Maharashtra. The district lies 534 m above sea level and spreads from 19° 1' N to 20° 3'N in the North to 75° 4' E to 76° 4' E in the East and covers a total area of 77182 sq. km. Undulating landscape and terraces with flat tops characterize the topography of the district. The district has higher elevation in the north due to the Ajanta and Satmala hill ranges and slopes towards the south to form a part of the Godavari basin. Almost 30% of the district area is part of the Godavari basin and its tributaries cover additional areas.

For administrative convenience, Jalna is constituted of eight blocks or tehsils (Table 1; Figure 2), which include Bhokardhan, Jaffrabad, Mantha, Partur, Ambad, Ghansavangi, Jalna and Badnapur. Tehsils Jaffrabad, Mantha, Partur and Jalna share their borders with Buldhana and Parbhani districts in the east, tehsils Ambad and Ghansavangi are bordered by Beed district in the south and the district shares boundaries with Jalgaon and Aurangabad in the northern and western sides, respectively.

Jalna has a semi-arid climate with an average annual rainfall of 725.8 mm, which can go down to 400–450 mm in low rainfall years. There are four urban centres, viz., Jalna, Bhokardan, Ambad and Partur and in total 971 villages in the district (Table 1). The district has one Zilla Parishad, eight blocks and 791 GramPanchayats (GPs). Jalna covers a total of 2.51% of the area of Maharashtra. Population is 19.58 lakh. Density of population is 255/sq. km.

Table 1. Basic block- wise statistics of Jalna

Taluka	No of revenue villages	Area in hectares	No of Gram Panchayats
Bhokardan	156	1307	127
Jafrabad	101	727	74
Jalna	151	1147	120
Badnapur	92	769	81
Ambad	139	1157	111
Ghansawangi	117	1088	98
Partur	98	754	81
Mantha	117	778	99
Total	971	7727	791

Agro-climatically the district falls in the assured rainfall zone of Maharashtra. Five out of eight talukas of the district have been identified as drought-prone areas under the Drought Prone Areas Programme(DPAP). Summer is hot and dry with maximum temperature going up to 42–43°C, while winter temperature ranges between 10 and 25°C; 83% of the annual rainfall occurs during the monsoon months of June–September.

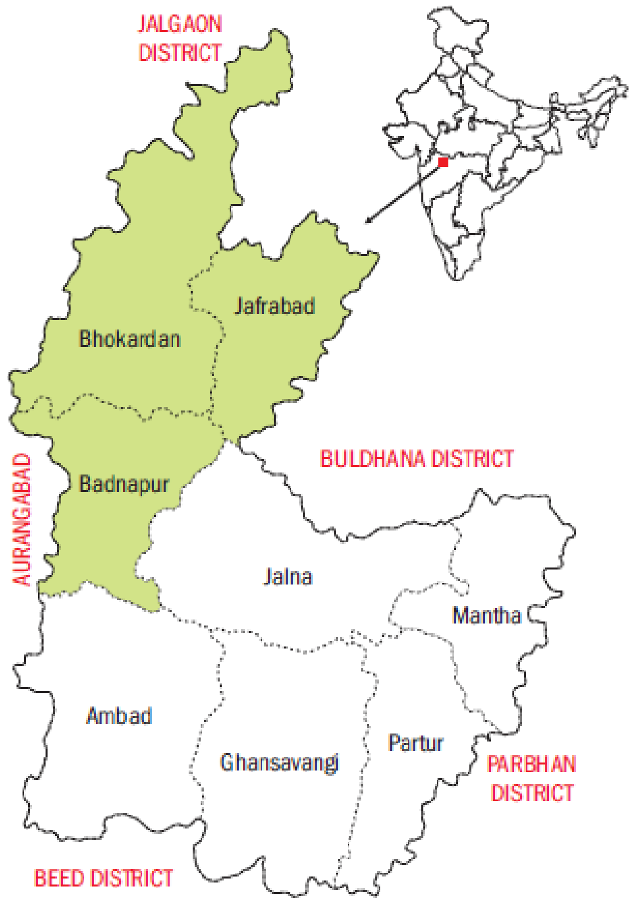


Figure 2. Study area in Jalna District, Maharashtra state, India

Long-term average annual rainfall in Jalna is approximately 700mm. There is some variation in the rainfall pattern across the tehsils constituting Jalna District with the northern tehsils (Bhokardan, Jafrabad, Badnapur and Jalna) recording lower rainfall than the southern tehsils (Ambad, Ghansavangi, Partur and Mantha). The main rivers flowing through Jalna District are the Godavari and its tributaries, Purna and Dudhana. The district falls majorly in the Godavari catchment. Only 16.99% of the area is irrigated (Vision 32, 2012).

The soil of Jalna District is derived from basaltic lava flows and the thickness of the soil cover thickness is less in the northern and western parts of the district as compared with the central, southern and eastern parts of the district. The soil of Jalna District is grouped in different land capability classes. Ambad and Ghansawangi tehsils have more arable soils, i.e., 18.81%, while Jafrabad tehsil has the least area, i.e., 9.44 % of arable soils.

The ratio of groundwater use to availability in Jalna District is 43% (the net annual groundwater availability is 917.28 million cubic metre, while the annual groundwater draft for irrigation and domestic purposes is 392.27 million cubic metre). Irrigation accounts for 98% of the groundwater extraction in the district. In fact, most of the irrigation requirement of the district is met by groundwater, with only 30% of the irrigation demand being met by surface water sources. There are an estimated 770,031 energized pumps used for irrigation in Jalna District (CGWB, 2010).

Moreover, the groundwater level has declined in 23 of the 25 stations in the district over the period 1998–2007. The fall in groundwater has ranged from 0.05 to 0.52 m/year in the pre-monsoon period and from 0.01 to 0.78 m/year in the post-monsoon period. Average groundwater quality is also quite poor (Table 2).

Table 2. Groundwater quality parameters for Jalna District

Quality parameter	Level in Jalna	Required limit
Fluoride	>1.5 mg/litre	0.3 mg/litre
Iron	>1.0 mg/litre	1.0 mg/litre
Nitrate	>45 mg/litre	45 mg/litre

Source: CGWB (2010)

With a population of 1,958,483 persons as per the 2011 Census, Jalna is among the less populated districts of Maharashtra. It is also among the lower income districts in the state, with a per capita gross domestic product of Rs 26,188 in 2006–07 (in current prices) (Planning Commission, 2009). The male population is 10.15 lakh (51.84%), while the female population is 9.43 lakh (48.16%). The sex ratio is 929. Jalna District's population is 1.94 % of the state population. During 2001–11 the total population growth rate is 2.84.

The district performs relatively poorly on gender indicators. For instance, the female literacy rate is low compared to the national average of 65% and the 0–6 years' sex ratio has declined alarmingly over the last decade. There are a total number of 2,76,543 cultivators in Jalna District operating 6,35,671 hectares of land.

3.2.1 Profile of case study villages in Jalna

Three clusters of three villages each were selected for three different blocks in Jalna for field work. The blocks from which these villages were selected were Badnapur, Jafrabad and Bhokardan.

The nine villages selected were Asarkheda, Nivdunga, Dongaon, Kadegaon, Malegaon, Warudi, Palaskheda Pimple, Thote Pimpalgaon and Barav Pimpalgaon (Fig. 3). These villages were organized into three different clusters on the basis of geographic location. Table 3 presents the selected case study villages, grouped in different clusters within the three selected blocks in Jalna.

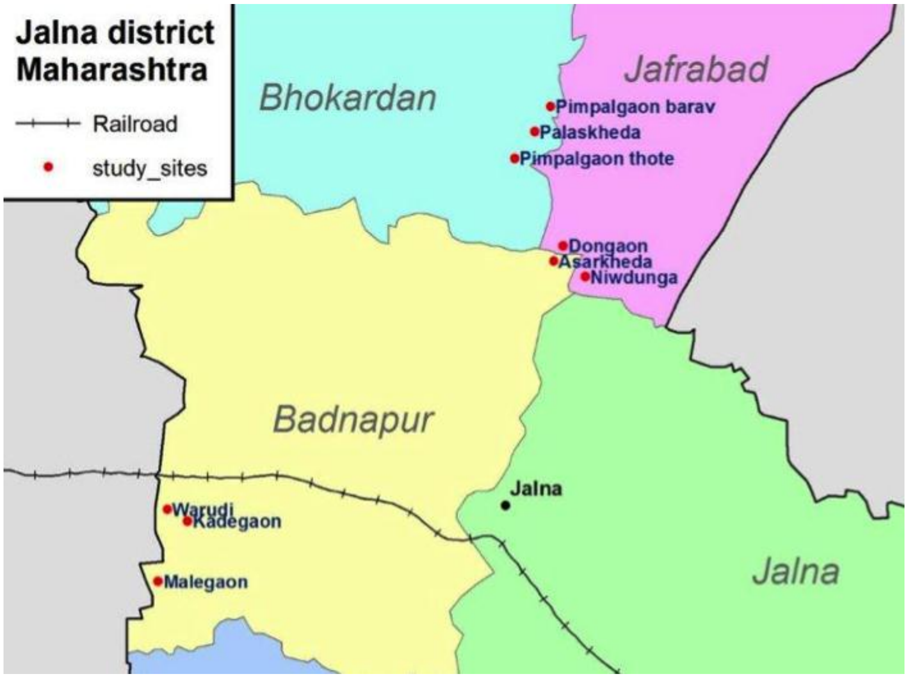


Figure 3: Case study villages in Jalna

Of the village clusters, Cluster I is closest to the Jalna–Aurangabad highway and had better connectivity than the villages in the other two clusters. Cluster III is the farthest from Aurangabad. Despite various differences in resource distribution and societal, demographic and economic structure of these clusters, there was one common aspect that did not vary. In all of these clusters, cotton was the primary kharif crop under cultivation.

Badnapur block has the least area while Bhokardhan is the largest of the selected case study blocks. However, despite having the lowest percentage area within Jalna, among the three selected blocks, the percentage coverage with respect to the district in miscellaneous tree crops and groves is highest in Badnapur (Figure 4). This could be due to the fact that the villages in the Badnapur cluster not only have a lot of land under permanent irrigation (borewells and canals) but also have a large share of land under seasonal irrigation (from open wells). As a result, they are able to grow perennial fruit crops, which constitute the tree and grove acreage within the block.

Table 3. Cropping pattern in field study villages

Cluster number	Block/s	Villages	Kharif crops	Rabi crops	Summer crops /Perennial crops
I	Bhokardan	Thote Pimpalgaon Barav Pimpalgaon Palaskheda	Cotton Soybean Maize Green gram	Sorghum Wheat Bengal gram	Vegetable
II	Jafrabad and Badnapur	Dongaon Nivdunga Asarkheda	Cotton Soybean Black gram Green gram	Sorghum (Jowar) Wheat Vegetable	

			Pearl millet (Bajra) Maize	Bengal gram	
III	Badnapur	Kadegaon Malegaon Warudi	Cotton Pearl millet Maize Pigeon pea (Tur)	Sorghum Wheat Gram	Sweet orange Pomegranate

Of the villages, Asarkheda has been able to make significantly greater progress in increasing the area under seasonal irrigation through watershed development activities as compared to the other two villages in Cluster II. The villages in this cluster also have contract farming for seeds of horticultural crops due to their proximity to the seed companies in Jalna.

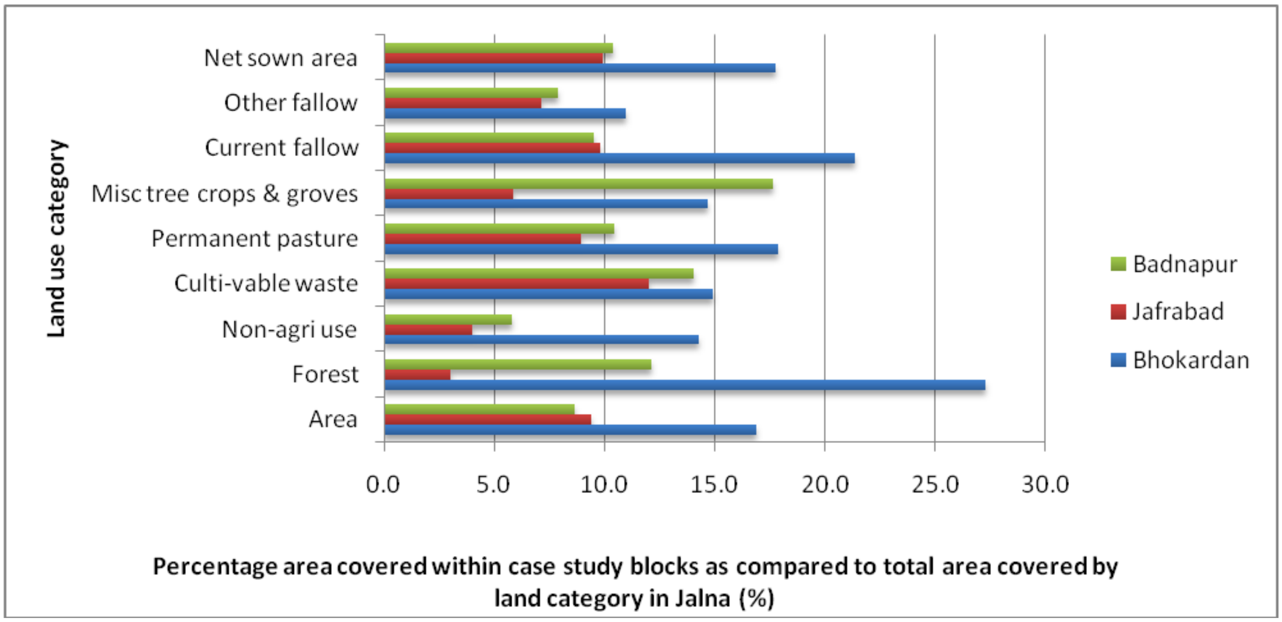


Figure 4: Percentage area covered as compared to total area covered by land use category in the selected case study blocks
Source: Data from Comprehensive District Agriculture Plan

In contrast, Bhokardan village cluster has little access to permanent irrigation, relatively low area under seasonal irrigation and no summer crops.

4 Methodological approach

The EVA study had a strong emphasis on understanding the present status of vulnerability in the region through information available from recognized secondary data sources. The study also tried to validate and add to the existing information through recording local perceptions from decision makers, practitioners and actors at the local level, on primary information on perceptions of change from the field as well as secondary data and information gained from recognized sources. Based on the same approach, the outputs from this work package were informed by secondary data and analysis as well as using primary information gathered through participatory approaches.

Drylands in the Maharashtra state face combined stress due to biotic and abiotic factors. This activity sought to focus largely on the biotic aspects of exposure to extremes, which is a combination of many factors including persistent droughts and highly variable rainfall, terrain characteristics, soil conditions, etc. Most of the parts of the district are occupied by basaltic lava flows of the Deccan traps overlain by alluvial deposits, which serve as fertile land for agricultural activities. The terrain characteristics and impacts on surface and ground water reserves were captured through field consultations and secondary information resources.

Cropping patterns and productivities and weather suitability for major crops was studied through the use of secondary literature and a mix of field learnings and institutional discussions. Land use change, cropping patterns and other socio-economic pressures were also studied to assess the effect it may have on climate sensitivities and adaptive capacities in regions exposed to extremes.

4.1.1 Secondary data analysis

National, regional as well as local information sources were utilized to obtain data to improve understanding of the occurrence and exposure to extreme events like droughts in the state to be able to discuss the occurrence and impacts at the case study site. EVA WP 1outputs on climate change projections were used to define future extremes and sensitivities in the region.

Using satellite imageries and with the help of GIS land use characteristics of the Marathwada region was studied. Land use and land cover change in future was also assessed using a modeling-based approach. Secondary data and assumptions on drivers of change have been used for this purpose.

Using secondary data trends in productivities of important crops were studied to gain an improved understanding on the sensitivities of crops to climatic conditions. Data was collected from various government departments including the agriculture department, planning department, department of water resources, the Indian met department and the Badnapur research station.

4.1.2 Participatory methods and tools

Participatory approaches have proven very useful in extracting information on a collective as well as individual basis on issues of common interest (Vovinov and Bosquet, 2012). The varied tools and techniques that can be used under this approach allow for discussion, consensus building and collective thinking and provide a larger gauge of institutional memory and evidence to inform research.

As in the case of the EVA study, the focus on the issue of extreme events like droughts was of common interest to groups and individuals alike. A mix of participatory methods and a mixed selection of participants who were chosen for interaction under specific methods helped to inform about common understanding of the events and their causes as well as varied perspectives of individuals from different backgrounds on the causes and history of the same events.

Models of interaction such as **group discussions** and **key informant interviews** with individuals helped in building an understanding rooted in combined local perceptions. A combination of such techniques allowed for not only a richer understanding of circumstances but also helped remove biases that are sometimes created in perceptions gained from group discussions with skewed participation of attending participants in vocalizing thoughts in an open forum, to a certain extent.

The field activities in the case study sites were conducted over a period of two years 2012 and 2013, during one of which (2012) Jalna was facing the worst drought in the past 40 years. In the following year of fieldwork, the case study site, Jalna District received good rainfall, which presented a contrasting picture and stimulated re-evaluation of existing conditions through tools like **transect walks** across the selected case study villages and surrounding farmlands. This was useful to understand existing land use patterns and resource distribution and generating further discussion on the dynamics of interaction of these elements change with the advent of extreme conditions.

While extensive discussions were conducted with members of the community at the local level, **key informant interviews** with officials in relevant departments at the district and the block level were also conducted. This exercise was useful in supporting as well as validating perceptions gained from the community interactions. In these discussions, key line departments that are directly responsible for recording status of local resources and situations were contacted. This not only helped in understanding evolution of present conditions from past decisions but also provided an insight into various factors that shape local perceptions. Through discussion with these line departments, processes of obtaining secondary data for further analysis were also discovered.

5 Exposure to extremes in Jalna

5.1 Frequency and Intensity of Drought Occurrence in Jalna

The IPCC in its Special Report on Extreme Events (SREX, 2012) defines droughts as ‘A period of abnormally dry weather long enough to cause a serious hydrological imbalance’ while The Manual for drought management (Government of India, 2009) describes drought as a temporary seasonal aberration, different from seasonal aridity, which is however a permanent feature of the climate. This absence of a universal definition distinguishes droughts from other extreme events in being defined in relative terms as opposed to absolute condition, depending on the context. The factors that define a drought are its geographical spread, duration and intensity. On the basis of their impacts, droughts have been classified in literature under three categories—meteorological drought, hydrological drought and agricultural drought.

Meteorological droughts usually precede the other types of droughts and are characterized by a deficit in precipitation from the expected precipitation in a specific region over a prolonged period. An area can be said to be facing a meteorological drought if the area receives less than 25% of its long-term average rainfall in a season. Deficits in surface and groundwater resources that leads to inabilities in meeting basic and specific needs is termed as a hydrological drought wherein water demand diminishes existing reserves.

Typically triggered by meteorological and hydrological droughts, agricultural droughts occur during inadequate rainfall and thereby soil moisture in the cropping season. It is the period when biophysical impacts of meteorological and hydrological droughts cause crop stress, as the crop system is unable to sustain the crops water demands. Therefore, agricultural drought can be related to variable susceptibilities of crops during varied stages of its development (ibid.). As the EVA case study site primarily consists of agricultural land with large dependence of local livelihoods on this economic activity, droughts in this case significantly relate to agricultural drought.

In the drought-prone region of Marathwada in Maharashtra, droughts have been a relatively regular occurrence in the region, however with varying severity. Figure 5 shows the historically significant drought years between 1970 and 2000 for the state of Maharashtra as a whole. The drought of 1972 is regarded as a particularly severe drought with only the recent drought of 2012 measuring up in terms of intensity and coverage within the state. While the drought of 1972 is widely remembered due to its severity, the other droughts that have occurred in the interim (between 1972 and 2012) did not come forth during community discussions. Very few individuals remembered the droughts of 1984–85 and some remembered the droughts of 2004. The reasons for this might be that the interim droughts were not as severe and, therefore, paled in comparison to the very recent drought of 2012. It is also possible that since the coverage of each of the droughts may have been different within the state and also within Jalna District, the responses vary based on the locations of the respondents’ farmlands. For example, in the 2004 drought, only Ambad and Ghansavangi blocks of Jalna District were affected.

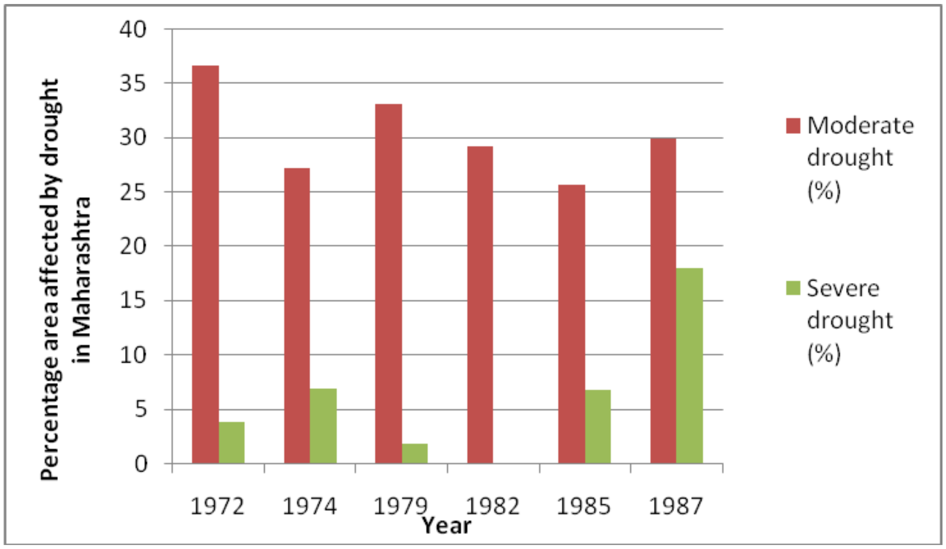


Figure 5 : Years of drought in Maharashtra in the last thirty years (1970- 2000) and % area affected

A study done by IMD, Pune (2010) showed that the probability of moderate and severe droughts in Jalna from 1901 to 2000 was 14% for moderate droughts and 2% for severe droughts. The only drought that is collectively remembered from that time period is the drought of 1972. Figure 6 shows the historical timeline of droughts as documented in literature. The severe years are marked as red arrows and the moderate drought years are marked in green arrows. The years that were cited as drought years throughout the field discussions at the community level in Jalna have been highlighted in
orange.

Figure 6: Historical timeline of drought years in Maharashtra (1970-2012)

Looking at the rainfall in the area, Figure 7 presents a plot of the mean monthly rainfall in the months of June, July and August from 1971 to 2002. The figure shows the low rainfall received in the year 1972 which shows a correlation with the severe drought of 1972 with the mean monthly rainfall of less that 100mm rainfall in July and August months. Similarly, in the years 1974 and 1979, which were recorded a moderate droughts, the mean monthly rainfall for the initial monsoon months is less than 150 mm per month.

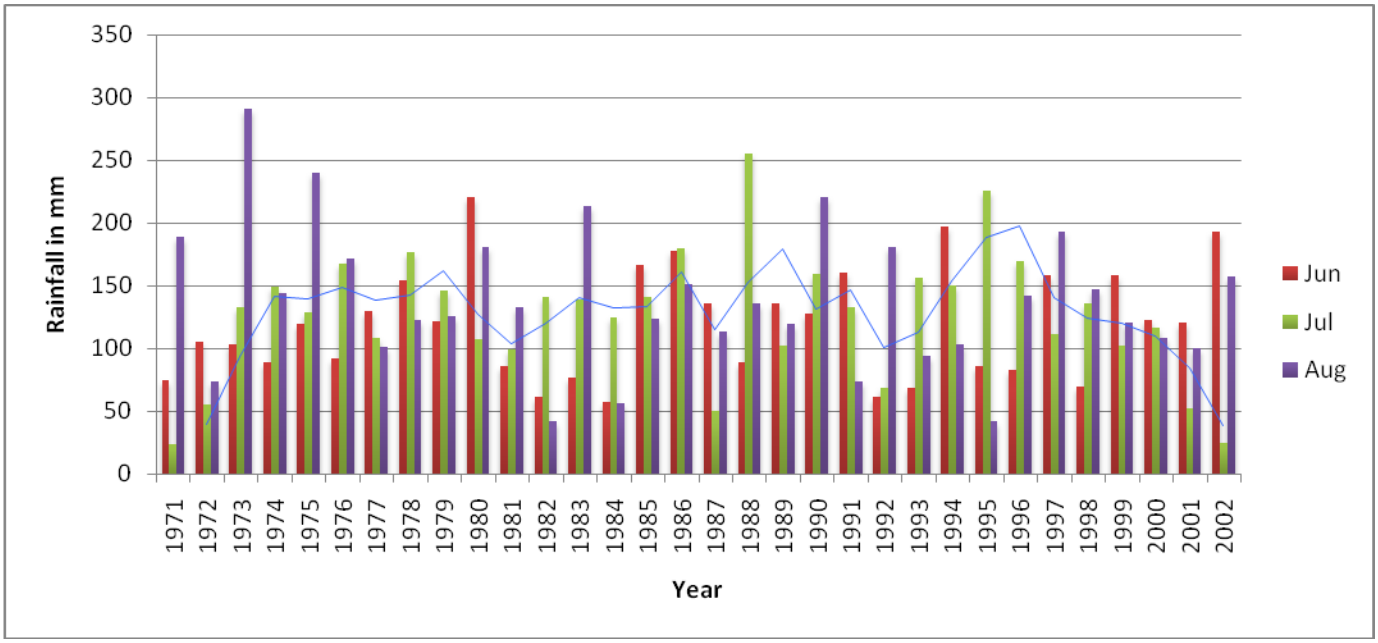


Figure 7 Graph showing monthly mean of rainfall in the monsoon months (JJA) from 1971 to 2002
Source: India Water Portal

In the three decades before the year 2000, there was only one severe drought in 1972. Beyond the year 2000, the droughts in the region have become more frequent with 3–4 severe to mild droughts recorded in the past 13 years in the case study area. Among them, the drought of 2012–13 was the most severe with several blocks in the Jalna District affected. In the drought assessment done by the Government of India during the months of June and July in 2012, the rainfall deficit in Jalna was found to be having a deficit of 51% (Fig. 8; Block 14: Jalna) (NADAMS, 2012).

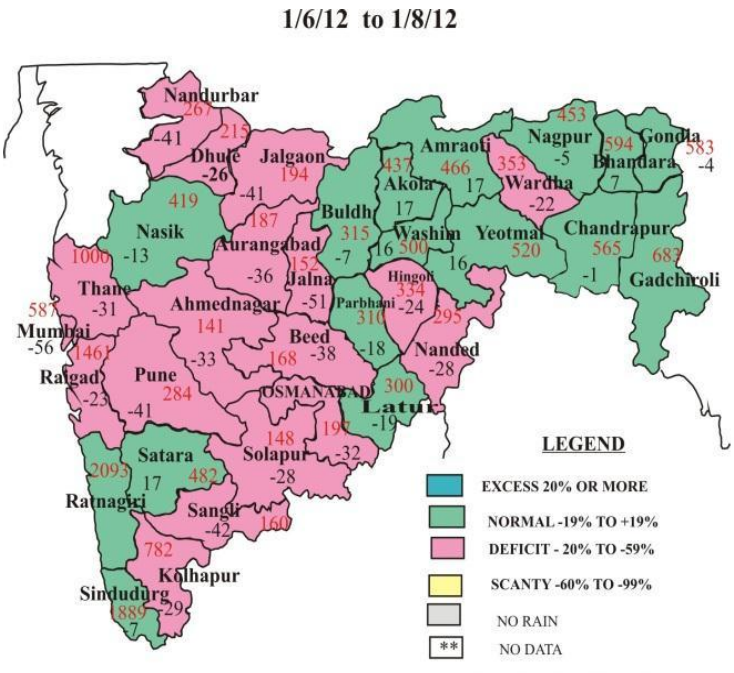


Figure 8: Seasonal Rainfall for June and July; Jalna - Block 14 (NADAMS, 2012)

This decreased rainfall had a direct impact on the water available for agriculture. This further led to lower crop productivity and buttresses into several other impacts covering different aspects of the local ecosystem. In Figure 9, a significant reduction in vegetation vigour in Jalna is observed. Moreover, the extent of decline in vegetation vigour in the EVA case study blocks of Bhokardhan, Jafrabad and Badnapur is much more as compared to other talukas of Jalna District (See top portion of Block 14 in the map).

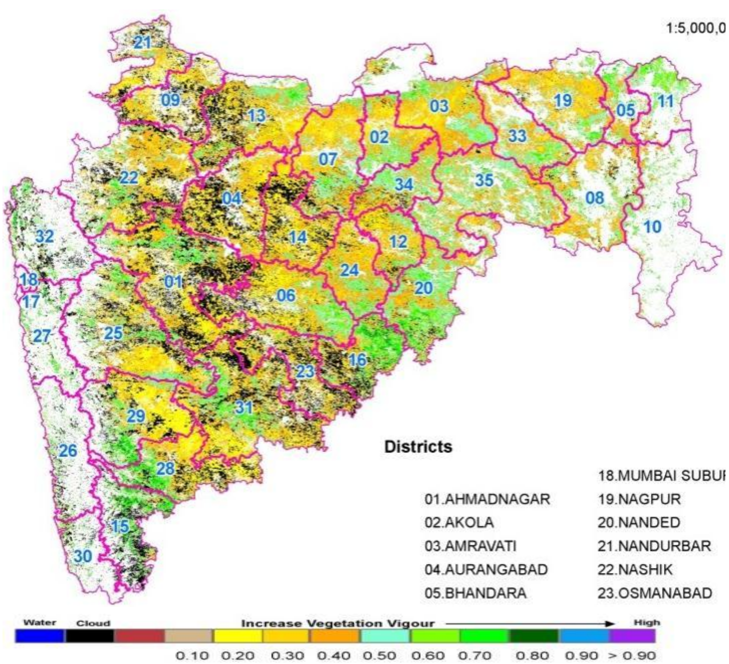


Figure 9: MODIS based Normalized Difference Vegetation Index (NADAMS, 2012)

Therefore, while it may be reported that certain districts within the state are affected by drought, the degree of impact of the drought may be differential within the blocks of the district.

Figure 10 demonstrates the variability in rainfall received by the different blocks from 2004 to 2011 The figure not only shows the variability in rainfall received over the years but also the variability within the blocks for rainfall received within the same year. The case study blocks of Bhokardhan, Jafrabad and Badnapur (Fig. 11) also clearly show this distinction between the amount of rainfall received by each block in respective years. For example, in 2007, Badnapur block received the highest rainfall while Jafrabad block was close behind. However, Bhokardhan block received a lower than average rainfall for that year.

Figure 10: Variation in annual mean rainfall received in case study blocks from 2004 to 2011.

5.2 Expected extremes in the future

Based on the outputs for extremes in the future from EVA WP 1; it can be concluded that changes are expected to happen in both temperatures and rainfall. While the study presents an overall increase in percentage precipitation over the case study region, it also indicates an increase in the probability of high intensity rainfall events in the 2030s with a decline and again an increase in the 2050s. Given an increase in the rainfall and extreme rainfall conditions, the number of rainy days are on a decline, indicating more interspersed dry spells in the region.

In terms of temperature changes, the study shows a steady increase in minimum temperature from 1.48°C–3.38°C from 2030s to 2080s and a 1.06 °C –2.56°C increase in maximum temperature from the 2030s to the 2080s, respectively. In addition to this, the percentage of warm nights is likely to increase over Jalna to a larger extent than neighbouring areas like Vidarbha. This is likely to cause more heat waves in areas in and surrounding Jalna. Further elaboration on the nature of change has been highlighted in the WP 1 report.

6 Terrain features and its effect on recharge and runoff

Surface runoff is one of the main components of the terrestrial hydrological cycle along with precipitation, which determine water supply for livelihoods and upkeep of natural resources that constitute an ecosystem. Therefore, changes in precipitation patterns resulting from climate change, along with terrain characteristics, would also influence surface runoff. As variation in surface runoff may also contribute to extremes like floods and droughts and determine future water resource issues, it is important to consider the impact of future climate scenarios on surface runoff in the Marathwada region.

6.1 Surface Runoff modelling

The Soil Conservation Service (SCS) method developed by United States Department of Agriculture (USDA, 1972) was used to compute surface runoff for Marathwada region in the state of Maharashtra. The SCS method is a versatile method and a widely used procedure to estimate volume of direct surface runoff and also relatively easy to use with minimum data requirements (Chatterjee et al., 2001; Bhuyan, et al., 2003; Elhakeem and Panicolaou, 2009). The model takes into account various properties of the watershed such as soil characteristics (texture, effective depth, infiltration rate, permeability, etc.), land use, rainfall (antecedent soil moisture condition) and basin coefficients. Basin coefficient, also known as runoff curve number (CN), represents the runoff potential of a particular land cover soil complex. This aim of this study was to provide spatial distribution of mean surface runoff for baseline (1990s) and projected scenarios (2030s, 2050s and 2070s).

Figure 11: Marathwada region in Maharashtra

Population explosion has created regional imbalances in the available water resources. Scarcity caused due to these imbalances makes it important to have proper planning and management of water resources. Thus, to understand the water scarcity problem at a place, detailed analysis of the relationship between the precipitation and runoff is highly imperative.

6.2 Data

Data used to perform the surface runoff modeling for the current study include predicted rainfall data as provided by the assessments from EVA WP 1 for the baseline (1990s), 2030s, 2050s. Percentage of clay and soil texture are derived from Harmonized World Soil Database (HWSD) to prepare Hydrological soil Group (HSG). The four types of soil texture found in Marathwada region are – sandy loam, sandy clay loam, loam and clay. Land Use Land Cover (LULC) used in this study is derived from SPOT vegetation data.

6.3 Methodology

Computation of surface runoff requires several steps to be taken. First, the Hydrological Soil Groups are prepared on the basis of percentage of clay and soil texture for the soils of Marathwada region and is classified into four types, viz., A, B, C, and D. As mentioned, SPOT data is used to prepare LULC maps.

Further, LULC and HSG maps are combined to generate Hydrological Soil Cover Complex (HSCC). On the basis of various combinations of LULC and HSG, 20 HSCC units are made for Marathwada region.

On the basis of established curve numbers for different combinations of HSCC, a base CN map is prepared for AMC-II (Antecedent Moisture Condition) for the rainfall events of the monsoon season, viz., June, July, August and September months. The AMC is an indicator of watershed wetness and availability of soil moisture storage prior to a storm. The SCS method has developed criteria for adjusting CN according to AMC. The criteria are based on the total rainfall accumulated in a five-day period prior to a storm event. Three levels of AMC are AMC-I for dry, AMC II for normal and AMC-III for wet conditions.

Table 4. Classification of antecedent moisture conditions

AMC	**Total 5-days Antecedent Rainfall (mm)**	
	Dormant Season	Growing Season
I	<12.7	<35.6
II	12.7–27.9	35.6–53.3
III	>27.9	>53.3

In our assessment, we have chosen the extreme events for all the four months of the monsoon season. For each month, six to eight events are selected on basis of maximum, minimum, mean and total amount of rainfall. On the basis of total accumulation in the preceding five days of these selected events, AMC is assigned. Most of the events fall in the category of AMC-III with very few occurring in AMC-II.

CN (AMC-II) is decided for each HSCC unit and then modified for AMC-III using the following formula

$$CN\ (AMC-III) = 23 \times \frac{CN(AMC-II)}{10+0.13 \times CN(AMC-II)}$$

(1)

Rainfall runoff (Q) map is prepared using the following equation modified for Indian condition (NIH, 1972)

$$Q = \frac{(P-0.1\times S)^2}{P+0.9\times S}$$

(2)

Where, P is the storm rainfall in mm and S is the maximum potential retention in mm, given by

$$S = \frac{25400}{CN} - 254$$

(3)

The methodology for surface runoff estimation is shown in Fig. 11. The same methodology is followed for future projected scenarios.

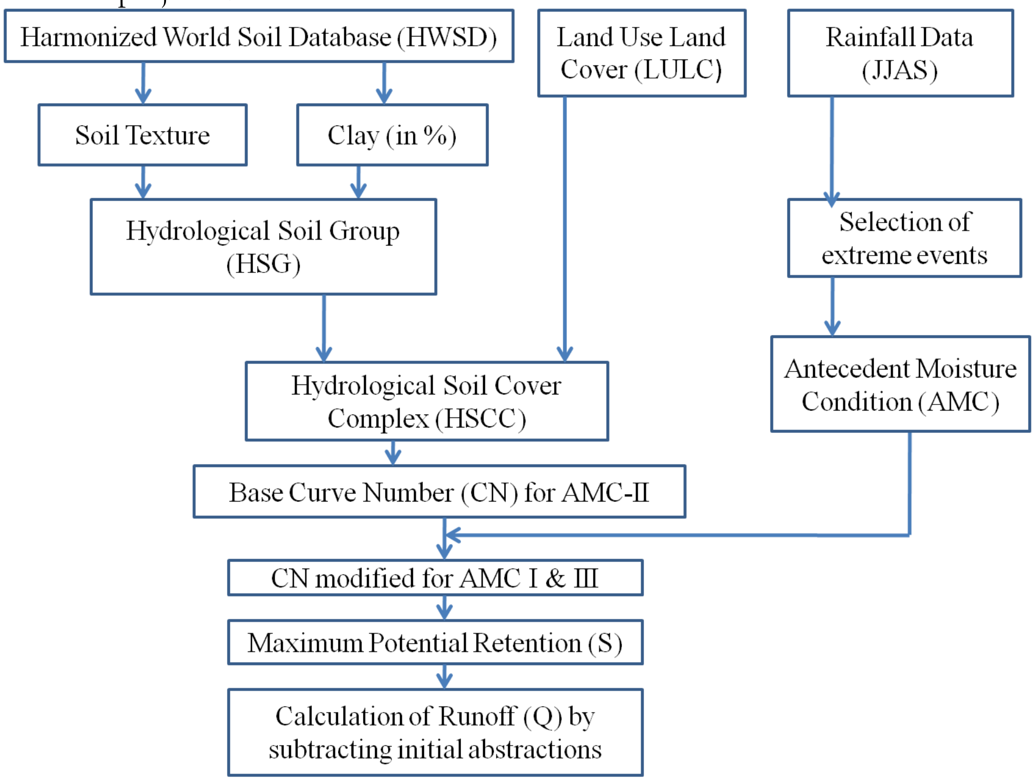
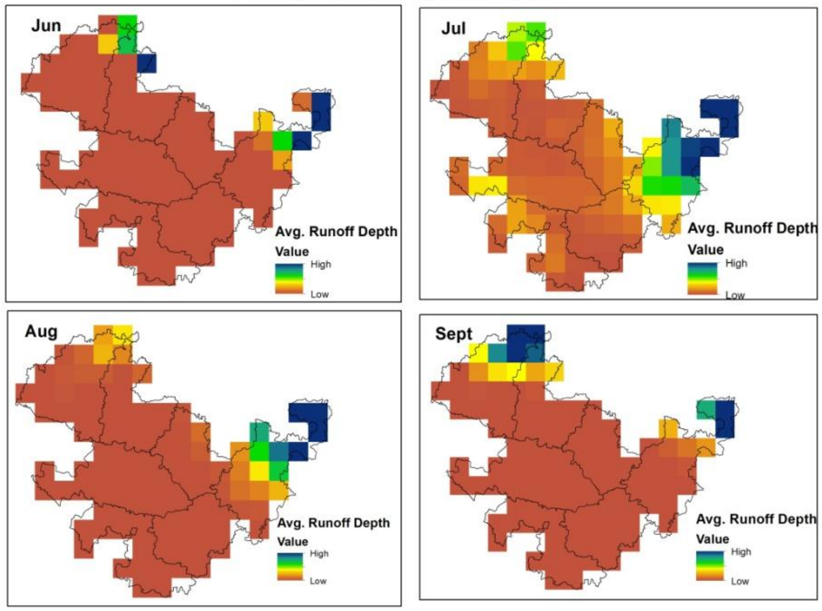


Fig. 11. Methodology used to compute surface runoff

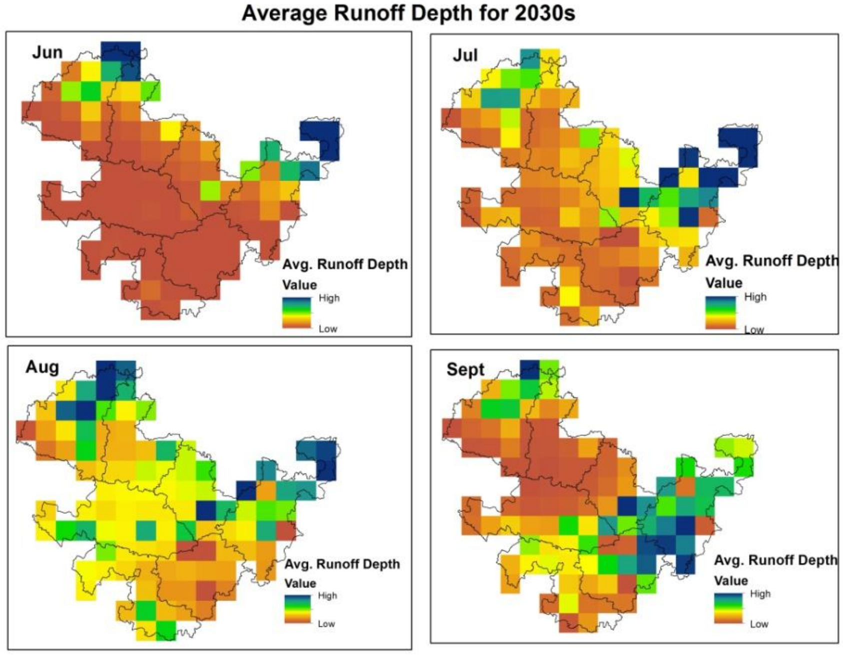
6.4 Result and Discussion

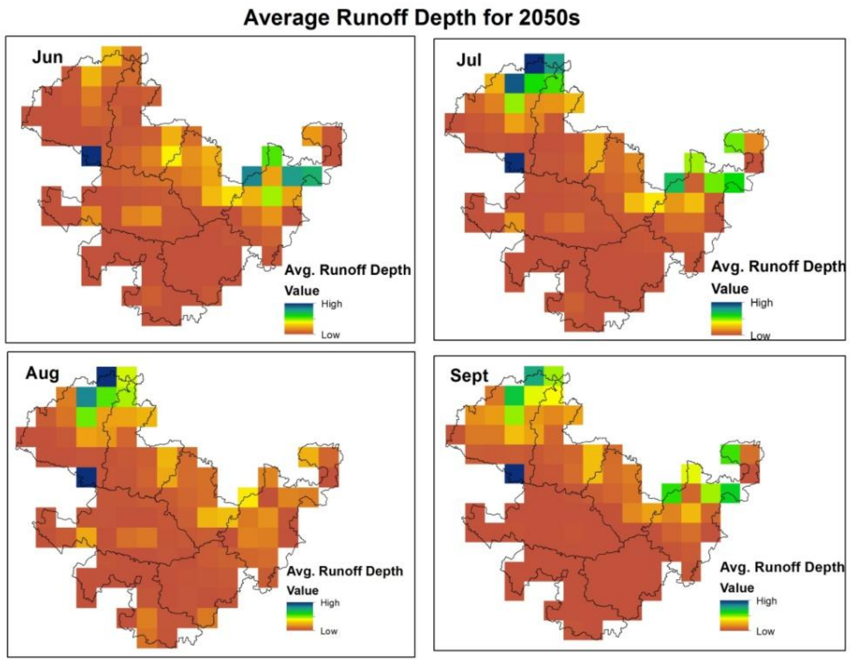
Spatial distribution of average runoff depth calculated for the monsoon months in the study area is shown in Figure 12.

Average Runoff Depth for 1990s



Average Runoff Depth for 2030s





*units in $Kg/m^2/day$

Fig.12. Average Runoff Depth in different time periods (Baseline 1990s, 2030s, 2050s, for Marathwada region, Maharashtra state.

In the baseline period (specify period), surface runoff in the Marathwada region is highest in Nanded District followed by Aurangabad District, for all the monsoon months. Maximum surface runoff is observed in the month of July. Surface runoff shows a gradual increase in 2030s and a decline in the 2050s in the respective areas as compared to the baseline. Thus, based on this study, overall in the Marathwada region, the surface runoff in the future is likely to increase.

In the case of Jalna, the changes in surface runoff in the 2030s and 2050s are most pronounced in the northern areas of district near the Ajanta and Satmala ranges and in the southern areas of Jalna.

7 Land use and land cover change

7.1 Introduction

Land use and land cover change (LULCC) analysis seeks to assess the changes in structure and composition of land use over space and time. These changes describe the underlying physical, biological and socio-economic forces. LULCC is in a continuous state of change and the causal factors of these changes are natural as well as anthropogenic.

Increasing human population has resulted in increased conversion of natural landscapes into human-dominated landscapes resulting in land use land cover changes (LULCC) (Turner, et al., 2007; Sarma, et al., 2008; Giriraj, et al., 2008). Deforestation is one of the major aspects of LULCC with well-known impacts on biodiversity and other natural resources (Mayaux, et al., 2005; Turner, et al., 2007; Lele, et al., 2010). Hence, accurate and timely information at regular intervals on Land Use and Land Cover (LULC) is of utmost importance for understanding dynamics of the processes induced by human interventions.

Changes in land use, derived from remotely sensed data, can be related to landscape and location attributes. A model can be established to describe the relationship between the dependent variable (land cover change) and independent location variables (Lambin, 1997). Then, the model can be used for predicting the spatial patterns of land use land cover changes (Giriraj, et al., 2008). Such models can provide a better understanding of the factors that drive land cover changes, they can generate future land use land cover scenarios, and they can support the design of policy responses to changes (Lambin, 1994). Land use land cover change is associated with multiple factors. The relationships between change and its driving factors can be very complex and are often non-linear (Mas et al., 2004), requiring an appropriate modeling approach that accounts for such complex non-linear relationships. Such changes can be predicted using empirical models and simulation models (Lambin, 1997). One of the ways could be the use of multi-layer perception neural network with an integrated Markov transition change model approach for spatio-temporal dynamic modeling of LULCC (Eastman, 2009).

Maharashtra state surrogates one of the biodiversity hotspots in India and is rich in thousands of endemic species. Apart from this the state also provides fertile land for agricultural production and also supports various socio-cultural land use patterns including wide-ranging catchments and watersheds. The area is witnessing rapid land cover changes due to increasing developmental activities, apart from the threats of poaching of animals and overexploitation of forest products, leading to habitat degradation and fragmentation, habitat loss, ultimately affecting the ecological processes. It is, thus, essential to carry out continuous monitoring to understand the pattern of changes, ecological health and the underlying factors for the changes. Field-based techniques can be time consuming, laborious and costly, due to remote and inaccessible terrain conditions of the area. Gathering data for several continuous years is also not possible by these techniques. Integration of remote sensing and GIS offers continuous observation of an area at spatial and temporal scale with more accuracy and cost-effective manner. Thus, geo-spatial tools have emerged as a promising tool

for undertaking various mapping, monitoring and inventorying activities over space and time (Munsi, et al., 2009).
This work attempts assessing the pattern of land use land cover dynamics in Marathwada region over space and time. Explanatory variables (that can possibly explain the changes in the area) and the LULCC maps prepared were further used to predict the future land use land cover scenario.

7.2 Approaches for studying land use land cover dynamics

Satellite remote sensing provides a synoptic view of land use and land cover and their condition on real time basis and has played a pivotal role in generating information about forest cover, vegetation type and land use changes (Houghton and Woodwell, 1981). After the launch of commercial remote sensing satellite systems, rapid analysis of the large as well as comparatively inaccessible areas became an easy task for frequent monitoring and assessment. The advancements in the field of geoinformatics were tested for mapping deforestation and modeling (Kerr and Ostrovsky, 2003; Wright, 2005). In South Asia, national-level attempts have been made to map forests on the scale of 1:1 million or 1:250,000, using visual interpretation of satellite data. The standardization of ground sampling methods, understanding of spectral and temporal responses of vegetation, coupled with advancements in digital image processing techniques have brought about a profound acceptance of the application of satellite remote sensing data in tropical forest mapping (Lele, et al., 2005).
Use of remote sensing also helps to get information about the natural phenomenon and human activities in real-time, in a fast and cost-effective manner as well. The large area land use land cover studies particularly after 1980s spanned a range of geographic places and spatial resolutions. Daily coverage of NOAA-AVHRR, SPOT-Vegetation, Terra-MODIS and other similar sensors have proven very effective in the understanding of large-scale studies.

With reference to India and studies on status of forest cover, use of satellite remote sensing was initiated by National Remote Sensing Agency (NRSA). Since 1983, the task of forest cover mapping and monitoring has been carried out by Forest Survey of India (FSI), once in every two years to prepare National Forest Vegetation Map (NVM), making use of satellite remote sensing. Also remote sensing studies have been need for preparing thematic maps at the national level. Researchers have prepared land use land cover database using IRS WiFS (Joshi, et al., 2006), SPOT Vegetation (Agarwal et al., 2003), IRS AWiFS (NRSC, 2006), IRS LISS III (NRSC, 2011) and now attempting to prepare such database using IRS LISS IV.

7.3 Approach for land use land cover mapping

7.3.1 SPOT Vegetation – data used for temporal mapping

To meet the primary objective of uniform mapping of the entire region, we relied on data from the SPOT-VEGETATION (VGT) Earth observing system. The VGT sensor onboard the SPOT-4 satellite delivers daily acquisitions with a swath width of 2200 km and a spatial resolution of about 1 km. The sensor records data from four channels, located in the blue (0.43–0.47 μm), the red (0.61–0.68 μm), the near-infrared (NIR, 0.78–0.89 μm) and the short-wave infrared (SWIR, 1.58–1.75 μm) range of the electromagnetic spectrum. In addition to daily acquisitions (S1 products), 10-day composite images (S10 products) were operationally generated based on a pixel selection by the maximum Normalized Difference Vegetation Index (NDVI). The combination of spectral range, spatial resolution and exceptional geometric fidelity with a pixel-to-pixel registration across different dates within 500 m (VITO, 2004) are forward to be well suited to regional vegetation studies. Dataset of year 1999 and 2009 was used to map and monitor the temporal changes.

7.3.2 Data pre-processing

The SPOT Vegetation S10 (VGT-S10) data products were downloaded from http://www.vgt.vito.be/. VGT-S10 products (ten-day synthesis) and were compiled by merging segments (data strips) acquired in ten days. All the segments of this period are compared again pixel by pixel to pick out the 'best' ground reflectance values. These products provide data from all spectral bands, the NDVI and auxiliary data on image acquisition parameters. The data is corrected for system errors (error registration of the different channels, calibration of all the detectors along the line-array detectors for each spectral band) and resampled to predefined geographic projection. Auxiliary data supplied with the products allow users to process the original reflectance values using their own algorithms. The pixels selected for the syntheses are based on the selection of the maximum NDVI value, to ensure coverage of all landmasses worldwide with a minimum effect of cloud cover. The pixel brightness count is the ground area's reflectance (corrected for atmospheric effects); pixels in the sea area are set to 0. The data is procured in the Hierarchical Data Format(HDF), is a multi-object file format 'self describing' for sharing scientific data in a distributed environment (http://www.vgt.vito.be/).

7.3.3 Vegetative indices

NDVI is one of the band ratios (Rouse et al., 1973) that has been shown to be highly correlated with vegetation parameters such as green leaf biomass and green leaf area and hence is of considerable value for vegetation discrimination.

NDVI = (Infrared–Red)/(Infrared+Red)(1)
Moreover, it reduces variation due to surface topography (Holben and Frasher 1984) and compensates for variation in radiance as a function of sun elevation for different parts of the scene, which is highly valuable in continental studies. To demonstrate the utility of SPOT vegetation data for monitoring vegetation status at the regional scale, random temporal plots are selected and analysed for the NDVI values. The maximum NDVI is calculated to determine the index of greenness of the vegetation at the time of peak growth season. It is calculated to represent the maximum foliage cover in the study period. It was re-scaled from 0 to 255, i.e., as 8-bit data for using it for classification.

$NDVI_{max}=MAX\ (NDVI_i \ldots NDVI_n)$ (2)
Townshend et al. (1987) have discussed in detail the utility of NDVIs and its matrices while performing biome-level classification of African and South American continents using NOAA AVHRR data of different seasons.

7.3.4 Image classification

Analysis of the satellite sensor data was carried out using various digital analytical procedures. For the classification of the satellite sensor data, stack of maximum NDVI dataset was taken. The mapping step involves using unsupervised classification based on the K-means algorithm run on monthly NDVI maximum value. Each cluster was assigned a preliminary cover type label taking care of the spatial pattern and spectral or multi-temporal statistics of each class and on comparison with ancillary data and extensive ground data. Ancillary data included descriptive land cover information, NDVI profiles and class relationships to the other land cover legends. Related 'single category' classes were then grouped using a convergence of evidence approach (Lillesand and Kiefer 1999). Some of the shadow area was put to the respective classes on the basis of extensive field knowledge. The unsupervised classification was followed by post-classification refinement for a coherent set of classes. On the final output, median filtering was carried out for image smoothing.

7.4 Predictive modelling

A multi-layer perceptron neural network (MLPNN) with a Markov chain model (MLPNN-M) was used to predict the forest conversions in the area. In general, two forest cover maps were derived (1999 and 2009) and used to predict a forest cover map for a third date. The prediction process can be characterized by the estimation of forest conversion potentials followed by the forest conversion prediction stage. For this, first, observed forest changes were used as dependent variables and spatial variables were used as independent variables to train the MLPNN and then estimate the forest conversion potential maps. Second, forest conversions were predicted using a competitive land allocation algorithm similar to the multi-objective land allocation (MOLA) algorithm. It looks through all conversions from host classes (that lose some amount of land) to the claimant classes (that acquire some amount of land from each host) based on Markov chain transition probabilities. The purpose of using the Markov chain is to determine the amount of change that may occur to some point in the future. A Markovian process is one in which the state of a land cover is identified by knowing its previous state and the probability of conversion from each state to another. After this, MOLA is used to allocate land for all claimants of a host class. These overlaid to produce a final prediction map. Detailed descriptions of the multi-objective land allocation algorithm can be found in (Eastman et al., 1995).

In this study, the several independent variables included are: (i) social agents of change, viz., proximity to road and proximity to settlement, (ii) topographic agents of change, viz., proximity to water, elevation, slope, aspect and dependent variable the change in the forest cover and land use in past more than a decade (1998–2005–2012). These social and topographic agents of change are derived by calculating the Euclidean distance between the pixels and the target layer. The nature of the association between observed forest changes and spatial variables was examined using Cramer's V coefficient (Eastman, 2009). A Cramer's value indicates a higher potential explanatory value of the variable; however, it does not guarantee a strong performance because it cannot account for the mathematical requirements and the complexity of the relationship. A high Cramer's value (close to 1) indicates that the potential explanatory value of the variable is good. A Cramer's value of about 0.15 or higher is useful while those with values of 0.4 or higher are good.

7.4.1 Land use land cover potential estimation

MLPNN was trained as a network with three layers: (i) input layer with the number of nodes equal to the number of spatial variables; (ii) hidden layer with the same number of nodes; and (iii) output layer with one node representing a conversion potential map. The neural network is trained to derive the appropriate connection weights between the input layer and hidden layer and between the hidden layer and the output layer for classifying unknown pixels. The training process starts by iteratively presenting input data to the network. The connection weights are adjusted during network training to minimize the difference (error) between the network output and the desired output.

We estimated the conversion potential maps for the prediction of forest cover in 2030, 2050 and 2070. These prediction maps of future land use land cover were used to identify areas vulnerable to conversions. MLPNN automatic dynamic training mode was followed where all training parameters were automatically changed to better model the data. A detailed account of the MPL training procedure can be found in (Ibid.).

7.5 Results and Discussion

7.5.1 Current status of land use land cover based on satellite imaging analysis

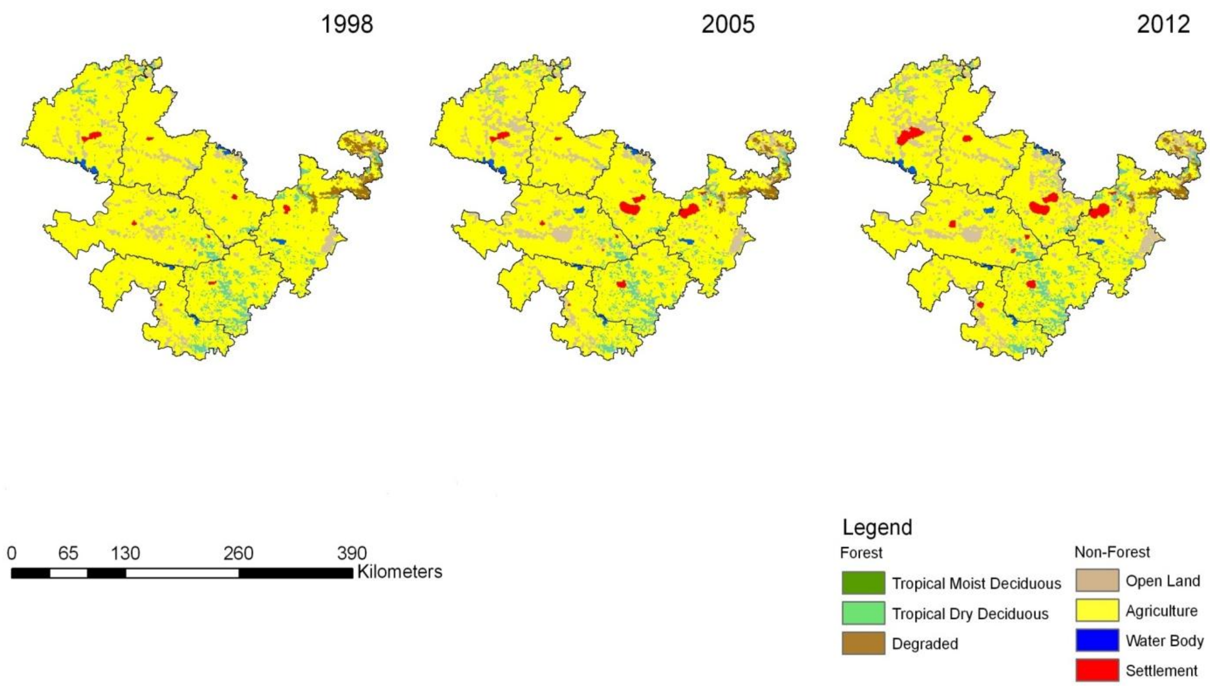


Figure 13: Land use land cover map for the Marathwada region(1998, 2005 and 2012)

7.5.2 Predictive modelling and changes in LULC in 2030s, 2050s and 2070s

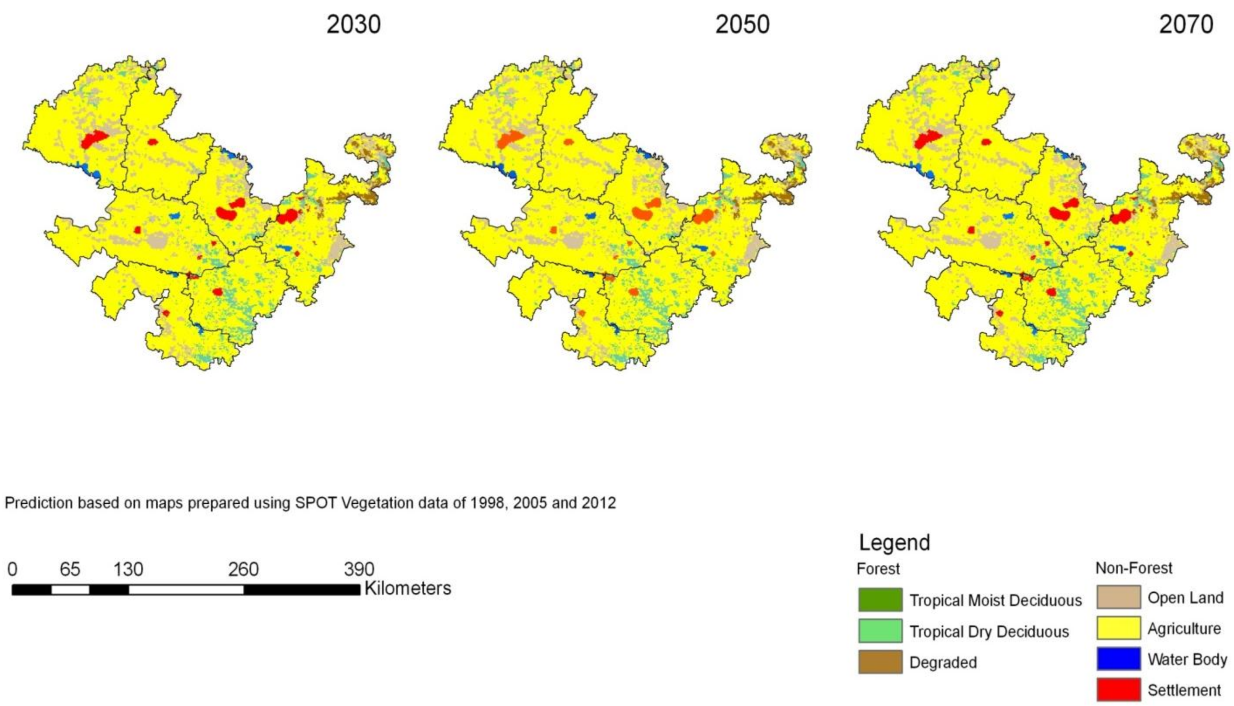


Figure 14: Land use land cover maps for the Marathwada region (2030, 2050, 2070)

Overall from 1998 to 2012, there is observable change in terms of expansion of settlements across the urban centres in the region. In addition to this, a marginal increase in open land is observed in the southern half of Jalna. Corresponding to this increase in open land, a marginal decrease in agricultural land is observed. Most of the land is and remains as agricultural land. The crop distribution and cropping pattern may, however, change.

8 Cropping patterns and productivity changes

8.1 Agriculture in Jalna District

Almost 85% of the land in Jalna is engaged in agriculture. Agriculture is the primary economic activity that governs economic and social well-being in the district. A wide variety of kharif and rabi crops are grown in the villages. Most parts of the district are cultivated primarily for cotton and sorghum. In addition to this, horticultural crops like sweet lime and pomegranates are also grown in some areas. The practice of intercropping is prevalent in many parts of the district.

Land utilization pattern of the Jalna District (Table 6) shows that net sown area constitutes 77% of the total geographical area of the district, indicating the overwhelming importance of agriculture to the district's economy. However, only 13% of the area is irrigated (Table 7), which indicates the climate sensitivity of agricultural livelihoods. Further, nearly half the landholdings are 'very small' and 'small' in size, i.e., less than 2 hectares (Figure 15). Low access to irrigation, combined with drought proneness, falling groundwater levels and uneconomic landholding size, reflect the vulnerability of the region to climate change.

Table 5. Land utilization statistics (in '00 hectares)

Tehsil	Area	Forest	Non-agri use	Culti-vable waste	Permanent pasture	Misc tree crops & groves	Current fallow	Other fallow	Net sown area	Gross cropped area	Cropping intensity (%)
Bhokardan	1307	18	79	51	36	5	85	75	1060	1212	114
Jafrabad	727	2	22	41	18	2	39	49	591	927	157
Jalna	1147	17	159	31	22	7	75	311	611	701	115
Badnapur	669	8	32	48	21	6	38	54	621	746	120
Ambad	1157	14	50	52	45	3	32	51	976	1045	107
Ghansawangi	1088	6	48	42	35	2	29	43	927	1107	119
Partur	754	1	87	18	11	1	37	38	590	868	147
Mantha	779	10	84	59	7	1	459	63	589	694	138
Total	**7727**	**66**	**553**	**342**	**201**	**34**	**398**	**684**	**5965**	**7300**	**122**

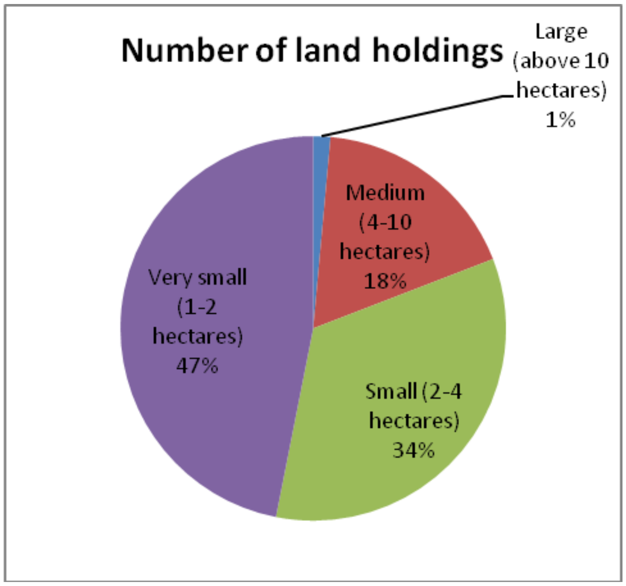
Source: Comprehensive District Agriculture Plan (2007–12), Jalna

Table 6. Irrigated area in Jalna District

Project	**Irrigated land (hectares)**
Large project (Jaikwadi)	36000
Medium projects	15975
Minor irrigation	9650

Lift and other	1544
Wells	36641
Total	99810 (12.93% of area)

Source: NBSSLUP (2005)



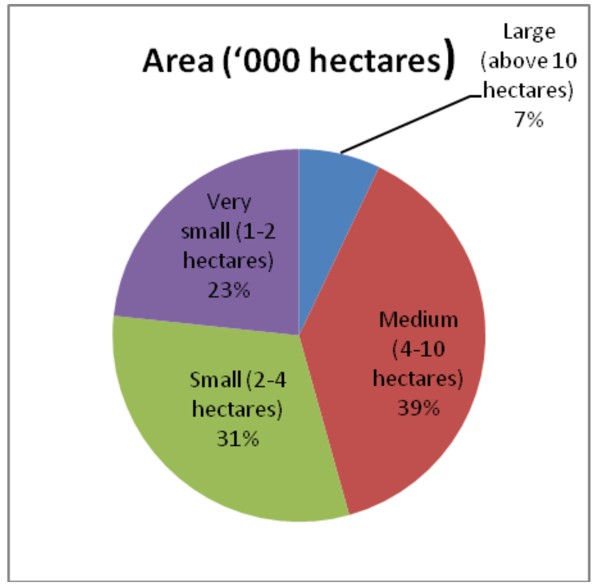
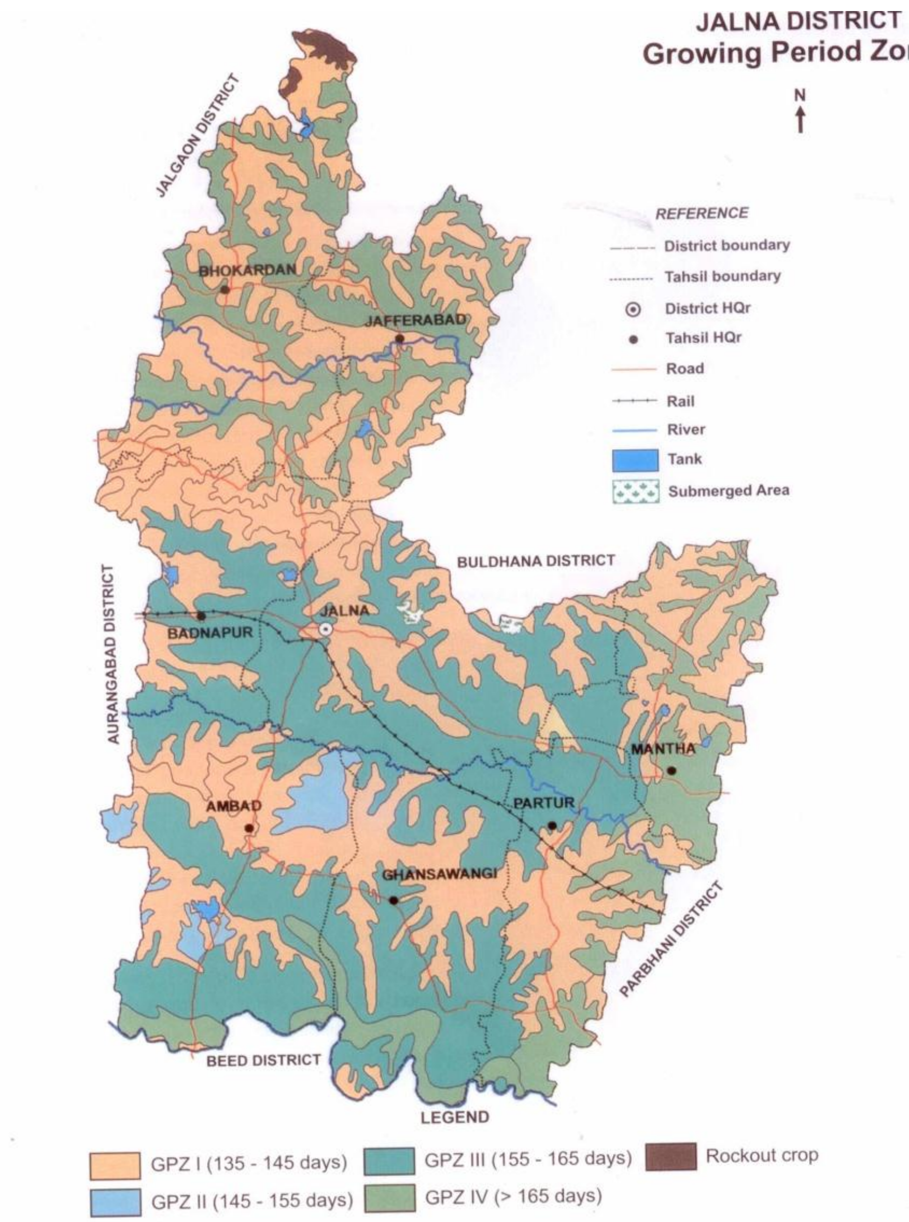


Figure15. Distribution of land holdings by size in Jalna district
Source: Comprehensive District Agriculture Plan (2007–12)

Figure 16 shows the growing period zones for various sub-regions of the district. The northern parts of the district (Bhokadan and Jafferabad tehsils) have a growing period of only 135–45 days, except in parts which lie along rivers, where the access to surface irrigation increases the growing period to more than 165 days. The former areas mainly grow pearl millet (bajra) and grasses, while the latter areas mainly grow cotton and pigeon pea (tur dal). Badnapur tehsil has large areas of land with a growing period of 155–65 days, which grow a combination of sorghum (jowar), cotton and safflower.

Figure 16. Growing period zones in Jalna



Source: NBSSLUP (2005)

8.2 Cropping pattern in Jalna

The cropping pattern in Jalna has seen a good amount of changes in time. A very small fraction of area was cultivated for rice in early 2000 which has slowly been replaced with other crops given that rice was not a suitable crop to agro climate, and over the years, the productivity rates of the crop kept falling. Bajra was a main crop amongst cereals in kharif in the late 1990s and early 2000 but this has been replaced by maize over a period of time. Overall, there has been a reduction in area under cereals, pulses and food grains. While in case of most crops the area has declined, area under rabi pulses has more than doubled in the last decade, over the period 2000 to 2010.

Instead, the growth of crops like sugarcane and cotton has grown over this period. While very small increase in area has been observed for sugarcane, cotton has expanded by 52% from 2000–2010. The boom in oilseed production over this period has largely been on account of growth of soyabean. Soyabean, for instance, has grown by 88% during the same period.[2]

There has been a strong policy move to diversify the cropping pattern in favour of oilseeds (Table 9). There is also a major emphasis in Jalna on fruit cultivation (particularly, mango and sweet orange) under the National Horticulture Mission and on pulses under the National Food Security Mission. Relevant institutions in the district include the Badnapur research station for pulses, the Krishi Vigyan Kendra, the citrus research centre in the Marathwada agricultural university and the pest surveillance centre for pigeon pea (tur dal) in the Badnapur Agricultural Research Station under the National Initiative on Climate Resilient Agriculture.

Jalna is also a major hub for seed companies (like Mahyco, Mahindra, Bejosheetal) who engage in contract farming with small farmers for cotton seeds and vegetable seeds.

[2] http://www.districtsofindia.com/maharashtra/jalna/agriculture/index.aspx

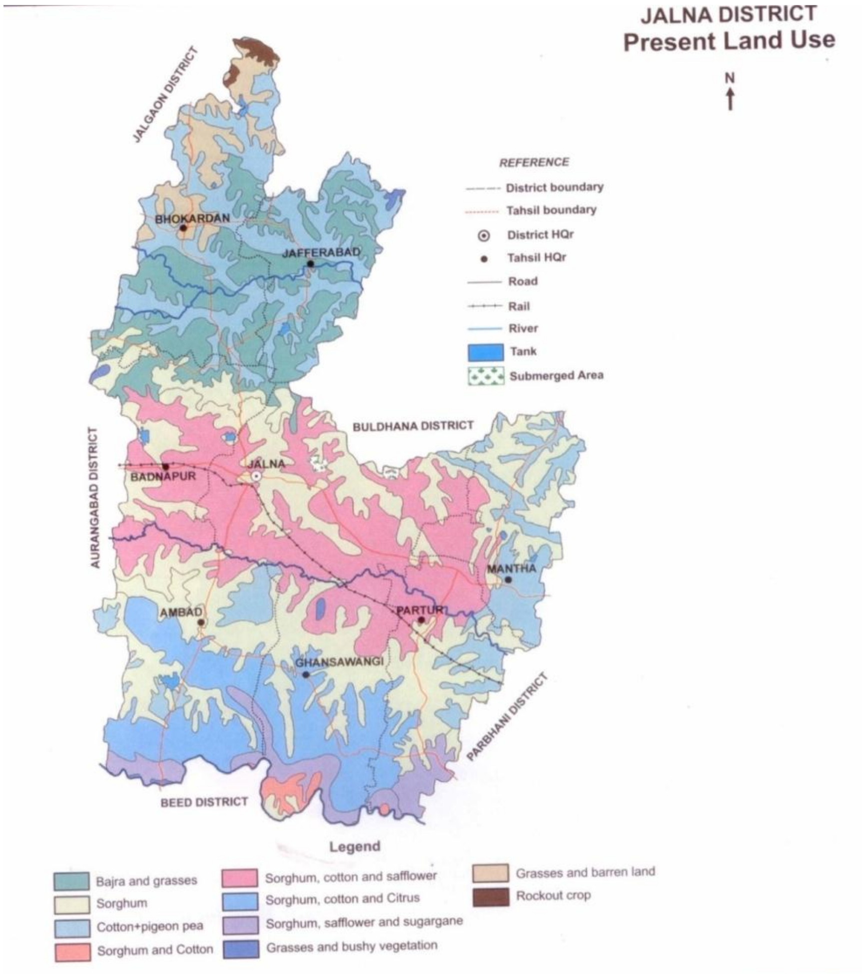


Figure 17. Present cropping pattern in Jalna

Source: NBSSLUP (2005)

Table 9 below highlights the importance of the cotton crop grown in the kharif season and jowar in the rabi. Very less amount of land is cultivated in the summer season largely contingent upon availability for irrigating the fields.

Table 7 Area under major crops in Jalna District grown in different seasons

Crop	**Area ('00 hectares)**	**Crop**	**Area ('00 hectares)**
Kharif crops		***Summer crops***	
Kharif Sorghum (Jowar)	149	Summer Groundnut	19
Pearl millet (Bajra)	754	Sunflower	15

Maize	489	Maize	2
Pigeon pea (Tur)	532	***Vegetables***	
Soyabean	249	Tomato	3
Cotton	2258	Cabbage	2
Rabi crops		Brinjal	2
Rabi Sorghum (Jowar)	1593		
Wheat	232		
Gram	157		
Sugarcane	110		

Source: Comprehensive District Agriculture Plan (2007–12)

Of the villages in the Jafrabad cluster, Asarkheda has presumably been able to increase the area under seasonal irrigation through watershed development activities, compared to the other two villages. The villages in this cluster grow summer vegetables— – presumably for seeds – due to their proximity to the seed companies in Jalna.

In contrast, the Bhokardan village cluster has no access to permanent irrigation, relatively low area under seasonal irrigation, and no summer crop.

Table 8 Summary of irrigation profile of field study villages

Name	Population	(Families)	Land under rainfed agriculture	Land under seasonal irrigation	Land under permanent irrigation	Summer crop /Perennial
Jafrabad cluster						
Dongaon	1510	263	817	210	2	Vegetables
Nivdunga	1320	281	752	263	7	Vegetables
Asarkheda	1520	212	618	**523**	12	Vegetables
Bhokardan cluster						
Thote		190	720	210	0	

Pimpalgaon						
Barav Pimpalgaon	1120	245	810	220	0	
Palaskheda Pimple	1180	234	720	190	0	
Badanapur cluster						
Kadegaon	3500	125	1700	**700**	50	Sweet orange
Malegaon	1100	100	615	**500**	25	Sweet orange
Warudi	1384	100	1200	**500**	270	Sweet orange, Pomegranate

Pulses like tur dal are not only part of Maharashtra's traditional staple diet, but are also hardy crops that require low soil moisture. They are well suited to enhance the adaptive capacity of farmers in Marathwada. Under the National Food Security Mission for pulses, 18 districts of Maharashtra, including Jalna, are covered. Maharashtra won the newly instituted 'Krishi Karman' award for the best performance in pulses production. It produced 31.44 lakh tonne in 2010–11, accounting for 18% of the country's pulses production. Some of the good practices adopted in the state include the following.

- In situ soil moisture conservation through construction of tanks
- Adoption of Crop e-Pest Surveillance Project under the Rashtriya Krishi Vikas Yojana
- Extension activities through Krishi Mahotsav and Dhanya Bazaars
- Focus on project based agriculture extension for 100–500 hectare group farming, in which end to end services from seeds, nutrients, plant protection, training to farmers and market facilities are provided
- Agricultural advisory through SMS service

Sorghum (jwari/jowar), pearl millet (bajri/bajra) and finger millet (nachni/ragi) have always been part of Maharashtra's traditional diet. Millet crops are very important for adaptation to climate change as they need less water and have carbon-fixing properties. But their economic value currently does not provide incentives to farmers to grow these crops. So a market needs to be created and appropriate incentives and institutional support need to be provided.

Horticulture also has great potential for crop diversification, but requires supporting infrastructure for risk reduction and value addition (e.g., cold storage and agri-processing enterprises).

8.2.1 Trends in area and productivities of important crops in Jalna

From 2007 onwards there has been a shift in cropping pattern that is observed. It is visible from the data that acreage under foodgrains and also sugarcane and other crops being grown in the region have declined over this period and cash crops like cotton and oilseeds have grown. Overall, the district still has a large proportion of its area under cotton, sugarcane, maize, oilseeds and traditional crops like jowar and bajra. Most crops are grown in the kharif season given that the area is largely rainfed and part of the dryland belt in Maharashtra.

Maize, jowar and bajra constitute the main cereals in the kharif season of which except for maize where the cultivated area under the crop has grown by 25% during 2000–2010, both areas under jowar and bajra has decreased significantly. The productivity of maize more than doubling in the decade has increased from 0.9t/ha in 2000 to 2.1t/ha in 2010. Overall total area under kharif foodgrains has declined with the decline in cereals reported to be about 33% and in pulses 57 %. However, the area under pulses in the rabi season has nearly doubled.

Total foodgrains, cereals and pulses show a net decline in the area. There are some variations within the crops. While area under some crops has reduced significantly, it has grown in other cases, for instance, cotton, oilseeds and sugarcane. Cotton and soyabean definitely stand out to be the two most important crops being grown in the region.

Table 9 Table showing changes in area, production and yield from 2001-2010 for key crops in Jalna

2001-2010	A	P	Y
Kharif season			
Jowar	-496	-501	no major changes
Bajra	-138	-109	Slight increase
Maize	26	66	Doubled (0,9 to 2.1 t/ha)
Cereals	-67	8	Nearly doubled (solely on account of maize)
Pulses	-42	5	Slight increase
Food Grains	-42	-39	Slight increase
Rabi season			
Cereals	-10	13	Increase
Pulses	109	71	Increase
Food Grains	9	6	Slight increase
Cash crops			
Sugarcane	12	267	-
Cotton	52	98	-
Oilseeds			
Soyabean	88	95	Doubled
Total oilseeds	21	62	Doubled

Source: Department of Agriculture, GoM

However, a glance through the productivities of the various crops in the district over the period 2000–2012 highlights that the productivity of most of the crops including sugarcane, cotton, maize have increased and thus benefitted the farmers. This may be attributed to the development and adoption of better varieties of these crops and farm management practices being used on ground.

8.3 Impact of extremes on crop growth

Weather is one of the most important factors that influence crop growth and its yields. Crop production is influenced by temperature, light intensity, radiation and precipitation. Temperature, in many cases, determines the duration of a crop's growing season. Distribution of rainfall leading to continuous wet spells may cause crop damage and loss to the local economy in the region. There have been examples of losses to crops in Jalna because of heavy rainfall and hailstorms resulting in huge damage to standing crops early this year (2014).

It is projected that rainfall is likely to increase in the future and in some cases may fall as heavy precipitation and therefore have direct damage to crops being grown. Almost all crops grown are sensitive to the extreme weather conditions depending on the stage of growth, flowering and harvesting periods are particularly sensitive to such events.

However, past analysis of the data indicates drought periods to be prevalent in the region which would continue even in the future and the implications of this would be clearly visible in terms of the area under agriculture being affected thereby affecting overall production.

8.3.1 Major crops grown in Jalna and their sensitivities to climate variability and change

Both cotton and soyabean stand out to be the major crops grown in the district. The areas under both crops have increased over the last decade as well as productivities of these crops have improved.

8.3.1.1 Cotton crop

Cotton as a crop has an inherent tolerance to a wide range of temperature regimes although optimum time for realizing good yields is much more limited. Variations in the yield of cotton arise due to:

- variation in the standing crop
- post flowering growth
- shedding of flowers and bolls

All these growth stages of the crop are widely influenced by environmental conditions. The crop is highly sensitive to wet conditions and overcast skies at any stage of its growth. Temperature controls cotton development and indirectly its water requirement.

Optimum temperatures for seed germination of cotton (about a week) lie between 14°C–40°C which is higher than that needed for maize and wheat. Thus cotton if sown in winter should be sown much ahead in time; if in spring then later; and if in summer soil temperatures should not exceed 40°C. Branching of the crop is sensitive to night temperatures and therefore desired limits stand below 21°C.

The range of temperature for the growth of the crop lies between 15°C –40°C. Exposure to high soil temperatures for several days may have an effect on the yields. The phases when budding, flowering, fruiting and boll shedding are influenced by temperature.

The crop is prone to red leaf blight based on stage of growth and temperatures. Early leafing in winter has a potential for pest infestation. Untimely rains at the fruiting stage effect overall yields. Therefore, optimum sowing periods are identified across the year in different parts of world where cotton is being grown. Across India, also in different parts, the sowing time for the crop varies. For instance, in Vidharbha, cotton sown in pre-monsoon months with irrigation show higher yields.

8.3.1.2 Soyabean crop

Soyabean sprouting is high dependent on soil moisture conditions. Too much or too less moisture in the soil has a high tendency of affecting the germination of the seed. Ideal temperature limits for the growth of soyabean lie between 21°C–37°C. Higher temperatures in the earlier stage of the crop affect the overall growth of the crop. Soyabean is also quite sensitive to soil moisture stress during its pod formation stages. A temperature range of 10°C –21°C is optimum for warmth tolerant cultivars.

9 Conclusions and recommendations

Through the land use predictive modelling exercise it is simulated that land use will still largely be under agriculture in the next two to three decades. Therefore, there is a strong need to understand the sensitivities of changes in the climate variability and climate to crop growth which in turn will have huge socioeconomic implications and highlight the growth in the region.

The two major crops, cotton and soyabean, which are currently grown in Jalna, are quite sensitive to weather conditions. While they do grow in a wide range of temperatures, these crops have defined sensitivities based on high and low temperatures, light intensities, soil temperatures and soil moisture conditions in each stage of their growth. Untimely rainfall and its implications on yields are also well highlighted.

Overall, the productivity of crops in Jalna has been improving over the years. It is also observed the shift is towards cotton, oilseeds and pulses which are ideal crops for growing in drylands. Also, a large proportion of the area is covered under the traditional crops of jowar and bajra which also seems to be climatically well suited for growth in the region. Jalna thus provides ideal conditions for the growth of these crops given the current weather conditions and projected changes in future. Current policies also provide the right kind of environment for uptake of oilseed and pulse crops.

While rainfall trends indicate a decline over the past few decades which has had an impact on the growth of some crops, incidents of extreme precipitation and other extreme events like hailstorms have resulted in damage to crops. It is projected that rainfall in future may increase and in some cases may come as extreme events—heavy precipitation. Damage to standing crops due to such events is likely. Also such weather may harm the yields of cotton during its maturity stages. Too much of soil moisture may affect seed germination in soyabean. Untimely rains, heavy precipitation may have a net negative effect on the crops. Cotton and soyabean are also sensitive to rise in temperatures but the range of temperatures in which they grow and the development of new varieties may reduce their exposure to such changes. However, continuous exposure to high temperatures sensitive to their growth may result in a net negative impact on yields.

Research institutions like the Indian Council for Agricultural Research (ICAR), good practices and initiatives in crop and farm management and the private sector have a crucial role to play in the way in which crop development occurs in future time periods. Fundamental research in development of suited varieties under different climatic conditions and its effective demonstration and uptake by farmers is contingent upon the scientific progress and its delivery on ground. Also timely provision of agri-advisories, setting up of warning mechanisms, crop guidance to farmers through its various growth stages would prove to be beneficial. Best practice guidance initiatives and its documentation and circulation to all farmers growing those crops would serve as useful material to be followed for crop and farm management practices. Seed companies and other private industries using the farm products benefit from providing proper information and guidance to the farmers. This would ensure that farmers are following the right practices to ensure maximum yield and encourage them for the uptake of the crop.

Given the terrain characteristics of the region, most water is likely to flow as runoff without adequate recharge to the ground given that the district lies in the core of the basaltic stretch. Water storage potential could be enhanced given the undulating terrain. Bunds and CNBs, as well as check dams could be constructed to limit runoff and allow recharge at strategic points where there is potential to recharge and contribute to improving groundwater levels.

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About the Project

The EVA project focuses on the state of Maharashtra. More than 30 % of the state of Maharashtra falls under the rain shadow area and about 84 % of the total cultivated area is rainfed. Drylands in Maharashtra face the combined stress of human pressures and drought. Communities within these drylands are poor and face extreme conditions of water stress. This pilot project aims to assess the extreme risks and vulnerabilities to climatic extreme events in the drylands of Maharashtra and their impacts on agriculture and water resources, and the implications for community-based adaptation in response to these extreme events.

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