Farmers Perception on Climate Change in Semi-Arid Topic Region of India

Report Submitted to

School of Rural Management, KIIT University, Bhubaneswar, India

By,

ABHINANDAN DAS

International Crops Research Institute for the Semi- Arid Tropics

Patancheru 502324

Andhra Pradesh, India

icrisat@cgiar.org

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Title	**:**	**Farmers Perception on Climate Change in Semi-Arid Topic Region of India**
Name	**:**	**Abhinandan Das**
Institute	**:**	**School of Rural Management, KIIT University, Bhubaneswar, India**
Supervisor	**:**	**Dr. Naveen Pratap Singh**
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Abstract

The climatic trend of the study area in the region has shown a significant decrease in the rainfall with increase the deviation from the prevailing rainy pattern. The maximum and minimum temperature of summer and winter season has also shown an upward trend in the last two decades. The cropping pattern of Andhra Pradesh and Maharashtra has changed considerably from cereal crops except maize towards pulses and other cash crops like sugarcane and cotton. Increase in fertilizer application, irrigated area and market price with change in rainfall has been the probable reasons which account for the shifting of crops. From the farmers perception it is quite notable that most of the farmers perceive the change in climate, increase in the annual temperature and reduced with more erratic rainfall more precisely in the last decade. This led to shift in the irrigation practices due to decrease in the ground water level and drying of wells and tanks. The cropping of the study villages also showed shifting from cereal and non cereal crops. Decrease in rainfall is one of the reasons to change the crop varieties and reduction of cultivable area in the villages. The main coping mechanism adopted by the farmers are migration, taking credits, use previous saving, selling of asset, diversification of livelihood activities including livestock. A sound Governance with proper awareness about soil and water conservation by enhancing the institutional involvement and further crop improvement research could provide a better way forward.

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1. Introduction

Climate change is one of the defining issues of the early 21st century. The research effort is enormous, and media attention is intense. The unimpeded growth of greenhouse gas emissions is raising the earth's temperature. The consequences include melting glaciers, more precipitation, more and more extreme weather events, and shifting seasons. The accelerating pace of climate change, combined with global population and income growth, threatens food security everywhere. Agriculture is extremely vulnerable to climate change. Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation. Changes in precipitation patterns increase the likelihood of short-run crop failures and long-run production declines. Although there will be gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative, threatening global food security. Populations in the developing world, which are already vulnerable and food insecure, are likely to be the most seriously affected. In 2005, nearly half of the economically active population in developing countries—2.5 billion people—relied on agriculture for its livelihood. Today, 75 percent of the world's poor live in rural areas.

The researchers are of the opinion that while crops would respond favorably to elevated CO_2 in the absence of climate change, the associated impacts of high temperatures, changed pattern of precipitation and possibly increased frequency of extreme events such as drought and floods, would possibly combine to reduce yields and increase risks in agricultural production in several parts of the globe. In India agricultural production is often determined by the whims of nature. The climate change is expected to result in higher temperatures and rainfall. The higher expected temperature might lower the yields. However, at the same time, higher rainfall could enhance growing period of crops. Also the higher concentration of CO_2 in the atmosphere under changed climatic conditions might act as aerial fertilizer and enhance crop yields. All these factors have to be taken in to consideration while examining the climate change impact on agriculture.

a) Background of the study

The paper contributes to the perception of farmers about climate change and the suitable adaptation strategies practiced by them to mitigate the changed environment. In India about 60 percent population depends on agriculture and there are nearly 600 thousand villages. The agriculture sector contributes nearly 17.5 percentage currently while the growth rate of this sector is less than 4 percentage. Therefore there is growing need to focus in this sector as a huge chunk of the GDP is from this sector. Rainfall in India so far this year is 28% below par and this is a major cause of concern as the impact could be devastating. Monsoon in the northwestern region of India, the main growing area, is 40% below average. If agricultural production goes down in India then the direct impact would be a decline in the income of people. The economy as a whole and the GDP will get affected. This factor could lower production of food but raise the prices. Hence, the significance of the monsoon for the economic system cannot be under-estimated. The monsoon can directly affect government savings, public investment and foreign exchange reserves.

Global warming, as well known has resulted in the shift in the monsoon patterns which has adversely impacted the agriculture. Since the beginning of the monsoon, its advancement became slow into the nation. If, we see from the above charts the rainfall in the month of May 2009 was scanty over the regions but has gained momentum since the beginning of July 2009. India being an agri nation and farmers majorly relying on monsoon farmers stand handicapped if the rains are not in time. If we see the overall distribution of rainfall the northern region has not received adequate rainfall for its kharif sowing. Crops which stand at risk are as follows Paddy, pulses, bajra, cotton, Soy bean and sugarcane. Most of the farmers being small and marginal holding small lands depend entirely on the rains. They have poor irrigation facility. India, have done less on the monsoon management and rain water conservation.

The changing temperature and precipitation is not the only variables that affect the yield of agriculture crop. There are lots of other variables like market availability, price fluctuation of agri commodities and Government policies. The climate change could also bring minor changes in solar intensity, carbon dioxide concentration, ground water level and water availability. The gradual changes are also perceived by the farmers and they brought new cropping pattern, changing input doses and diverted to other livelihood sector. Broadly the adaptation taken by farmer's can be classified under four categories i.e. farm level, institutional level, technological level and social level. Therefore a proper micro level study is required for better understanding the changing practices of the farmer's as adaptation to climate change. This paper deals about the changing climate scenario of the villages of Maharastra and Andra Pradesh and the farmers adaptation due to climate change. This paper also gives careful consideration to the Government policies going on to create rural employment and conservation practices. The actual data and the perceived change in climate are compared to generate a fruitful suggestion for adaptation due to climate change.

b) Objective

The main objective of the study is to analyse the actual change in climate change and the perception of the farmers to this changes. In brief the main objectives are given below

1. To analyze the pattern of climate change in the semi-arid tropics of India especially, in Maharashtra and Andra Pradesh villages
2. To find out the farmer's perception on climate change in the targeted locations
3. To identify the adaptation strategies of the farmer's to cope with climate change and suggest future action to adapt in climate change

c) Limitation of the study

The perception of farmers was measured by using simple Likart scale and the area of study is restricted to four villages of Maharashtra and Andhra Pradesh. The data obtained may be homogeneous from broad perspective.

The range of data obtained is from 1971 till 2008. To understand the changing climate pattern over a region a much broader data range is recommended. A small range may reduce the significance of the study.

The change in livelihood and crop pattern of farmers was due to large number of variable factors. But due to time and resource constrains this report emphasize more on the climatic factor rather than considering all the factors.

2. Literature review

There are large numbers of studies related to climate change but only few of them are from the micro level Indian context. Most of the articles explain the probable causes of agriculture crop yield due change in climate and other factor using during probability models.

2.1 Trend of climate change

The total rainfall in India (Guhathakurta and Ranjeevan, 2005) has not shown any significant change in the last few decades but exception is there is some particular location. The predicted next decade shows a trend of wet period. The contribution of June and August rainfall on the total rainfall has been increased while the contribution of the month July has been decreased. This shows a changing pattern of rainfall intensity throughout the year without much change in the cumulative rainfall.

Murari et al (2001) generate various simulation models of surface temperature and rainfall under different emission scenarios. The simulation model compared with the observed data and on the basis of the future prediction of climate simulation trend has been determined. The temperature rise of Indian continent is suggested to be 3.5- 5.5 degree centigrade over the region till 2080's. They predicted that rainfall during winter may decrease by 5-25 percentages and that may lead to draught during dry summer.

Akinremi and McGinn (1997) analysed the precipitation trend with event and intensity of rainfall in Canadian Prairies. The high intensity precipitation so called big event is higher than the number of big event of snowfall. In some places increase in less intensity precipitation called small event has been observed. The trends in most recent period (1961-95) were also significantly difference from the 1921-60 periods for snowfall. The difference in trends between the two periods for snowfall, combined with the inverse relationship in the snowfall rainfall trend, suggest that these trends may be related to climate change.

Kao C (2009) examines the change in temperature, precipitation, frequency of extreme warm year and cyclones in the dry land of Africa (semi-arid and arid areas) and Asia.

The change in land use i.e. decrease in forest area effects the temperature and precipitation of the area.

2.2 Impact of climate change on crops

A micro-level study by Kubo (2005) stated that there has been a steady decrease in the rice area from the year 2000 onwards with increase of pulse area at the same time. Simultaneously the area under cotton and maize crop are also increasing as it proved to be remunerative. Decline of rice area could be result of weather related phenomenon and unavailability of canal irrigation.

Adejuwon (2004) In the study of impact of climate variability and climate change on crop yield in Nigeria. The climate change will lead to positive and negative effect on rainfall, temperature, enhance carbon dioxide level, water availability, soil fertility , erosion, agriculture output. It also suggest the encouragement in Government level to focus more on adaptable strategies of climate change.

The study was done to analyse the crop choice pattern changes due to climate change in Latin America (Seo N,2007). According to the study farmers would like to grow rice, fruits and squash in wet area and maize and potato in dry region. Global warming may shift them from rice toward fruits and vegetables.

Kurukulasurya (2008) stud y the change of cropland area and crop net revenue due to climate change by multi logit model analysis and AEZ model in two scenario, mild and harsh. The analysis reveals that reduction of productive AEZs in Africa. Prediction about the change has also been discussed about this paper. The loss in crop value is more identifiable than loss in crop land.

Kelkar U & Bhadwal S (2007) in the UNDP report about climate change discussed the various affect of climate changes in South Asian countries. The different prediction about probable disaster in the next 50 yrs by different institutions has been shown here. The impact of climate change has broadly classified under three subtitles- Agriculture, water resource and health. The developing and the underdeveloped nations are identified on serious threat due to high agriculture dependency on one side and food security on another side.

2.3 Impact of climate change on livestock

The climate change lead to selection of different livestock choice (Seo ,2007). With a multinomial analysis tool the farmer’s perception on livestock choice has been derived and a strong impact of climatic factors has observed for selection cattle. The global warming will cause farmers to switch to beef cattle at the expense of dairy cattle.

2.4 Adaptation for coping climate change

Hassan R (2008) determines the farm level climate adaptation measures in Africa using the multinomial choice model. Farmer’s adapt mixed cropping and multiple cropping. Increase precipitation reduces irrigation probability in dry region. Access to market, information and credit service require to adapt to climate change. This study tests the probability of selecting different farming model by the farmers.

Doss (2001) notes that the adoption of technology by women in Africa is especially low and Doss and Morris (2001) suggest that gender affects adoption rates indirectly through access to complementary inputs. Examining household data from rural Ethiopia Knight et al. (2003) find that schooling encourages farmers to adopt innovations.

Rauniyar and Goode (1992) investigate the interrelationships among technological practices adopted by maize-growing farmers in Swaziland. Technology adoption requires simultaneous decisions by farmers regarding the use of practices within a package. This study suggests that understanding interrelationships among practices is important for successful technology planning in developing countries.

Sukla P R et al (2004) discussed the cause and effect of climate change from different dimensions, the polices taken by Indian Government, the Millennium Development Goals from Asian perspective and from Worlds perspective. This paper also discuss about the International negotiation on climate change, UNFCCC.

Bandiera and Rasul (2002) note that despite their potentially strong impact on poverty, agricultural innovations are often adopted slowly. Using a unique household dataset on adoption of new techniques by sunflower farmers in Mozambique, they analyze whether and how individual adoption decisions depend on the choices of others in the same social networks. In line with information sharing, the network effect is stronger for farmers who report discussing agriculture with others.

Foltz (2003) deals with the adoption of drip-feed water conservation in Tunisia. It uses revealed preference and direct elicitation methods. The model introduces the factor of distance from the point at which the technology was first introduced and finds geographical proximity to be strongly predictive of adoption. This is consistent with information spillovers as well as with natural resource factors. Capital constraints, insecurity of tenure and information are all important. Baidu-Forson (1999) considers the adoption of various conservation measures in Niger including tassa water holes and crescent-shaped nutrient mounds.

Rogers (1993) argues that ethnic homogeneity, participatory norms and leadership heterogeneity all imply a greater range of contacts with the outside world. Isham (2002) examines the importance of social capital for fertilizer adoption in Tanzania and finds strong evidence in support of the views put forward by Rogers.

Leathers and Smale (1991) note that agricultural innovations are often promoted as a package – a new seed variety, a recommended fertilizer application, and other recommended cultivation practices. Nevertheless, many farmers adopt pieces of the package rather than the whole, in a sequential fashion. This paper presents a behavioral model which explains sequential adoption as a consequence of the way farmers learn. In order to learn more about the entire technological package, the farmer may adopt a part of it. The model is shown to be consistent with observed patterns of sequential adoption.

Anderson et al. (1999) note that strategic investments in agriculture are often lumpy and irreversible, with significant impacts on fixed costs. The implication is that large mechanized farms will probably be the first to adapt to climate change.

Summary

The trend of climate change as discussed by many researchers concludes that there is a probable increase in minimum winter temperature and average yearly temperature. Prediction has also been done to receive hot summer and drier climate in some region. In Indian context the average temperature may rise by 3-5 degree centigrade by next 80 years. The rainfall is observed to be more scattered without any change in the cumulative amount. Varies crop models observed changes in cropping pattern from high to low water requirement crop as well as shifting new varieties of crop. A similar change of rearing of milk cattle to dairy cattle has also been observed. Different regions have adopted different practices to cope with climate changes. Among them shifting cropping pattern, adopting new technologies, changing input doses, multiple cropping and traditional water harvesting mechanism is quite common.

3. Methodology

a) Data required: Daily average temperature, daily average precipitation and ground water level of the village and the district, detail about village demography, climate, natural resources, cropping pattern, infrastructure, livelihood activities, income, market availability and the perception of the farmer about the relative change of the above variables from 1970 till 2006

b) Source of data collection:

Primary data: The primary data was collected from a village level survey. The survey questionnaire contains two parts. The first part is for group level interview and the second part is for individual level interview. Therefore the primary data contain about village and district information was obtained from first part of the questionnaire and individual primary data was obtained from the second part of the questionnaire.

Secondary data**:** The secondary data related to temperature and precipitation was collected from ICRISAT data bank and the ground water level data was collected from CGWB. Other data related to the village and district data was collected from government offices.

c) Analytical tool

Qualitative data analysis: The quantitative data was obtained from the discussion and survey questionnaire from the group surveying in the villages. The interview in the villages was conducted with different farmers groups.

Quantitative data analysis: The temperature and precipitation data was analysed by using simple graphical and trend line analysis. The frequency and the length of temperature and precipitation was also calculated and analysed by graphical and trend method. The compound growth rate of area, production, yield, fertilizer use and producers price are also calculated to observe the changes and relation between the variables. For calculating the compound growth rate data was collected for the years from 1970 to 2005. Only some selected crop has been taken to simplify the calculation and lack of availability. The crop area, production, fertilizer, producers price and climate change has been related by simple statistical correlation. The farmers perception with simple scale has also been related to the actual change in climate.

4. Understanding climate variability and climate change

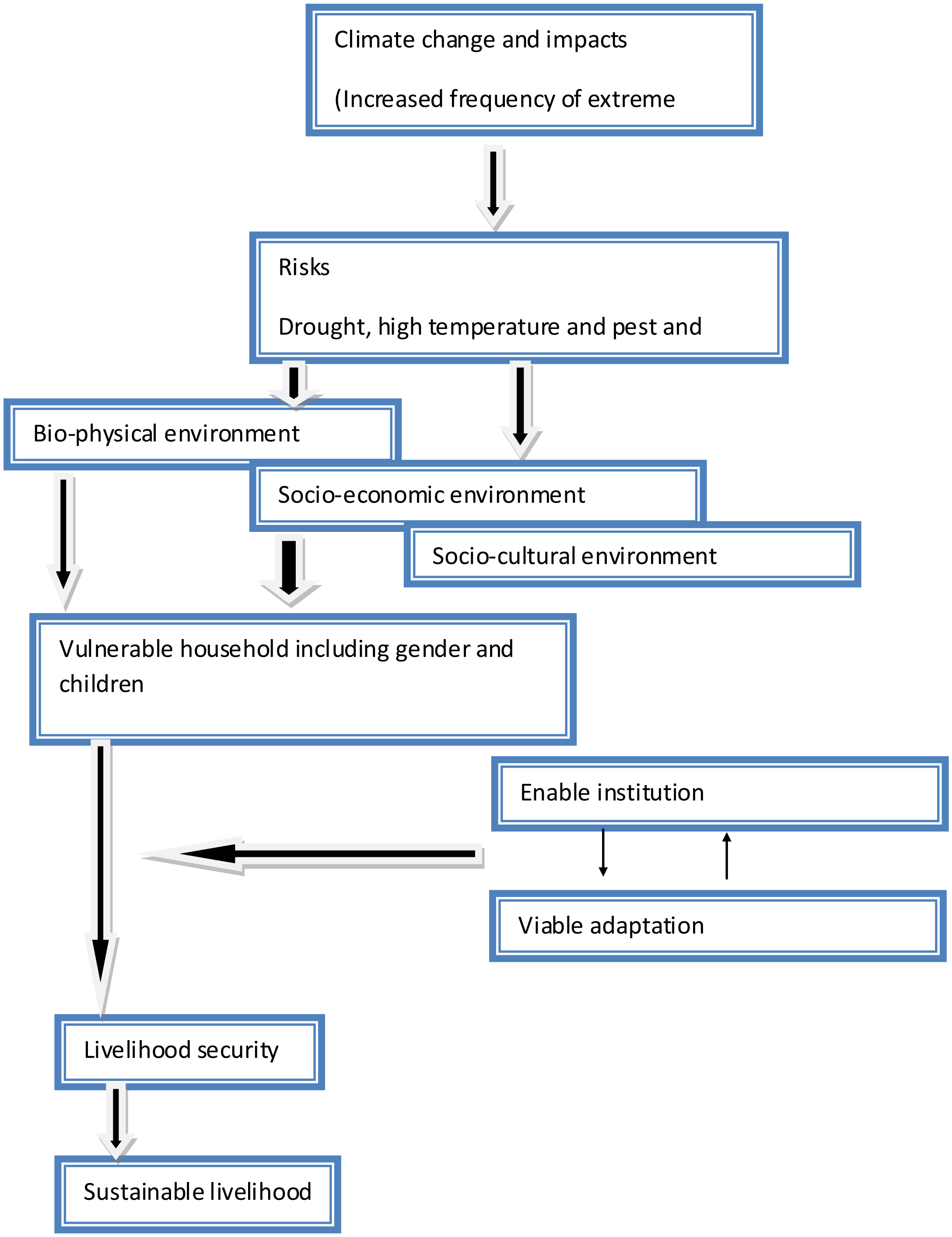
a) Adaptive capacity for climate variability and change in drought-prone areas: Future climate variability and change may increase the frequency of drought and thus reduce the coping range and adaptive capacity of the vulnerable population in drought-prone areas in Andhra Pradesh and Maharashtra. There are two factors contributing to increased vulnerability: i) higher frequency of droughts and dry spells that may effect the agriculture sector negatively, and ii) higher water requirements in the agricultural system as a whole due to increased cropping intensity. That's means low rainfall and increased evapotranspiration may further aggravate the current situation in a region that is already drought prone.

The rainfall amount often exceeds the lower (dry) threshold and thus breaches the existing coping range. Once the coping range is breached, a vulnerable population has difficulty adjusting to that low level of rainfall. However, it is possible to expand the coping range through introducing novel and stable adaptation practices that could improve the adaptive capacity of the rural livelihoods in drought-prone areas. Adaptation practices can reduce vulnerability of the exposed bio-physical systems in general- the rural population in particular- with a consequent reduction in vulnerability. The nature of adaptation required depends on the planning horizon under assessment and the livelihood of exceeding given criteria over that planning horizon. The coping range can also be used to explore how climate and coping ability may interact over time.

Climate variability and change and livelihoods

Based on the theoretical insights discussed above, a model was developed to implement adaptation to climate variability and change with an overall aim to improve the adaptive capacity of rural livelihoods in agriculture sector.

The figure below shows how different environmental factors together with risk factors influence household livelihood strategies and decision – making processes over time, taking the role of gender and other vulnerable populations into the account. At the



Conceptual framework for improving livelihood security and sustainable livelihood through adaptation to climate change

at the model from a systems perspective, climate change could influence the bio-physical (agriculture), socio-cultural and socio-economic environment of households, impacting resources and assets, including social capital. The resources management centre of the model are the households, where strategies are developed and decision taken to develop and maintain livelihoods by means of the livelihood portfolio. Looking strategies and decision making potential of the local population is also affected. The fact that coping range drops significantly under climate change is one of the reasons that improving adaptive capacity to maintain or improve livelihood security is one of the core aims of this effort.

b) Components of climate change adaptation

Designing and implementation livelihood adaptation to climate change in drought prone areas is well within the policy of the Government. On designing adaptation strategies the following elements can be used to form an overall strategy implementation plan.

i) Assessing current vulnerability- Involves responding to several questions regarding the relation between society and climate change and the efficiency of the effort to adapt to the climate change.

- Assess natural, socio-economic condition
- Assess current climate risks
- Assess local perceptions about climate risks and impacts
- Document livelihood profiles in the pilot sites
- Assess institutional frameworks

ii) Assessing future climate risks- focuses on developing scenarios of future climate, vulnerability and environmental trends as a basis for considering future climate risks. The major processes involved are

- Climate impact assessment & outlooks on agriculture
- Local agro-meteorological data collection and monitoring
- Downscaling climate change scenarios

iii) Testing adaptation options- involves the identification and selection of viable adaptation options and the future formulation of these into options into farmer-friendly adaptation menus, thereafter the testing and evaluating, with the goal of improving the adaptation options identified through stakeholder consultation. The major steps of this component are

- Institutional and technical capacity building
- Developing adaptation options & extension strategy
- Validation and selection of adaptation options
- Community mobilization and local awareness rising

iv) Designing adaptation strategy- prepares for broader dissemination and replication of successful field testing of adaptation option to current vulnerability and future climate risks.

- Advocacy, broader awareness and networking
- Economic feasibility studies
- Field-based demonstration and application/replication

5 Results and Discussion

5.1 Climatic situation and changes of the study area

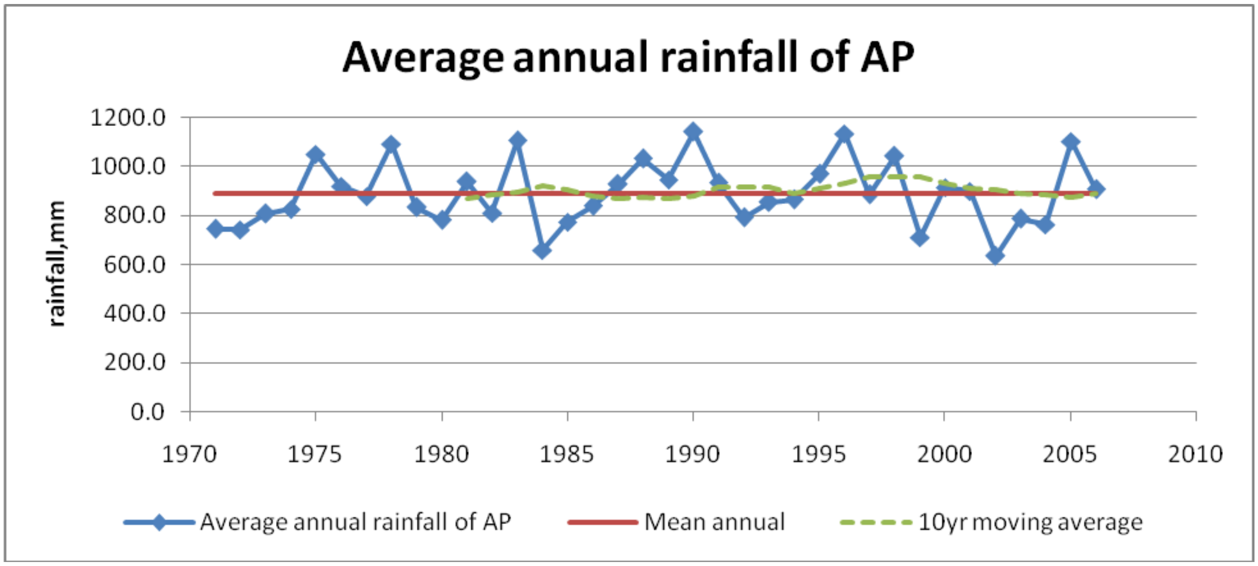
A) Precipitation situation of the study area

i) Andhra Pradesh: Andhra Pradesh is situated in the southern part of India. The total geographical area of 2.744 lakh sq kms, the third largest State in the Country with a population of about 7.00 crores, which depends mainly on agriculture. Out of the total geographical area of 2.744 lakh sq kms, about 53 per cent is cultivable land. This state is continuously being affected by drought in some of its areas. The gross area irrigated in Andhra Pradesh under all sources is around 6.28 million hectares, of which surface water accounts for 3.11 million hectares and the balance 3.17 million hectares comes from groundwater sources. Andhra Pradesh is divided into four major climatic division - Rayalaseema, Telengana and Coastal AP.

Fig 5.1Map of Andhra Pradesh

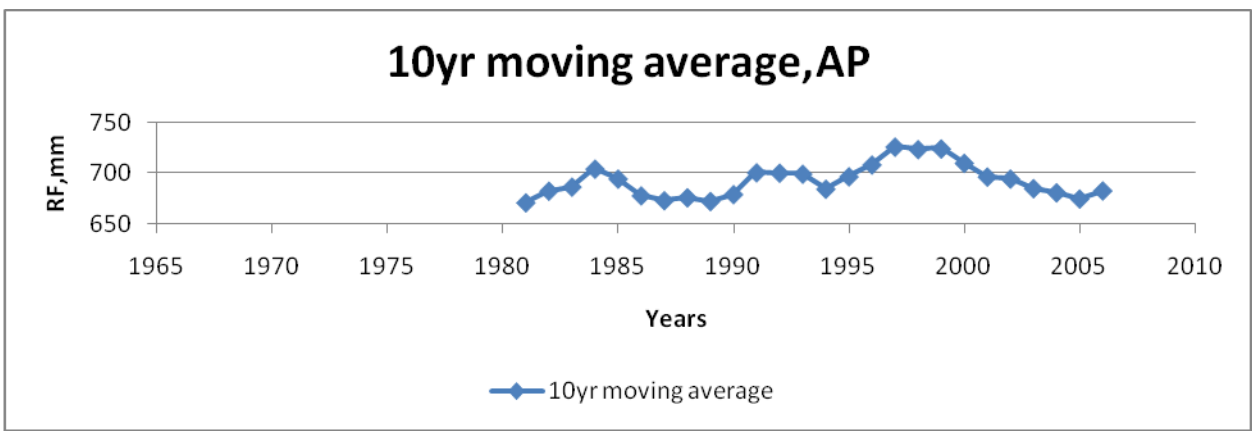
The dark region of the above map is the Rayalaseema region, the distrcts touching the coastal region of the state comes under coastal AP and the remaining areas are under Telengana.

The average mean rainfall of Reyalaseema, Telengana and Coastal AP are 750.7mm, 899.6 mm and 1021.2 mm. The annual rainfall is quite less in Reyalaseema region while the coastal region gets a higher rainfall. The mean rainfall of the state AP is 890.5 mm.



Graph 5.1The average annual rainfall of AP

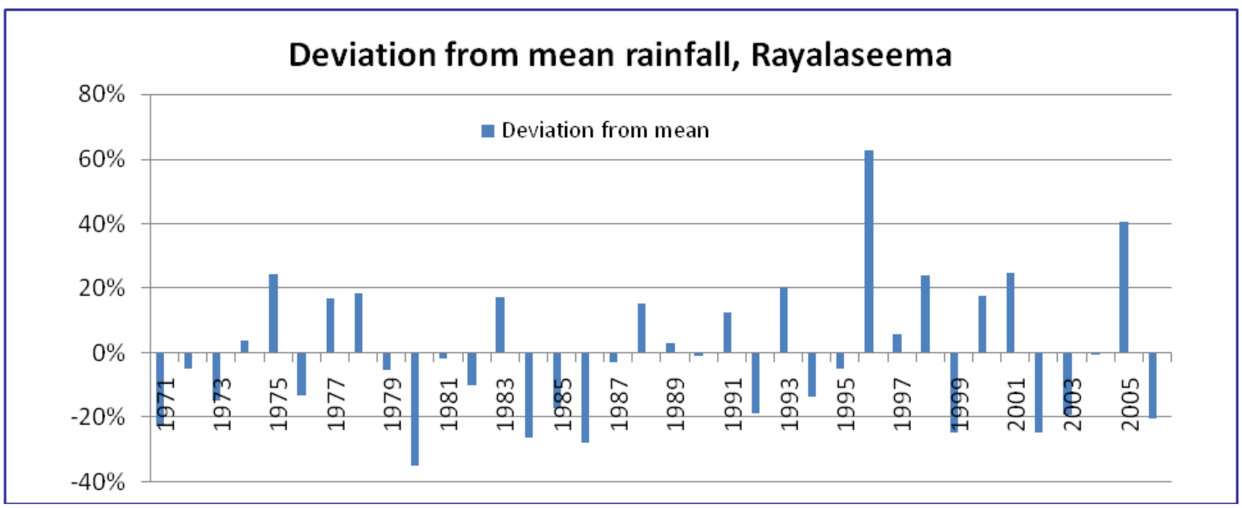
The above graph shows the mean annual rainfall and the annual rainfall of AP. The annual rainfall of AP ranges between 800-1100 mm roughly for the last 40 years.



Graph 5.2 Decadal moving average

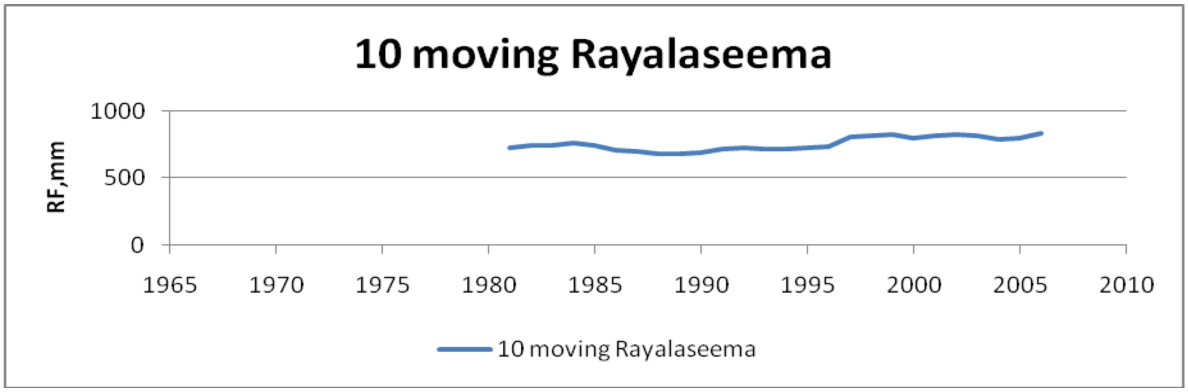
The annual rainfall of AP is not varying significantly from its mean though the rainfall after the year 2000 is showing negative trend. If the 10yr moving average of annual rainfall is considered then it is observed that after 2000 there is a clear decline of rainfall till 2005. Therefore even though there are ups and downs in annual rainfall from the last few decades, the sharp decline has been observed in this present decade.

i.a) Rayalaseema: The Rayalaseema comprises of four districts. Anantapur, Chittor, Cuddapah and Kurnool are the four districts under Rayalaseema region. The total area is about 6710134 ha which is nearly one- fourth of the total Andhra Pradesh. Out of 27.7 lakh hc pf cultivated area only only 10 percentage gets dependable irrigation from major projects. It has about 19.5 percentages of states population. The density of population in Rayalaseema, 117 per sq. km is the lowest among the three region of the state. Poverty encourages only migration. It is the driest region of AP among the three sub-divisions and it is considered among the drought prone region. The mean rainfall of this region is 750.7 mm. The entire rayalaseema region lies under rain shadow region of western ghats. Consequently this area receives very less rainfall during the south west monsoon and North East monsoon as well.



Graph 5.3 Percentage deviation from mean rainfall in Rayalaseema region

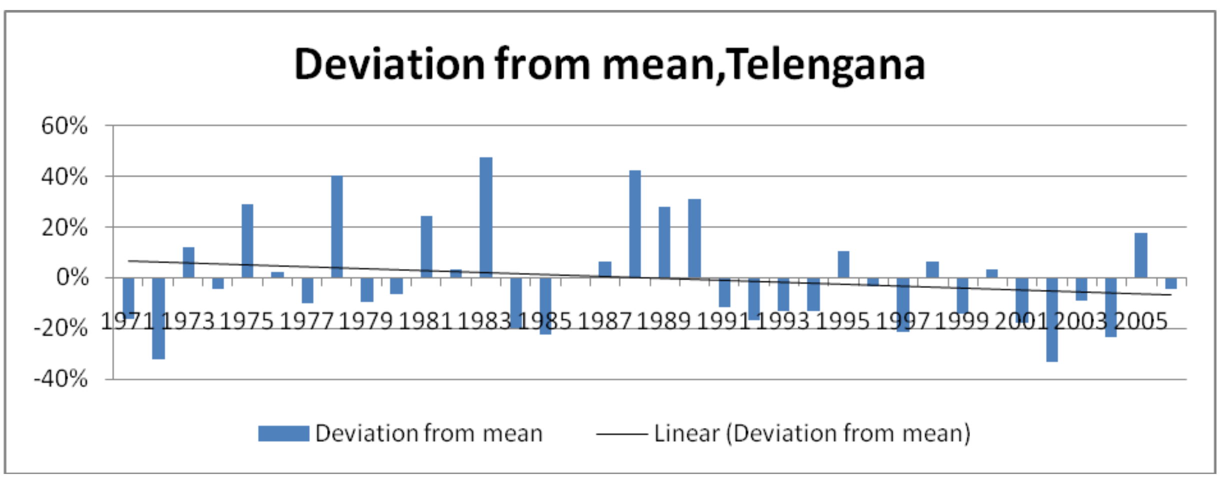
From the above graph it is observed that the deviation of rainfall from the mean rainfall in Rayalaseema region has been showing an increasing trend after 1996. Although there is increasing trend of rainfall but this increasing deviation from the mean will escalates the thread of unpredictable rainfall.



Graph 5.4 Decadal moving average RF, Rayalaseema

The above graph of moving average shows that the rainfall has not varied largely in the past few decades. The moving average varies between the range of 700 to 850 mm. Although there is an increase in moving average after 2000, it is not significant. Therefore this region particularly is among the driest region and significant changes in the last few decades has been observed.

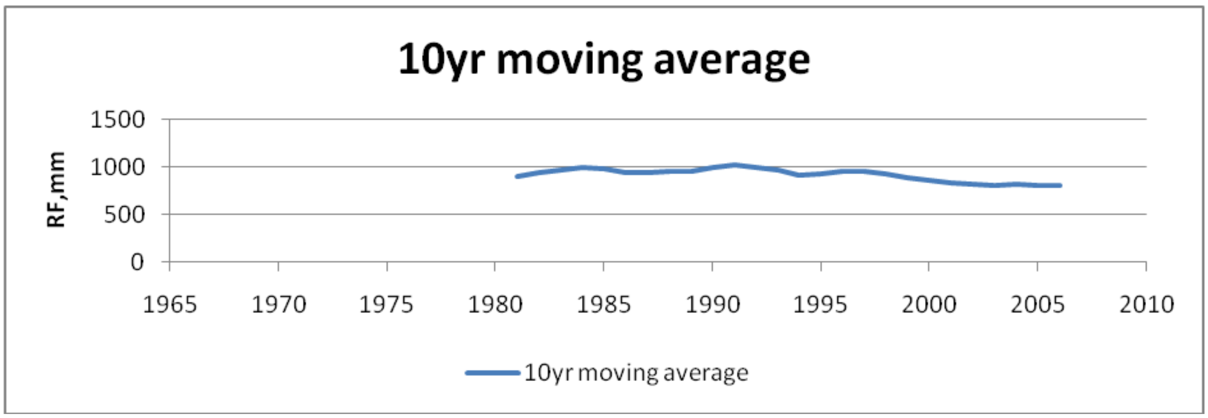
i.b) Telengana: The Telengana region of AP is situated in the north eastern part of the state. Among the three sub-divisions, Telangana has the largest area, with 1,14,800 km^2 yet much of the land is arid and not nearly as fertile as the agriculturally rich coastal region.



Graph 5.5 Deviation from mean, Telengana

It comprises of nine districsts, namely Adilabad, Nizamabad, Karimnagar, Sangareddi, Warangal, Rangareddi, Mehbuubnagar, Nalgonda, and Kammam.The Telangana plateau is drained by two major rivers, the Godavari and the Krishna. The entire region is divided into two main regions namely ghats and peneplains.It comprises of nine districts. This region is continuously facing severe rainfall shortage from the past few decades.

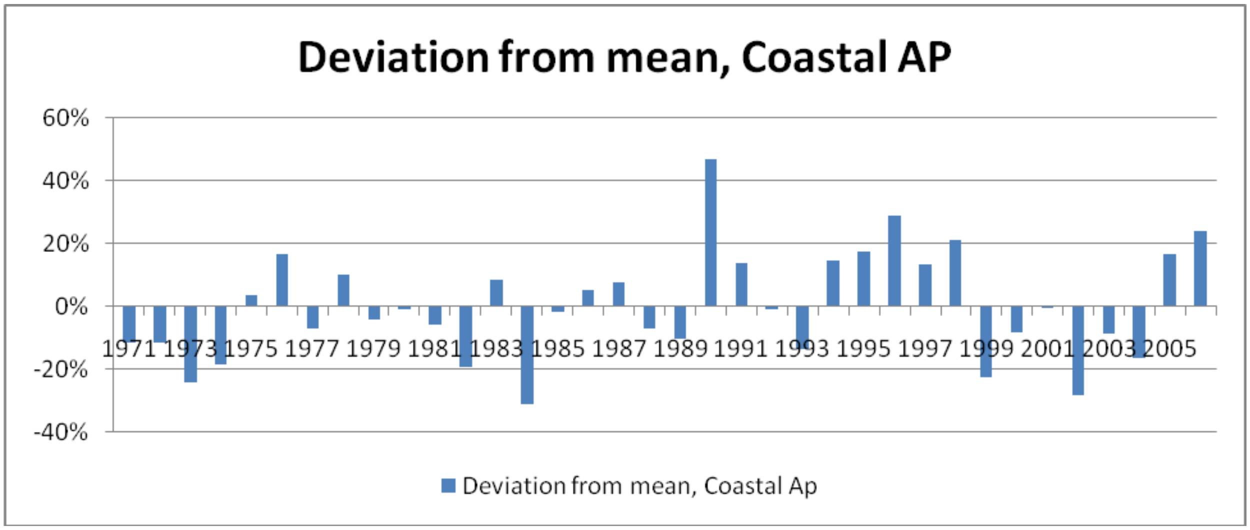
The mean rainfall of this region is 899 mm and after 1991 this region never received a positive rain rainfall compared to the mean.Except the year 2005, the deviation is always negative compared to mean. The trend line shows a decreasing annual rainfall from the last few decades. In 1983 it received the highest rainfall of 1326 mm and the lowest rainfall of 602 mm in 2002.



Graph 5.6 Decadal moving average of Telengana

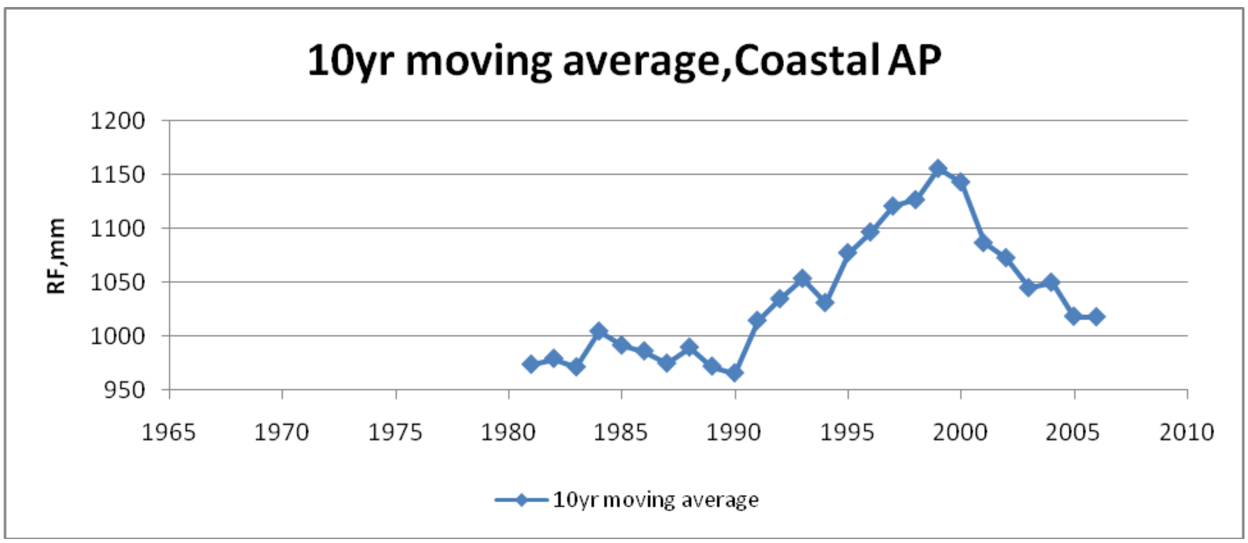
The decrease in annual rainfall can clearly be identified by the sharp decrease in 10 yr moving average. From 1980 there is decrease of about 10 percentages in the 10 year moving average.

i.c) Coastal Andhra Pradesh: Coastal AP is situated in the eastern coastal region of AP. It touches the Bay of Bengal along its border. The coastal AP consists of nine districts. These districts are Srikakulam, Vizianagram, Vishakapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasham and Nellore.This area is also showing a similar trend of decreasing rainfall from 2000.



Graph 5.7 Deviation from mean, Coastal AP

It received the highest rainfall of 1501 mm in 1990 and the lowest rainfall of 705 mm in 1984. During the period of last four decades there are several crests and troughs in the deviation of rainfall. But noticeably the deviation has been increased slowly making the rainfall more volatile and unpredictable.



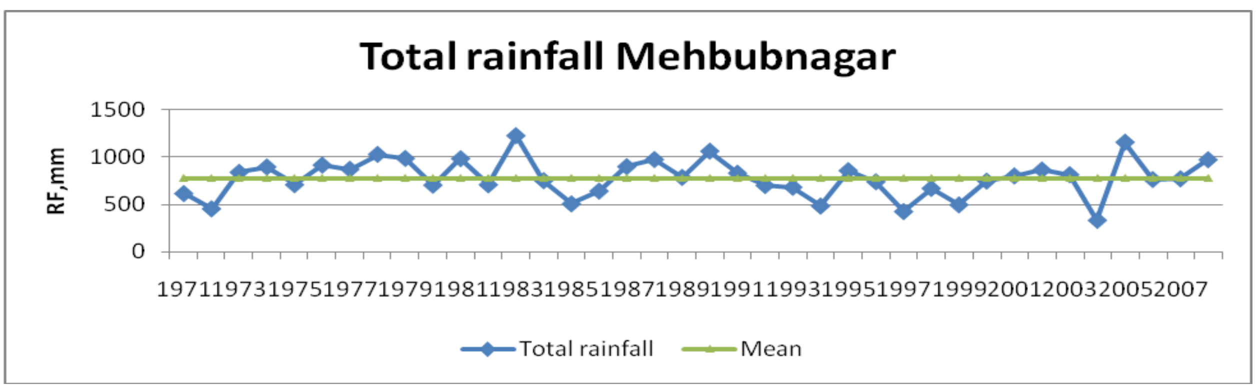
Graph 5.8 Decadal rainfall of Coastal Andhra Pradesh

i.d) Mahbubnagar: Mahabubagar, with a total geographical area of 18742 Sq.km. stands second largest of 23 districts in Andhra Pradesh state, which accounts for 6.73% to the state. The district having four(4) revenue divisions and 64 Mandals and 1554 revenue villages, with Headquarters at Mahbubnagar town lies between North Latitudes 77°55' and 17°20' and East longitudes 77°15' and covered in the Survey of India topographical maps no 56G and 56K. The district is well connected with road, rail and telecommunication as well. As per 2001 census, the population of the district is 35,13,034, with a density of 190 persons per square Km. with urban population and rural population accounts for 10.57% and 89.43%, respectively, to the population of the district. The district is mainly covered by three types of soils Viz. red sandy soil (Dubbas and Chalkas) Red earth (with loamy sub-soils and Chalkas) and black cotton soils. Red sandy soils and red earth are permeable and well drained.

Table 5.1The land use pattern of this area is given below (area, ha) (2005-06)

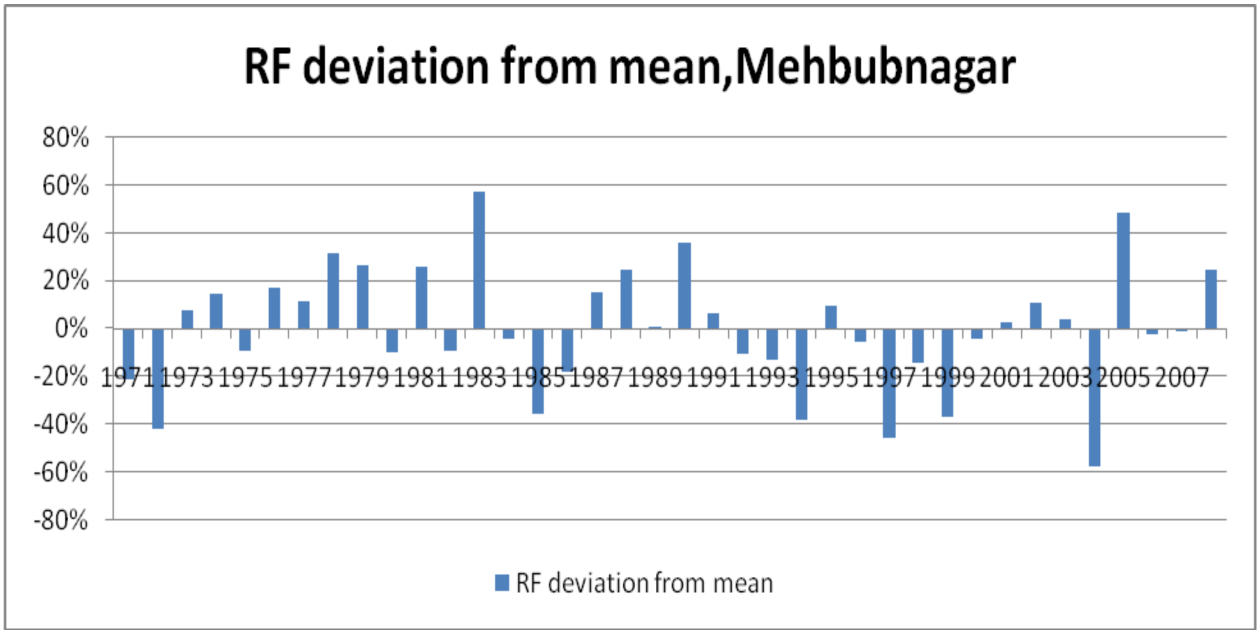
Forest	267000
Barren and uncultivated	96000
Cultivable waste	15000
Current fallow	435000
Net area shown	777000

The total net shown area is about 48 percentages of the total area. The current fallow is about 27 percentages while the forest area is about 17 percentages. The current fallow is nearly 27 percentages and cultivable waste is nearly 1 percentages. The rainfall and other climate factor has affected the current fallow area of this district. Due to lack of rainfall and ground water resource sometimes farmers kept their land fallow.



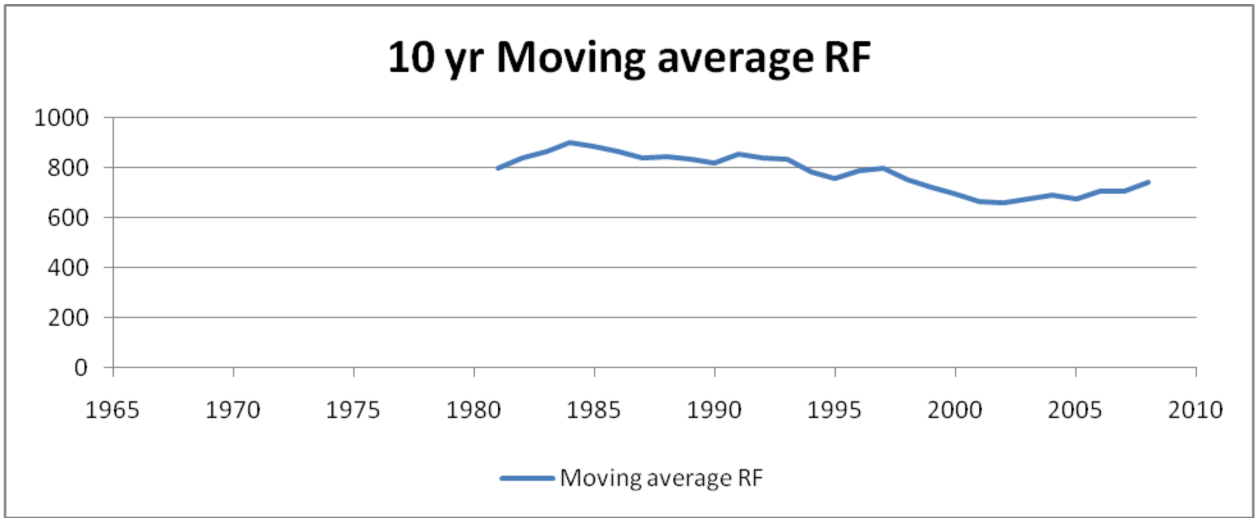
Graph 5.9 Total rainfall of Mahbubnagar

The average rainfall of this district is about 777 mm. This region is considered to a rainfall scarce region. From the last three decades there are various crest and trough of annual rainfall has been observed. The maximum rainfall of 1222 mm was in the year 1983 and the minimum rainfall of 329 mm was in the year 2004. After 1990s there has been a comparative lesser rainfall that the previous period. The deviation from the mean value of rainfall before 1990 was positive and after 1990 the deviation from mean is negative.

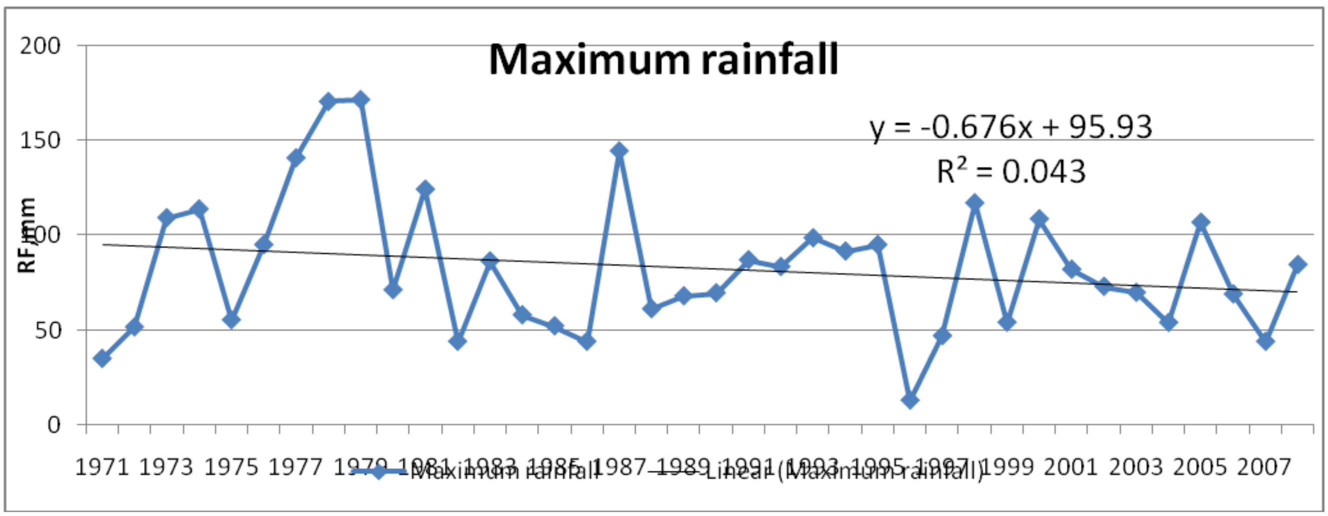


Graph 5.10 Rainfall deviation, Mahbubnagar

But the year 2005 was having 43 percentages more rainfall than the mean and even in 2007 the rainfall is nearly 21 percentages more. Therefore a comparative better rainfall has been observed from a period of 1970 to1990 and after 1990 the rainfall is being comparatively below the average rainfall having 2005 as an exceptional better year. Apparently the variation from mean has not been considered as reduction of rainfall, but the decadal moving average shows a negative trend of rainfall after 1990s. The graph below reveals that the per day maximum rainfall of Mahbubnagar has been consistently decreasing for the last 36 years.

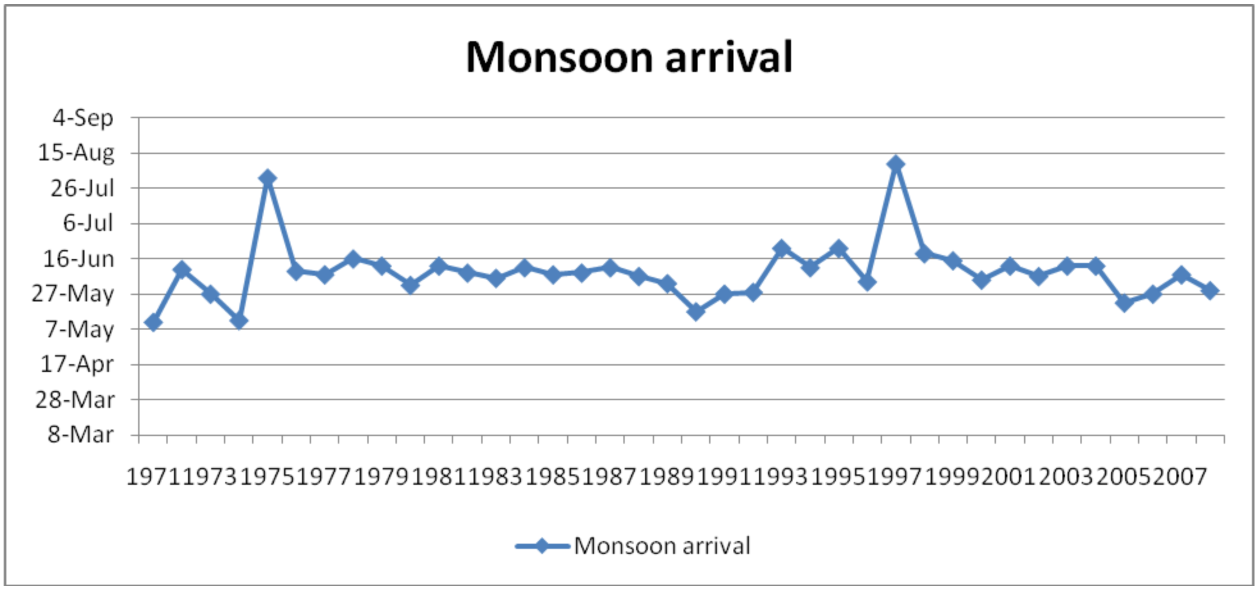


Graph 5.11 Decadal moving average annual rainfall in Mahbubnagar



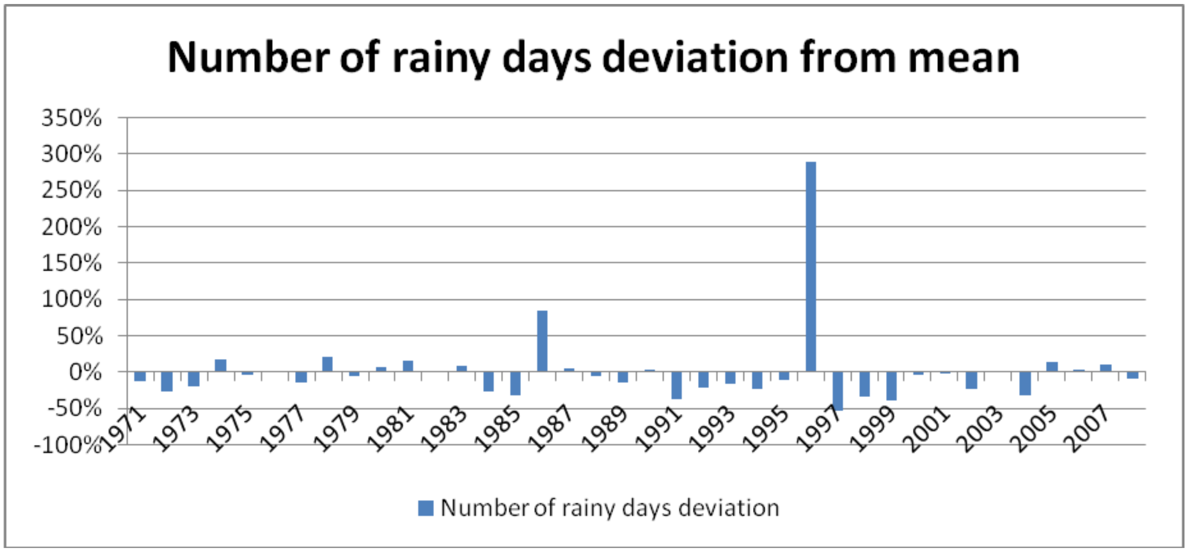
Graph 5.12 Maximum rainfall in Mahbubnagar

The maximum rainfall was nearly 170mm per day in 1978 and the lowest rainfall was 18 mm per day in 1996. Normally the maximum rainfall varies between the ranges of 40 mm to 120 mm. The arrival of monsoon (Graph) has been quite consistence within the last week of May to 1st to 2nd week of June.



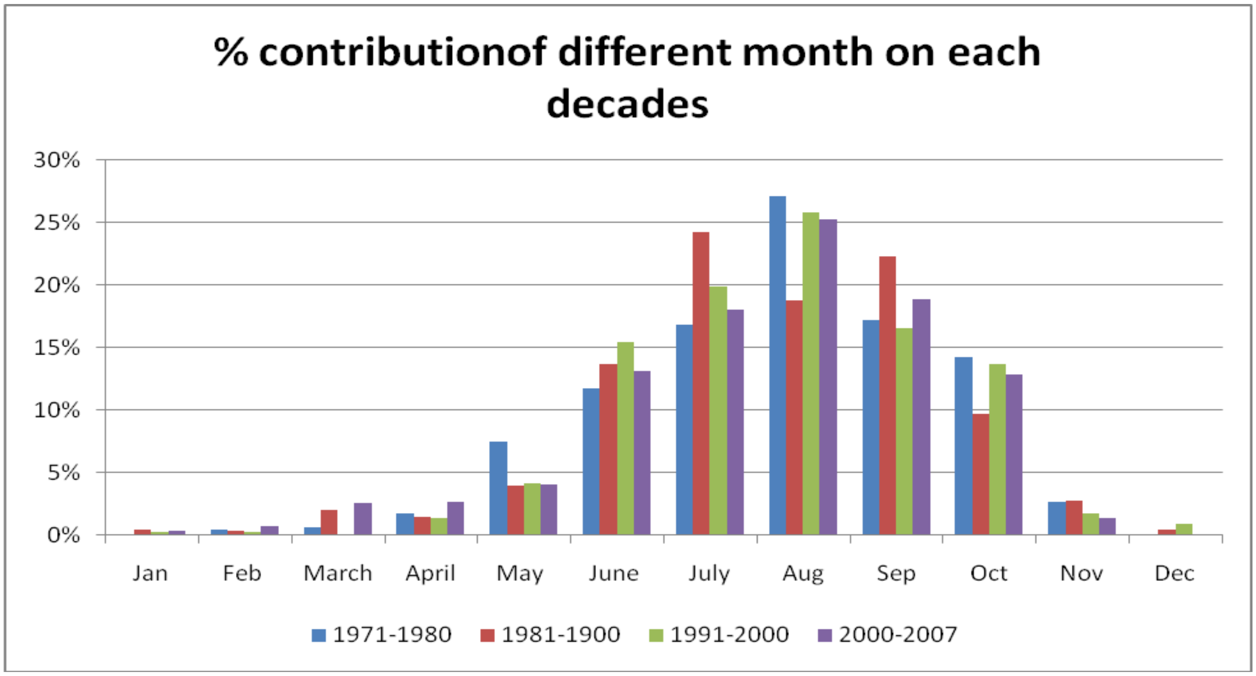
Graph 5.13 Monsoon arrival in Mahbubnagar

Therefore the arrival of monsoon remains nearly same but the maximum rainfall is decreasing and the total rainfall is also decreasing after 1990s. Therefore the rainfall timing may remain invariable but the intensity and amount varies slowly.



Graph 5.14 Deviation of number of rainy days, Mahbubnagar

The mean number of rainy days is about 67 days. The above graph shows that the deviation of rainfall from mean is not very significant. The number of rainy days in 1996 was inadvertently more than 230. This high amount moves the mean average to 67 days. Otherwise the mean rainfall would be nearly 62 days. There is decrease in the number of rainy days after 1991 till 2006 with one exceptional year of 1996. The year 1997 was having the lowest number of rainy days, as about 50 percentages less than the mean number of rainy days.



Graph 5.15 Contribution of different month, Mahbubnagar

Table 5.2 Monthly average contribution of different months

Month	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Average	2.055263	3.439474	10.47895	13.98158	38.8	104.3211	154.5737	186.3947	146.6053	96.93158	17.32895	2.734211
%rainfall	0%	0%	1%	2%	5%	13%	20%	24%	19%	12%	2%	0%

The month August has the average highest contribution of total rainfall, nearly 24 percentages. Three months, July, August and September contributes nearly 70 percentages of the total rainfall. From the above graph it can be observed that the contribution of months July and August has been declined sharply and that of October and November it decreased slightly. The contribution of the month September has been increased by 2 percentages and that of March it increased by 3 percentages. Therefore the rainfall pattern of this area has been slowly shifting toward more erratic rainfall. The main monsoon months are contributing less than the expected amount.

Significant rainfall changes at a glance:

a) From the last two decades i.e. from 1990, the deviation has been observed in a negative trend except for the year 2005.

b) The decadal moving average has been slowly decreased by nearly 11 percentages from 1980.

c) The arrival of monsoon is nearly identical i.e. from last week of May to 2nd week of June, but the maximum rainfall has been decreased significantly.

d) The number of rainy days has decreased after 1990s with one exceptional year of 1996. The mean number of rainy days being 67.

e) The contribution of the main monsoon months, July and August, has been decreased significantly by nearly 3 percentages while there was an increase in the contribution of the months of September and March, making the rainfall more erratic.

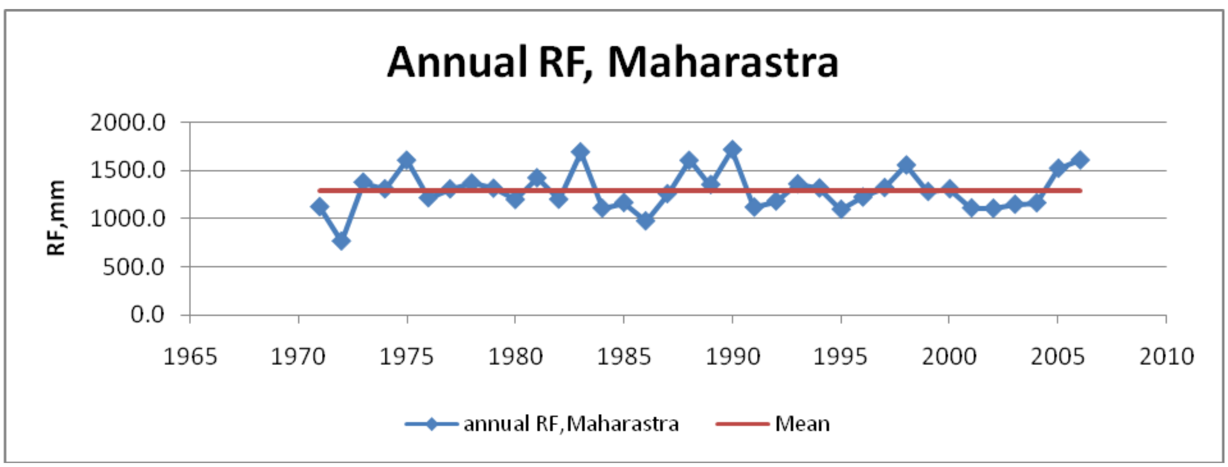
ii) Maharashtra: Maharashtra is divided into six revenue divisions, which are further divided into thirty-five districts. These thirty-five districts are further divided into 109 sub-divisions of the districts and 357 talukas.

Geographically, historically and according to political sentiments, Maharashtra has five main regions**:**

- Vidarbha Region - *(Nagpur and Amravati divisions)* - (Central Provinces and Old Berar Region)
- Marathwada Region - *(Aurangabad and Nanded Divisions)*

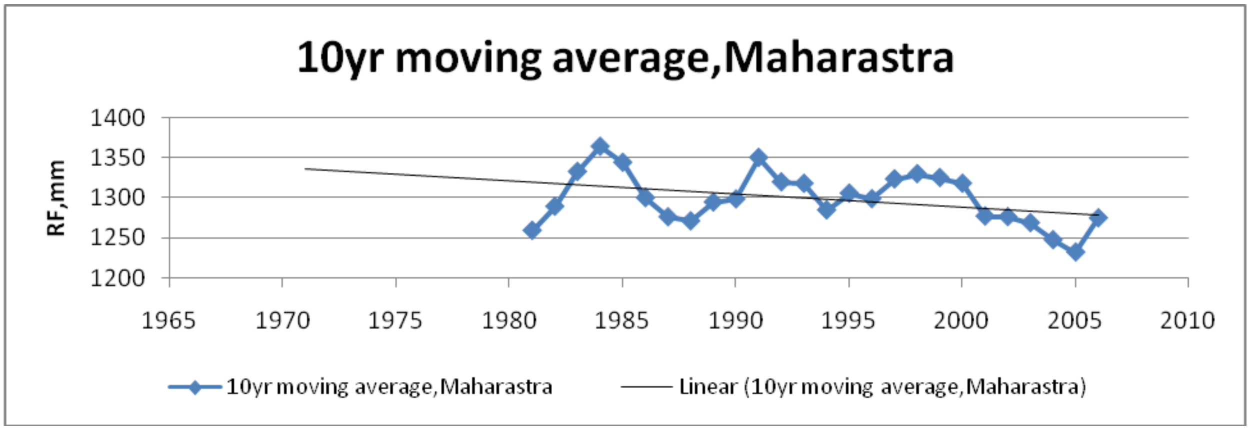
- Khandesh and Northern Maharashtra Region - *(Nashik Division)*
- Desh or Western Maharashtra Region - *(Pune division)* and
- Konkan Region - *(Konkan Division)* - (including, Mumbai City and Mumbai Suburban Area).

Figure 5.2 Maharashtra geographical map



Graph 1.16 Annual rainfall, Maharastra

The annual mean rainfall of Maharastra is 1293 mm. The lowest rainfall is about 700 mm observed in 1972 and the highest rainfall is about 1750 mm observed in 1990.

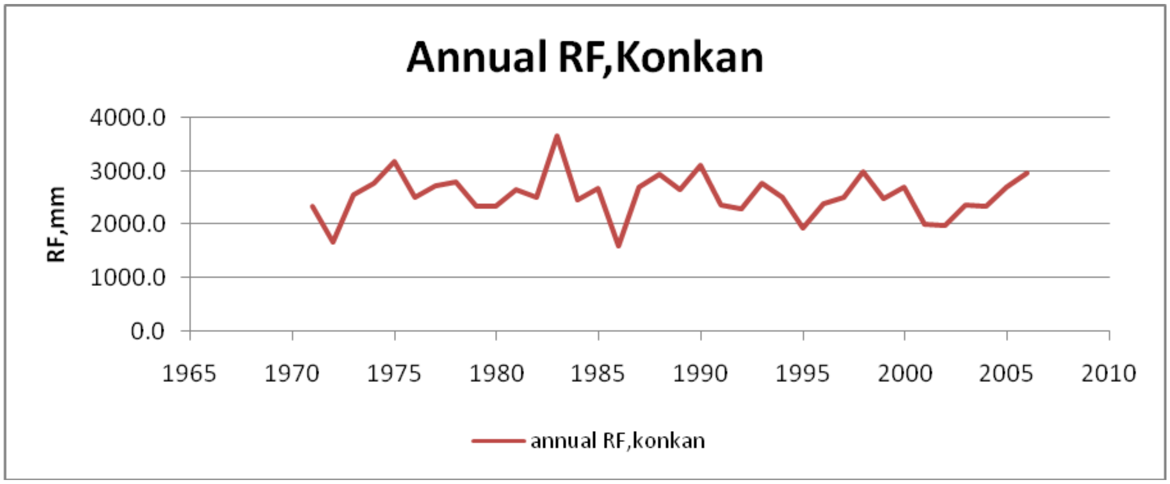


Graph 5.17 Decadal moving average of annual rainfall in Maharastra

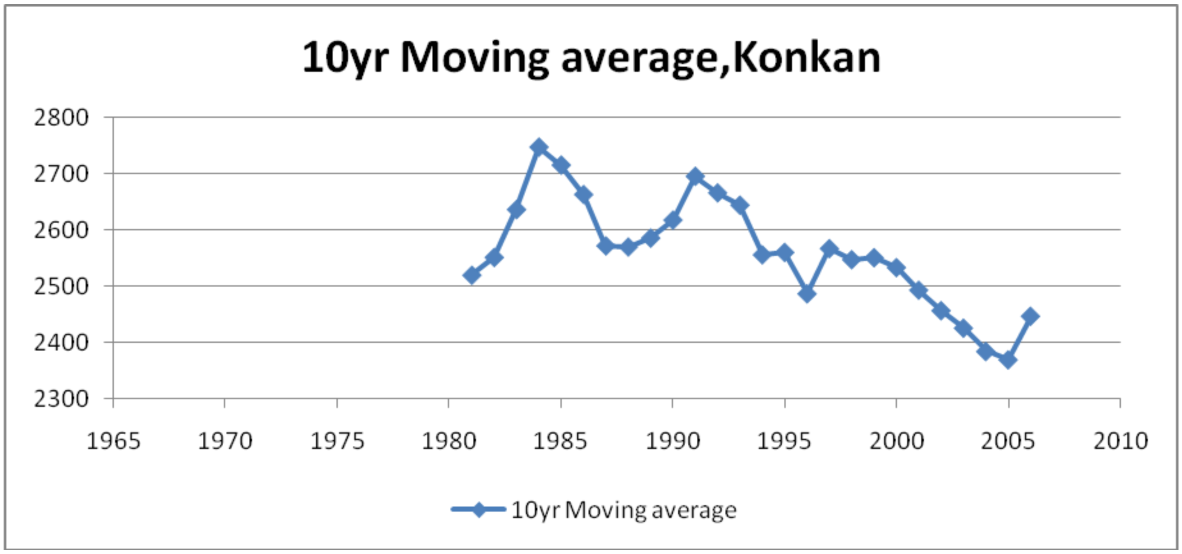
The variation of rainfall from the mean rainfall is within a range of -41 percentages to 33 percentages. From the above graph any major change of rainfall trend is not observed.

The above graph reveals that after 2000 there is a sharp decline of nearly 3 percentages in 10yr moving average. Although after 2005 there is an increase in rainfall but the trend line of the last two decades showing a decline in rainfall.

ii.a) Konkan and Goa: Konkan & Goa subdivision is the situated at the western border of the state along the Arabian Sea. It consists nearly 12 percentages of total area of the state. As it is a coastal region the average rainfall of this region is 2540 mm



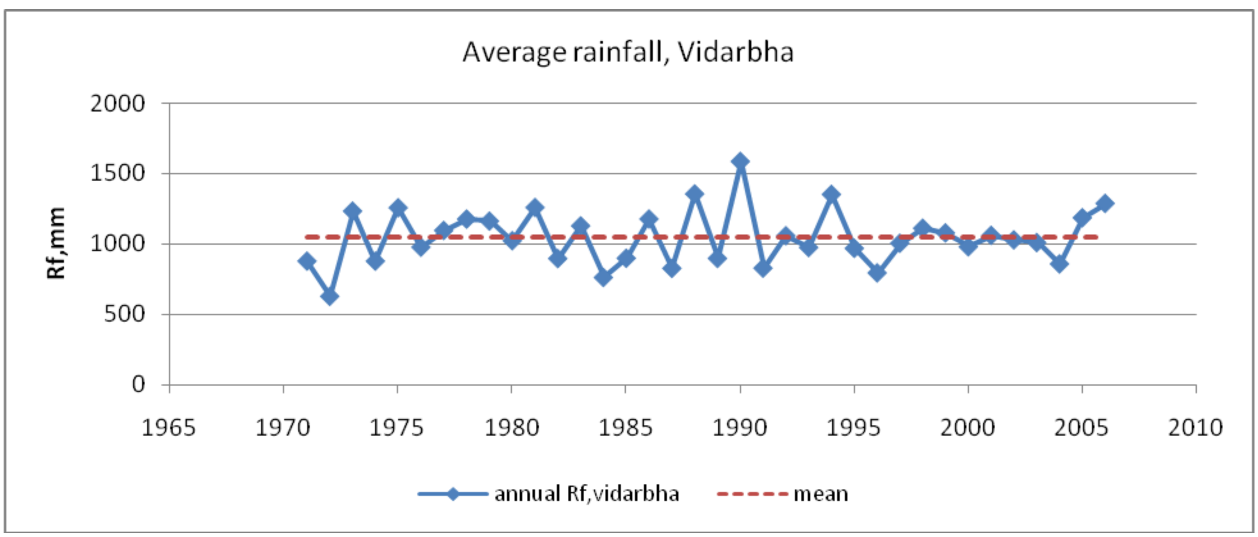
Graph 5.18 Annual rainfall, Konkan



Graph 5.19 Decadal moving average of annual rainfall in Konkan

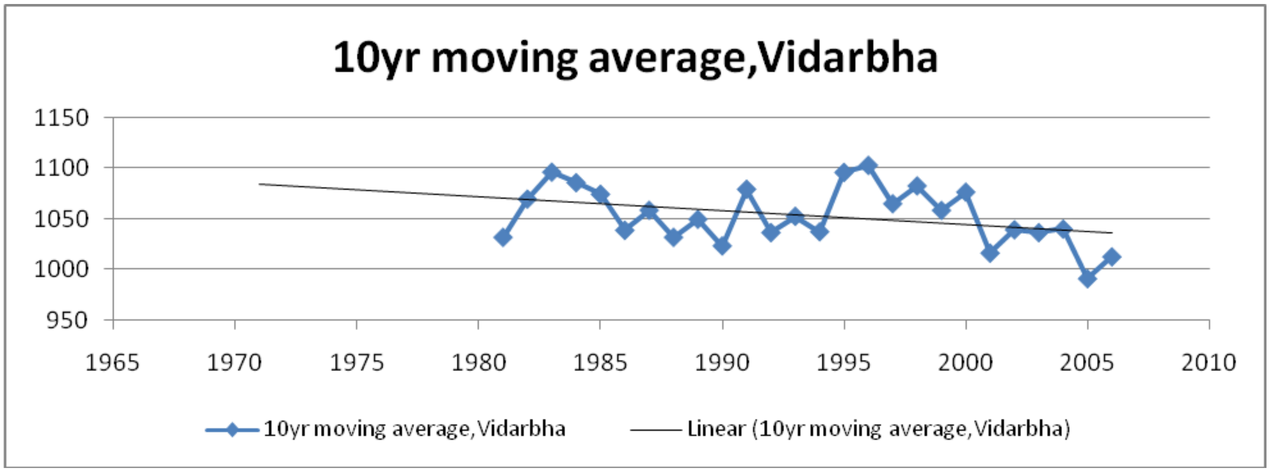
From the above graph of 10yr moving average of Konkan region, it can be observed that after 2000 the moving average is showing a downward trend. After 2000 the decrease in 10yr moving average is nearly 3 percentages.

ii.b) Vidarbha: Vidarbha region of Maharastra is comparatively drier than the other regions. The average mean rainfall of this region is 1048mm. The rainfall during the last 36 yrs is not varying deviating much from the mean.



Graph 5.20 Average rainfall of Vidarbha

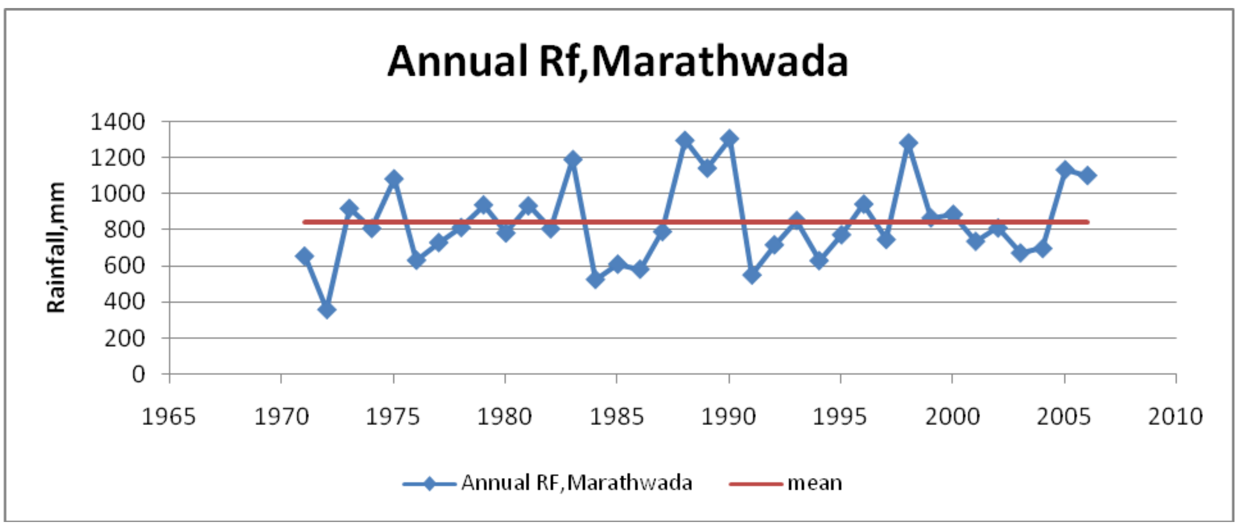
There are alternate crest and trough during these decades. But the variation from the mean is not significant.



Graph 5.21 Decadal moving average of annual rainfall in Vidarbha

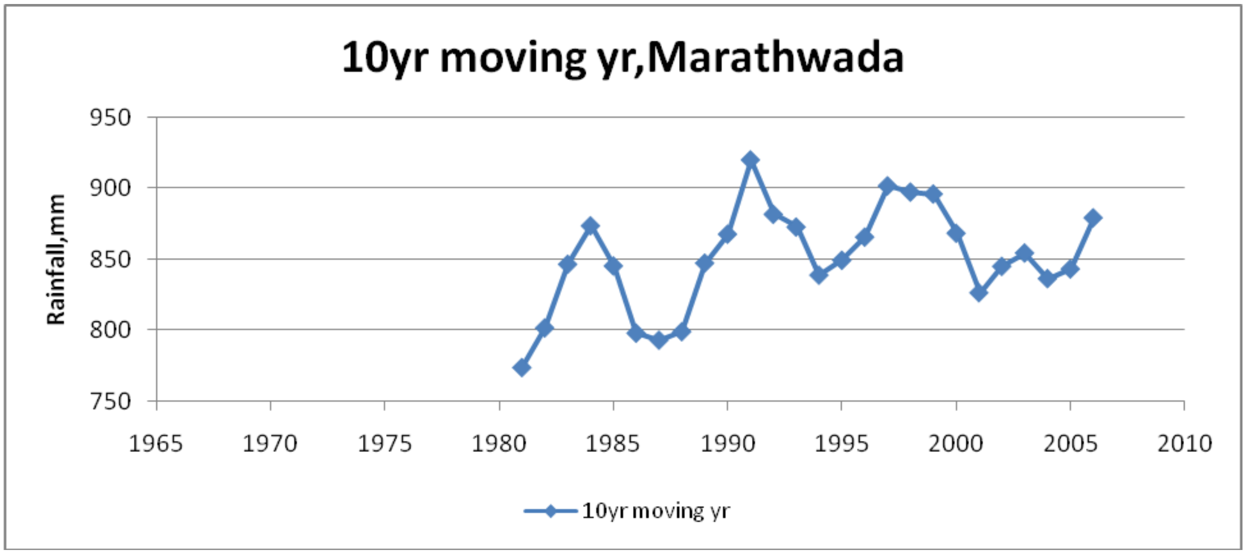
The 10yr moving average of Vidarbha region is also showing a similar trend like Konkan area. After 2003 it showing a decreasing trend.

ii.c) Marathwada: The Marathwada region is on the north western region of Maharashtra. The average mean rainfall of this region is 844mm. The variation of average rainfall has been decreased as compared to 1990s.



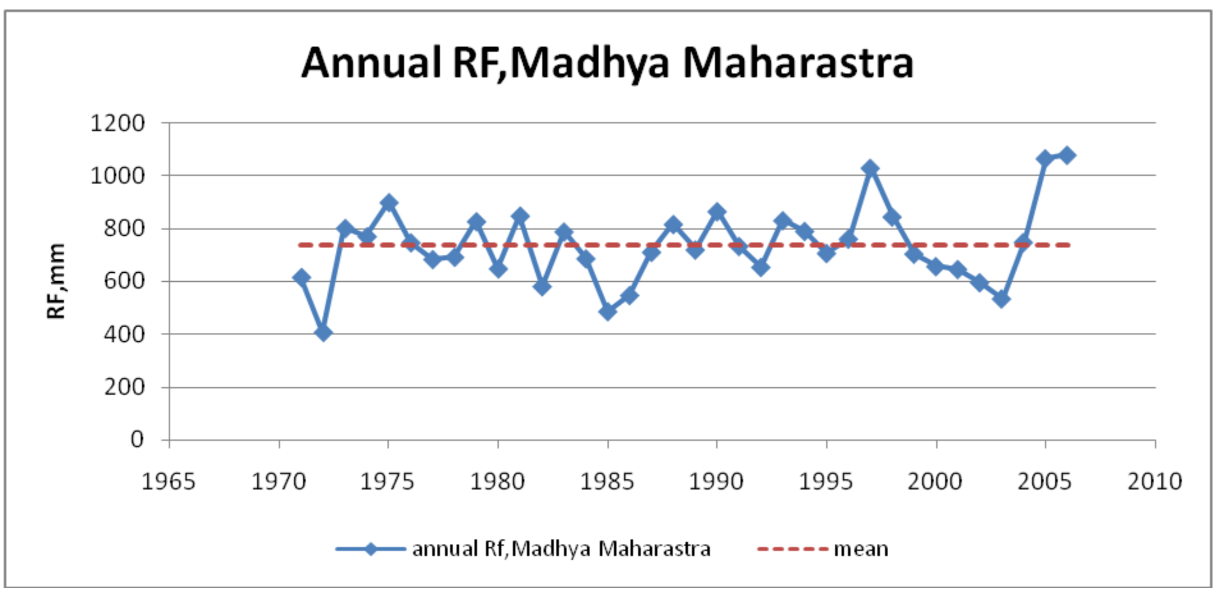
Graph 5.22 Annual rainfall of Marathwada

The 10yr moving average of Marathwada as contrary to other regions is showing an increasing trend in the last few decades. But after 2005 every region is showing a upward trend till 2007.

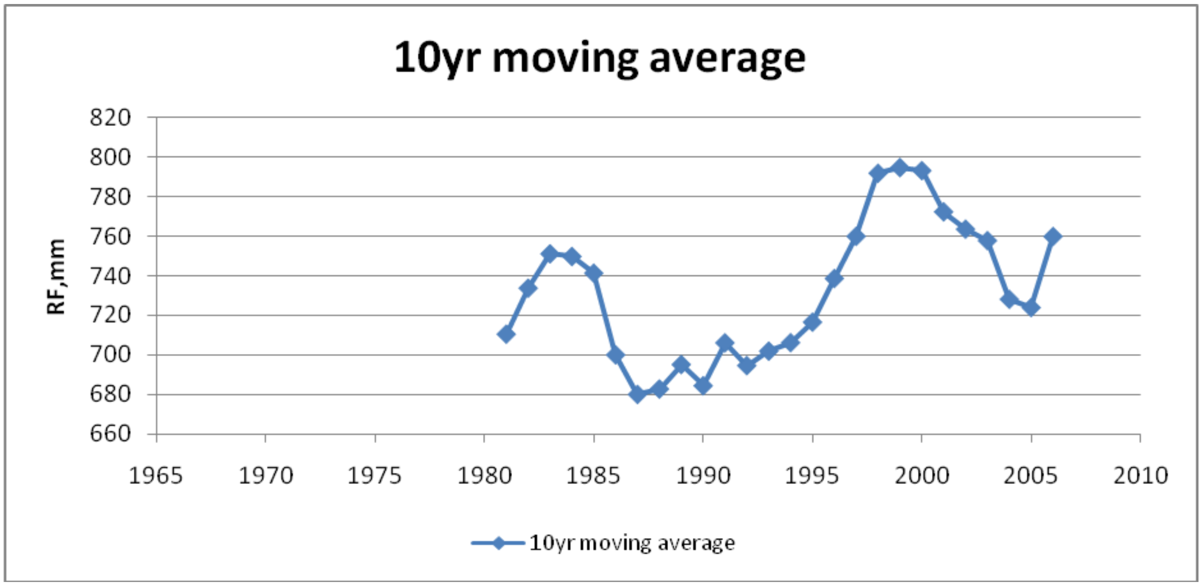


Graph 5.23 Decadal moving average annual rainfall in Marathwada

ii. d) Madhya Maharashtra: This region is situated in the middle region of Maharastra and comparatively drier than other regions. The mean rainfall of this region is 738mm.



Graph 1 Annual rainfall of Madhya Maharashtra



Graph 2 Decadal moving average of Madhya Maharahstra

The moving average incresed after 1990 and decreased after 2000. But after 2005 the rainfall is again showing an increasing trend.

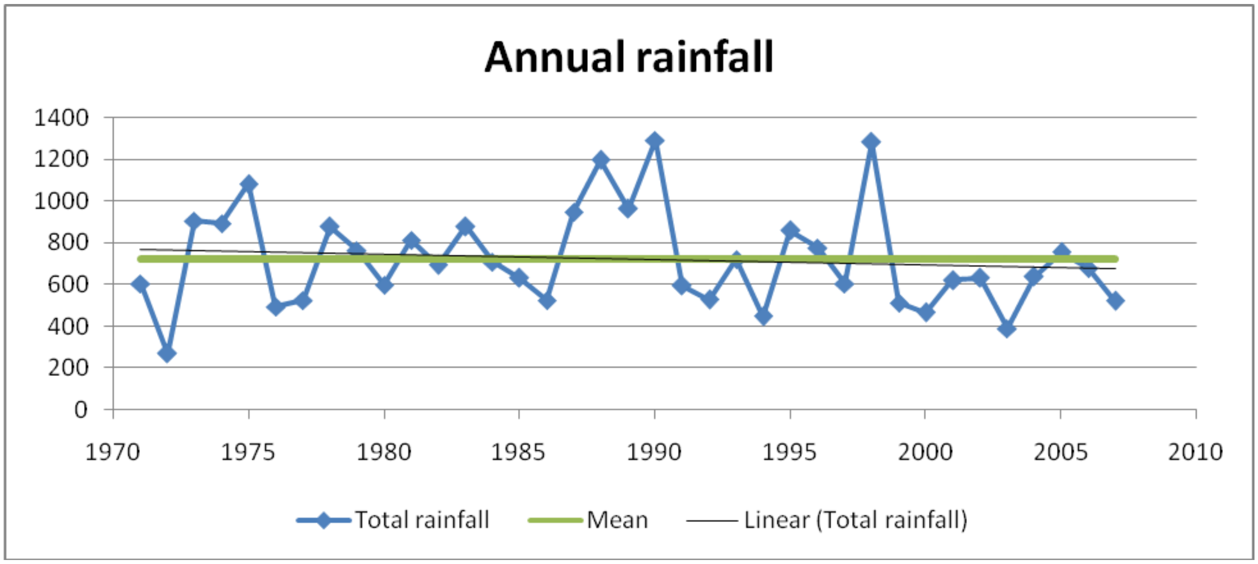
ii.e) Sholapur: Sholapur is a city and a municipal corporation in South Western Maharashtra, India near the Karnataka border and is the administrative headquarters of Sholapur District. **Sholapur** is one of the four districts that form the region of Western Maharashtra (the other three districts are Satara, Kolhapur and Sangli. It is the fourth largest district in Maharashtra in terms of land area (behind Ahmednagar, Pune and Nagpur) and seventh largest in terms of population. Sholapur has a population of 873,037. Males constitute 51% of the population and females 49%. Sholapur has an average literacy rate of 71.2%, higher than the national average of 65%: male literacy is 82%, and female literacy is 60%. ex ratio is 935 female per 1000 males. The district is having 11 Talukas and is surrounded by Ahmednagar and Osmanabad districts in the north, Osmanabad and Gulbarga (Karnataka State) in the East, Sangli and Bijapur (Karnataka State) in the South and Pune, Satara districts in the West.

The total area of this district is 148.86 km^2 (57 sq mi). Sholapur is located at 17°41′N 75°55′E / 17.68°N 75.92°E. It has an average elevation of 458 metres (1502 feet). It is bordered by Ahmednagar district on the North, Osmanabad district on the North and Northeast; Gulbarga district (Karnataka state) on the Southeast and South; Sangli district on the South and Southwest; Satara district on the West and Pune district on the Northwest. It is situated at a distance of 410 km from the Maharashtra State Capital of Mumbai by road and train. Sholapur is at a distance of 245 km from Pune and 305 km from Hyderabad. Sholapur is situated on Deccan plateau.

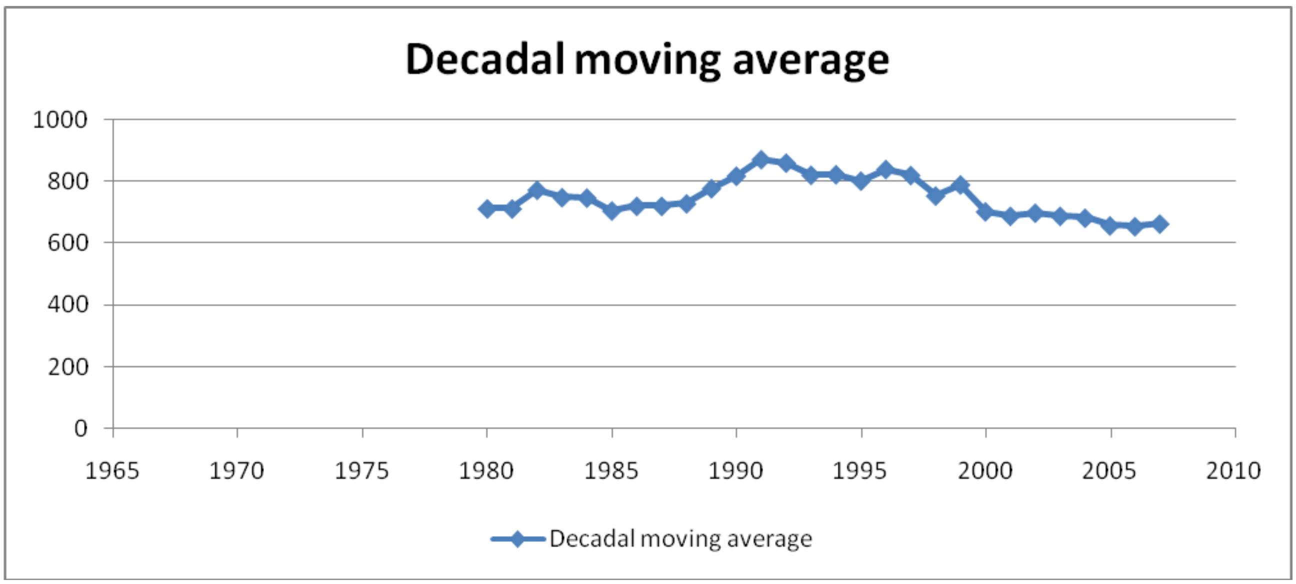
Soil represent the orders vertisol, insectsol & Entisol. Soils are derived from basic igeous rock namely basalt (deccan tract) & underlain with partially disintigrated rock locally called "*murum*". Soils are base saturated, with calcium as the predominant cation in the exchange complex. Lime concentrations are also met within the soil profiles. The soils are grouped into three broad categories according to the depth. Shallow soils (<22.5 cm), account for about 20 %, medium deep (22.5 to 45 cm) 50 % and medium deep (45-90 cm) 30 %. Soils are low in nitrogen, low to medium in available Phosphorus & high in available Potash. Vertisols and associated group soils are having adverse physical properties like high swelling and shrinkage, moderate rate of infiltration. The major crops are Jawar, Wheat, Chana, Tur, Groundnut. The major cash crop is sugarcane. The total net cultivated area is 1049 hectares.

The major rivers of this area are Bhima, Sub-rivers - Neera, Mann, Seena, Bhogawati. The depth of water level varies from 1.5 m to 29 m below ground level according to the location in premonsoon period. During post monsoon period the range varies from 0.4 m to 14 m below ground water level. Long term water level trend for premonsoon and postmonsoon periods for last 10 years (1998–2007) have been computed and analysed (CGWB). The analysis indicates that during premonsoon period rise in water levels ranging between negligible at few stations and 0.56 m/year have been recorded at 26 stations, while fall in water levels ranging between negligible at few stations and 0.51 m/year have been recorded at 20 stations. During post monsoon period rise in water levels have been recorded at 28 stations and it ranges from negligible at few NHNS to 0.32 m/year stations whereas at 16 stations fall in water levels ranging between negligible at few stations and 0.28 m/year have been recorded.

The mean annual rainfall of Sholapur is about 721 mm. The annual rainfall has been decreased after 2000. From 1970, the maximum rainfall of 1250 mm was observed in 1998. The minimum rainfall of 240 mm was observed in 1971.

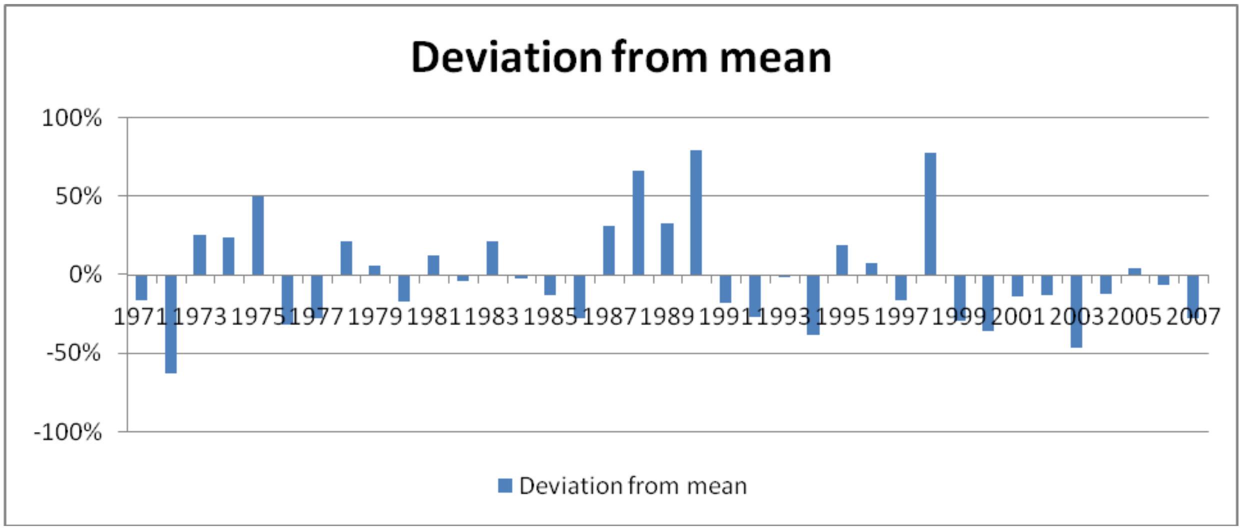


Graph 3 Mean annual rainfall of Sholapur



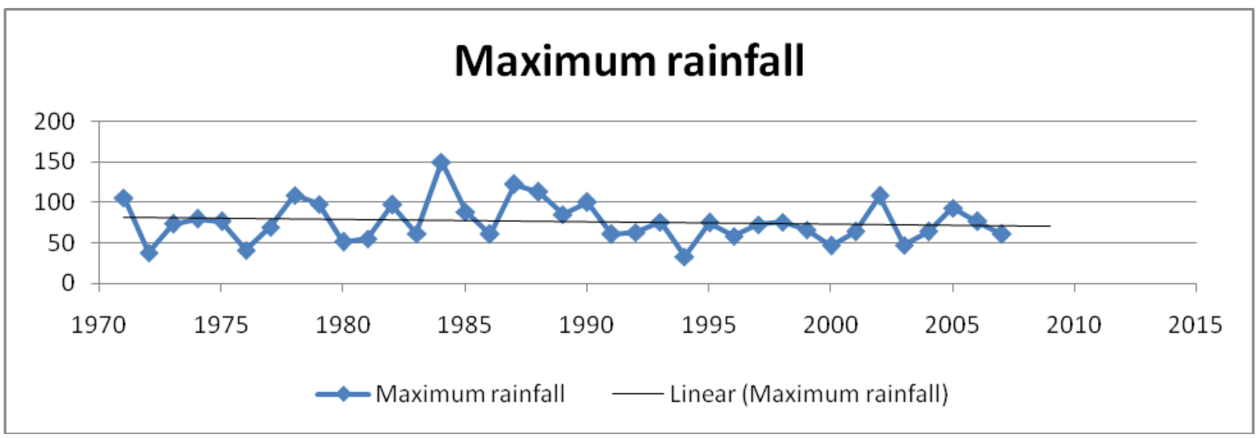
Graph 4 Decadal moving average of Sholapur

The above graph of decadal moving average shows that the moving average has been decreasing after 2000 in a significant rate. It decreased about 7 percentages from the1970 level and nearly 6.8 percentages from the 2000 level.



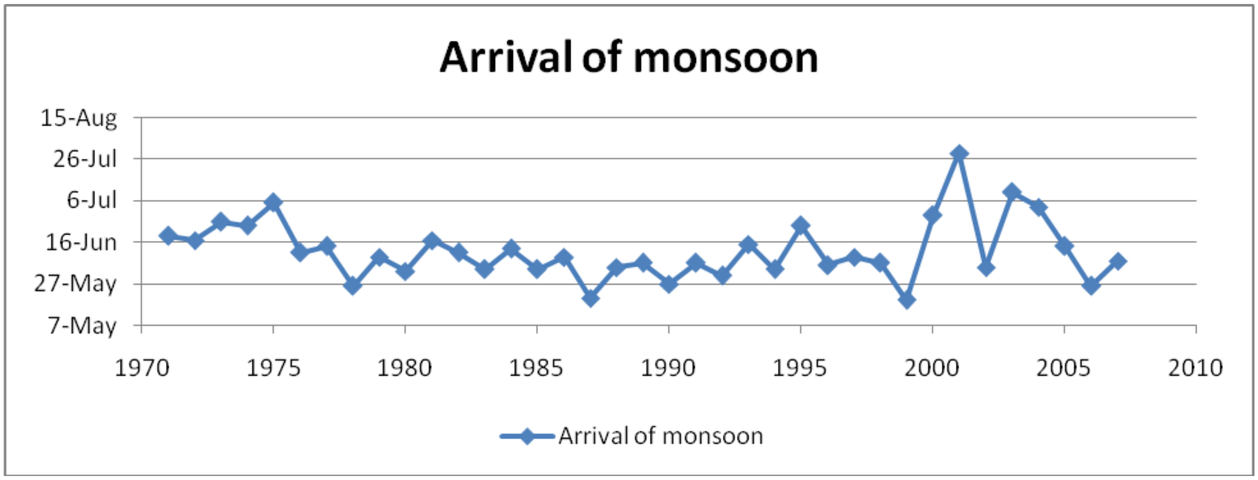
Graph 5.28 Deviation from the mean rainfall of Sholapur

The deviation from mean has observed at more than 20 percentages negative in most of the years after 1998. In 2003 a deviation of more than 40 percentages has been observed making it a drought year. Therefore the annual rainfall is showing a negative trend in the future.



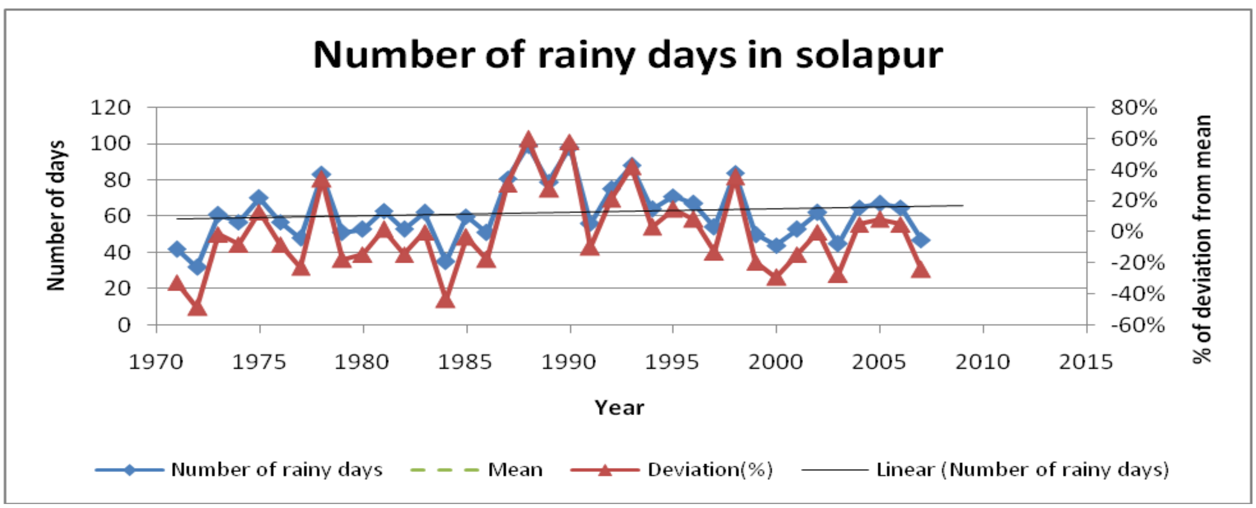
Graph 5.29 5 Maximum rainfall of Sholapur

The maximum rainfall event has been decreasing gradually over the decades. The per day maximum rainfall event was highest in 1984. After 1990 the maximum rainfall event never crossed 100 mm. The trend line is showing a decreasing trend in the future.



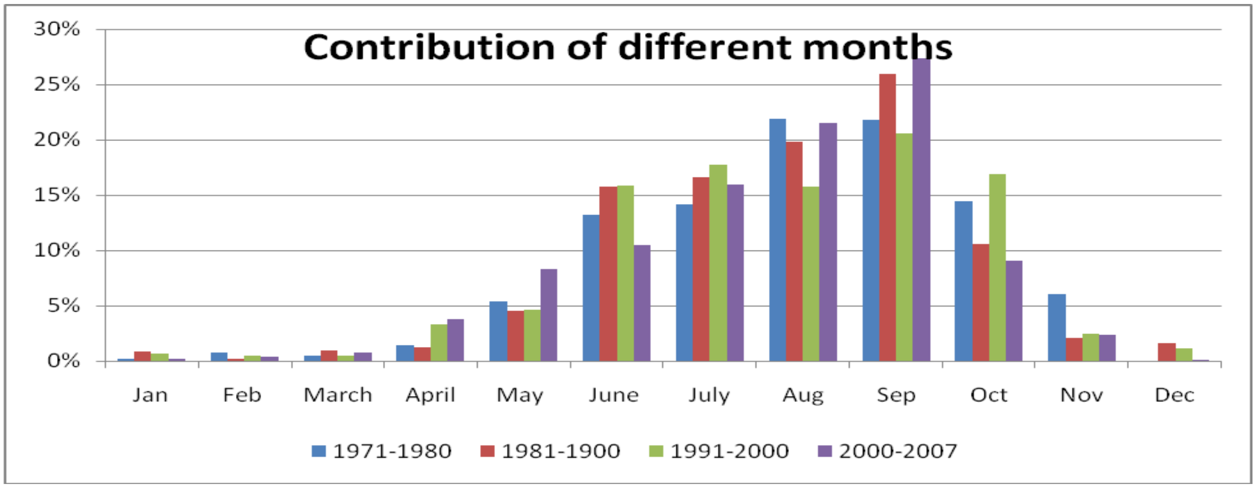
Graph 5.30 Monsoon arrival in Sholapur

The arrival of monsoon varies largely from last week of May to first week of July. But after 1999 the deviation of the arrival of the monsoon has changed significantly. In 2000 there was a very late arrival of monsoon on 26th July and in 2006 the arrival was before the normal range. Therefore the arrival is more unpredictable than the previous decades.



Graph 5.31 Number of rainy days in Sholapur

The average number of rainy days in Sholapur is nearly 62 days in a year. The highest number of rainy days was in the year of 1987 which was nearly 100 days. Before 1980s the average number of rainy days was nearly 50. But gradually the number of rainy days has been increased slowly. Again after 2000 the number of rainy days was again decreasing. But overall from the three decades data it can be inferred that the number of rainy days has increased by nearly 6 percentages. With the increase of rainy days the contribution of the monsoon months has been changed significantly.



Graph 6 Contribution of different months

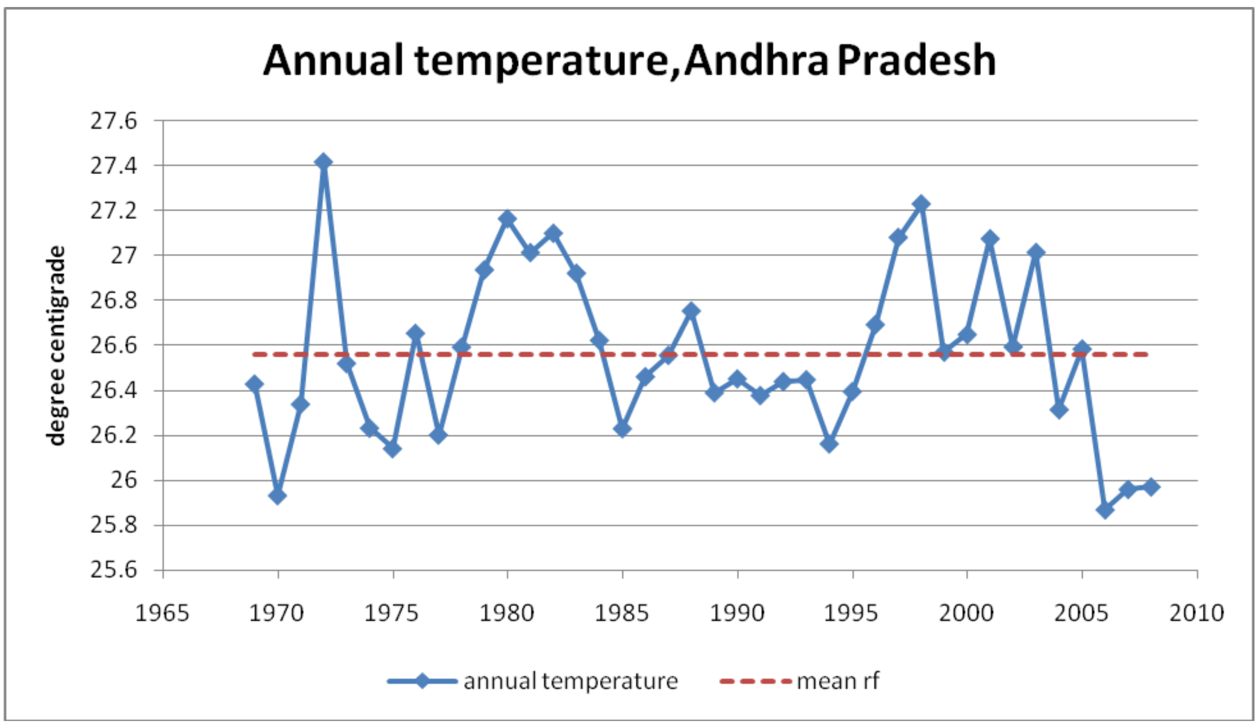
Table 5.3 Average contribution of different months

Month	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Average rainfall(mm)	3.748649	3.432432	4.672973	15.85135	38.91892	102.9649	116.3946	141.2405	171.0757	93.4027	23.38649	5.883784	645.4222
Contribution	1%	0%	1%	2%	5%	14%	16%	20%	24%	13%	3%	1%	100%

The contribution of the months April, May and September has been increased by 2.5, 3 and 3.5 percentages than the normal contribution. While the contribution of the months June and October has been decreased significantly by nearly 4 and 5 percentages. Therefore the monsoon arrives on last week of May with a heavy rainfall and after that the months of June and July are comparatively less rainfall than expected. It can be inferred from the above data that the distribution of rainfall became scattered than before and the intensity and as well as total rainfall has been decreased gradually.

B) Temperature and ground water situation of the study area

i) Andhra Pradesh: The annual mean temperature of AP is nearly 26.6 degree centigrade. 1972 being the hottest year as average temperature touches 27.4°C and 2006 being the lowest average temperature of 25.85°C. The summer temperature is always highest and the winter has the lowest. Least temperature affect has been observed in the coastal region while some districts in the south western part of AP has been adversely affected by temperature change.



Graph 5.33 Annual temperature, AP

From the groundwater point of view, rock formations in the State can be classified into three distinct categories of (a) hard rocks, (b) soft rocks and (c) alluvial formations. Groundwater in these rocks occurs under water table, semi-confined or confined conditions. Groundwater is present in secondary porosity of the host rocks limited to the weathered and fractured zones; joints and bedding planes etc., In the soft rocks and alluvium, the inter granular porosity contributes towards occurrence and movement of groundwater. Nearly 85% of the State is underlain by hard rocks and the chief contributors of groundwater in these rocks are the fractured systems. These fractured systems as mentioned above are not uniformly distributed and have limited aerial and depth extent. Rainfall is the source of recharge to groundwater and during the last decade this source has become erratic and sometimes very low. The number of rainy days has also come down. Thus the recharge to groundwater bodies has come down. Apart from this people are resorting to use groundwater more often because, it is economical, easily available and consumes less time to ground a project, in view of the limited surface water resources and their uneven distribution. Thus the strain on groundwater aquifers mostly in upland areas is increasing day by day.

Trends in groundwater development: Nearly 84% of the State is underlain by hard crystalline and consolidated formations like Archaean, Cuddapah, Dharwars, Kurnool, Deccan Traps etc. The rest of the State is underlain by semi-consolidated formation like Gondwanas and Tertiaries and unconsolidated deposits like Recent alluvium. The yield of wells ranges between 2-5 m3/hr in Dharwars comprising schist, phyllites, amphibolites and epidiorites. In granite gneiss, khondalites and charnokites, the yield ranges between 10-35 m3/hr. In Cuddapahs, the yield ranges between 7-50 m3/hr. In shales and Deccan traps, the yield ranges between 0.5-1.5 m3/hr and 10-40 m3/hr, respectively. The yield of wells in soft rocks like Gondwana sand stone varies from 12-220 m3/hr. The alluvial formations are confined mainly in the delta region where the tubewells yield from 15-60 m3/hr.

- During the last three decades:
- Well population increased from 8.0 to 25.0 lakhs.

- Average annual growth rate of well population in the state is about 50,000 wells per year.
- Area irrigated through groundwater increased from 10 to 28 lakh hectares.
- This constitutes about 50% of the total area irrigated.
- About 80% of the drinking water needs are met through groundwater.

Table 5.4 Changing groundwater scenario in hard rock hydro system

Years	Type of Wells	Yield	Well density/sq.km
1982	Dug wells	60 - 150 cu.m	< 5
1983-84	Dug wells/ Dug cum bore wells	60 - 150 cu.m	5 - 10
1984-94	Dug wells/ bore wells	40 - 100 cu.m / 150 - 600 lpm	> 10
1994-98	Bore wells/ Dug cum bore wells	50 - 400 lpm / 30 - 60 cu.m	> 15
1998-08	Bore wells/ Few dug cum bore wells	50 - 150 lpm / 20 - 40 cu.m	> 20

The continuous increase in number of bore well used for irrigation could affect the ground water level of the state. Therefore sufficient recharge is required for maintaining the ground water level constant. The domestic and irrigation use has been increasing which on contrary decreasing ground water level due to excess extraction. As rainfall is the main source of recharge of the ground water, a steady decrease in total annual rainfall in this present decade could lead to severe water crisis.

The climate of Rayalaseema is mostly dry. The maximum temperature varies from 37 degree C to 44 degree C. The region lies mostly at an altitude of 250m to 600 m.

In respect of ground water potential, this region comprises of hard crystalline rocks with unlimited ground water potential held in joints and fracture zones. The steep ground water slopes, the absence of adequate soil and vegetable cover inhibit infiltration of rain water into the substrata and allow sub surface flow. According to CGWB, three districts namely Anantapur, Chittor and Cuddapa are in highly water stress situation. The stage of ground water development in Anantapur, Chittor and Cuddapa are 74, 72 and 76 percentage. The condition of Kurnool is comparatively better. The stage of ground water development in Kurnool is 42 percentages. To mitigate the future water demand of this region proper management of available water is required.

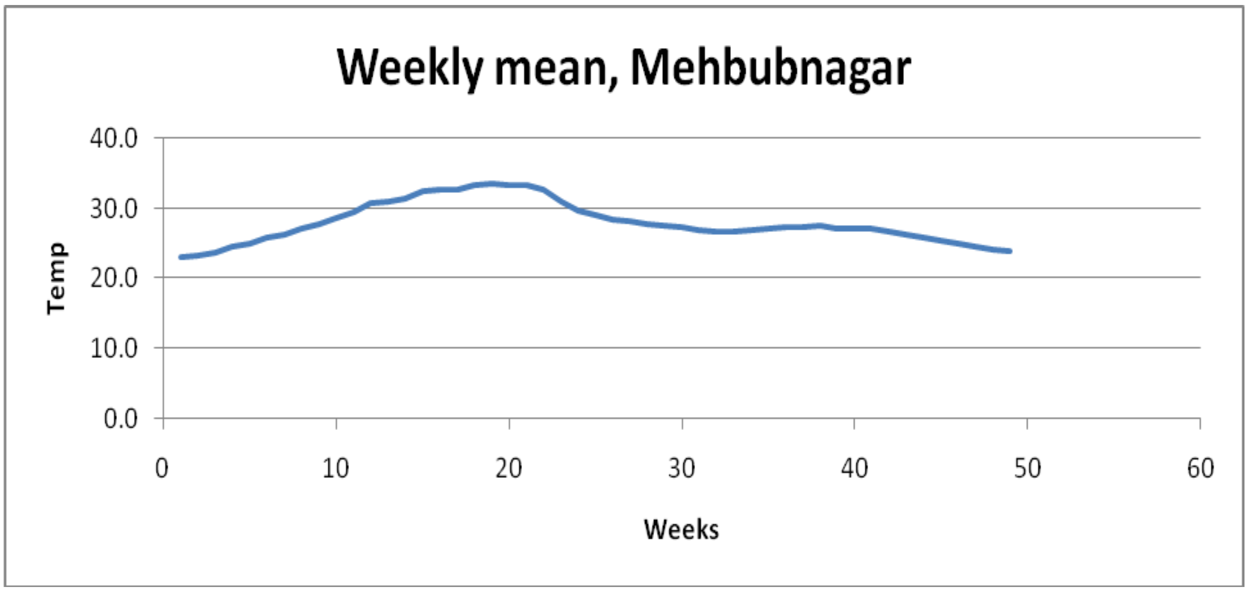
The annual average temperature of Telangana is 26 degree C. The average temperature varies mostly between 24 to 27 degree C. The temperature increases from the month of March and highest was in the month of May. The maximum temperature varies from 34 to 37 degree C. After monsoon the temperature starts falling. The minimum temperature was observed mostly in the month of January and it varies between 12-15 degree C.

Different parts of Telangana also receives drought frequently. The stage of ground water development in Adilabad, Nizamabad, Karimnagar, Sangareddi, Warangal, Rangareddi, Mehbuubnagar, Nalgonda, and Kammam are 33, 86, 53, 87, 69, 103, 62, 52 and 21 percentages. Therefore except thee districts the remaining other states have in high water stress situation. According to the CWGB future water demand prediction Randareddy district needs a high water management planning to meet the future water demand.

The average temperature of this region is 25.8 degree C. The maximum temperature of this region was about 36 degree C and the minimum temperature was about 15 degree C. Due to coastal vicinity the temperature remain slightly hot and humid throughout the year. Therefore temperature not remains extreme in any case.

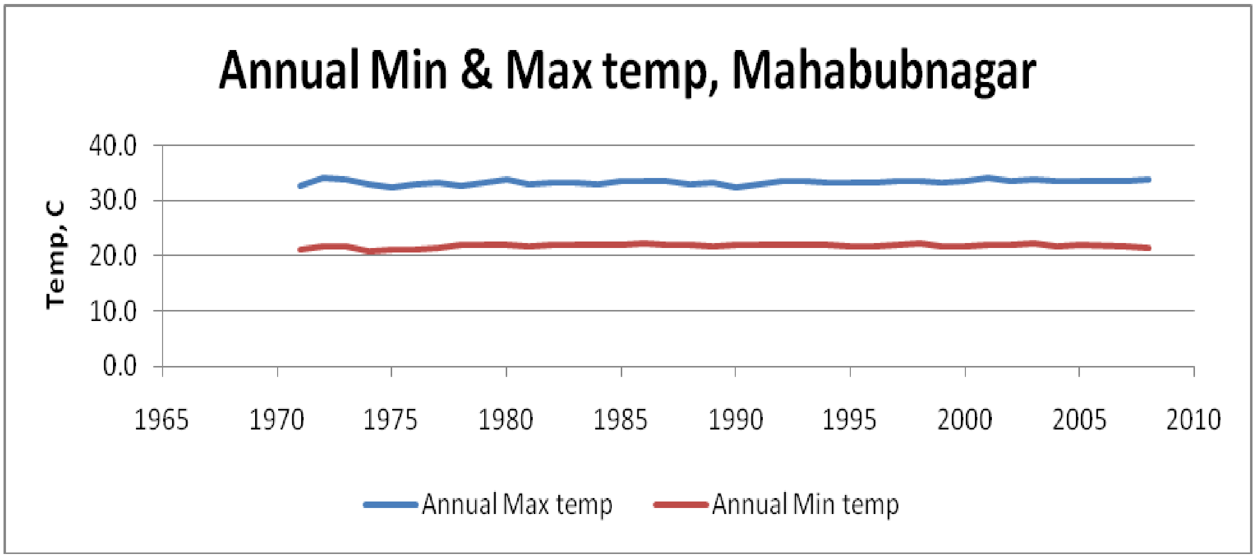
Due to vicinity to Bay of Bengal this region receives high rainfall throughout the year and comes under predominantly wet region. The stage of ground water development of Srikakulam, Vizianagram, Vishakapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasham and Nellore are 10, 24, 34, 31, 48, 24, 10, 57 and 44 percentages. Therefore these regions is comparatively not suffering water scarcity problem.

i.a) Mahbubnagar: The mean temperature of Mahbubnagar is nearly 27.5 degree centigrade. The maximum and minimum temperature ever observed in Mahbubnagar is 39 and 15.6 degree centigrade. From the weekly mean temperature graph it can be observed that the temperature starts rising from the month of March and being maximum on May. Then again after June due to Monsoon the temperature starts decreasing. The lowest temperature has often observed in January and the highest temperature in May.



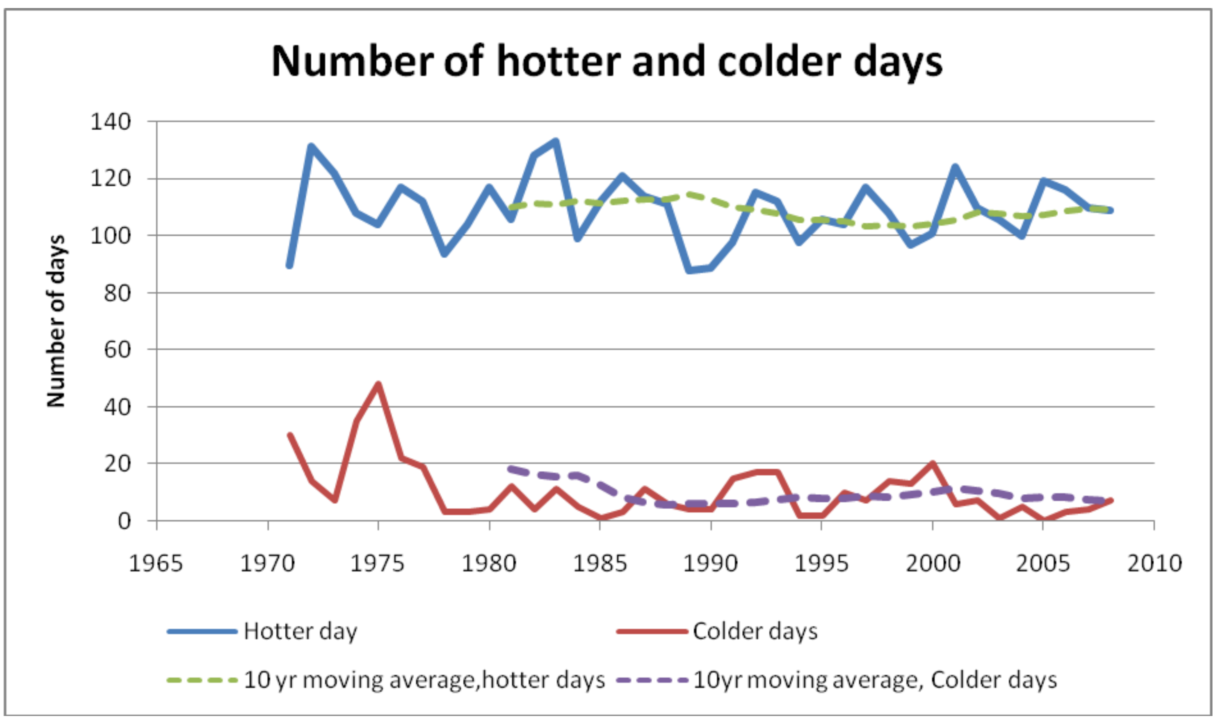
Graph 5.34 Weekly mean temperature of Mahbubnagar

The annual minimum temperature varies within a range of 20-25 degree centigrade and the annual mean maximum temperature varies within a range of 30-35 degree centigrade.



Graph 5.35 Annual mean Max & Min temp

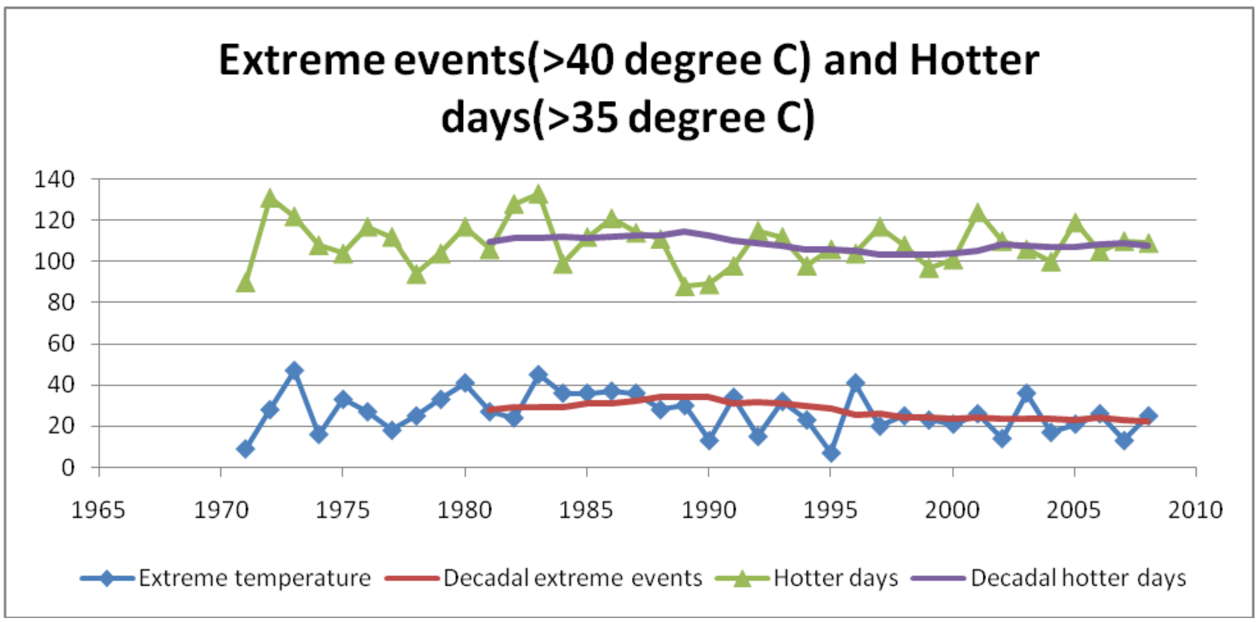
For the last 38 years there has not been any significant change in the annual mean maximum and minimum temperature.



Graph 5.36 Number of hotter and colder days

The number of hotter days (>35 degree C) varies within a range of 100-120 days in a year. The above graph shows that the number of hotter days has been changed significantly within the last 38 yrs. But the number of colder days (<15 degree C) has been decreased in a significant rate according to the decadal moving average. Before 1977 the numbers of colder days were more than 20, but after that it reduced to less than 10. After 2000 there was a sharp decline in the number of colder days and an increase in the number of hotter days.

Although the number of hotter days (>35 °C) has been increased slowly gradually from 1970s, the number of extreme temperature (>40 degree C) has not shown any significant change. The decadal extreme temperature showed a decreasing trend after 2000. But after 2000 the number of hotter days has been increased in a small amount. This increase in number of hotter days cannot be considered as effect of climate change as there were similar trends during 1980-1990.



Graph 5.37 Extreme temperature events in Mahbubnagar

The most considerable observation from the above graph is that the amplitude of the number of hotter days and number of extreme days has been decreased after 2000.

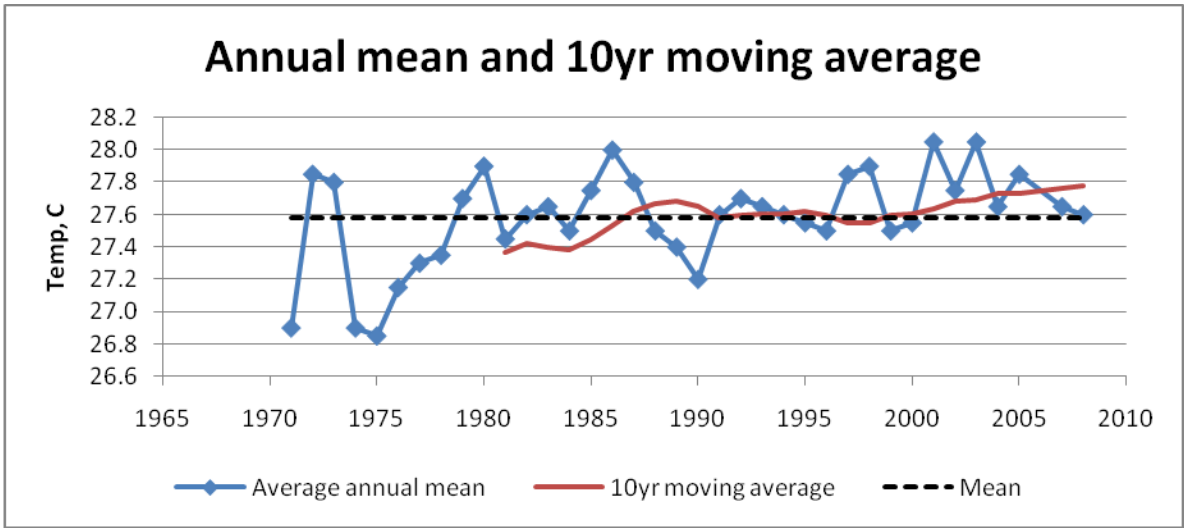
Table 5.5 Decadal variation of minimum temperature

Decadal variation in monthly, seasonal and annual minimum temperature at Mahbubnagar															
YEAR	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Winter**	**Summer**	**Annual**
1971-1980	16.2	19.1	21.6	25.5	26.3	24.2	23.1	22.6	22.5	21.4	18.9	16.4	17.6	24.4	21.5
1981-1990	17.2	19.4	22.7	25.7	26.8	24.6	23.2	22.8	22.9	21.4	19.1	17.4	18.3	25.0	21.9
1991-2000	16.9	19.3	22.6	25.5	26.9	24.8	23.6	22.9	22.9	21.7	19.4	16.6	18.1	25.0	21.9
2001-2008	17.2	19.3	22.6	25.8	27.2	24.9	23.7	22.9	22.8	21.3	18.8	16.7	18.2	25.2	21.9

Table 5.6 Decadal variation in maximum temperature

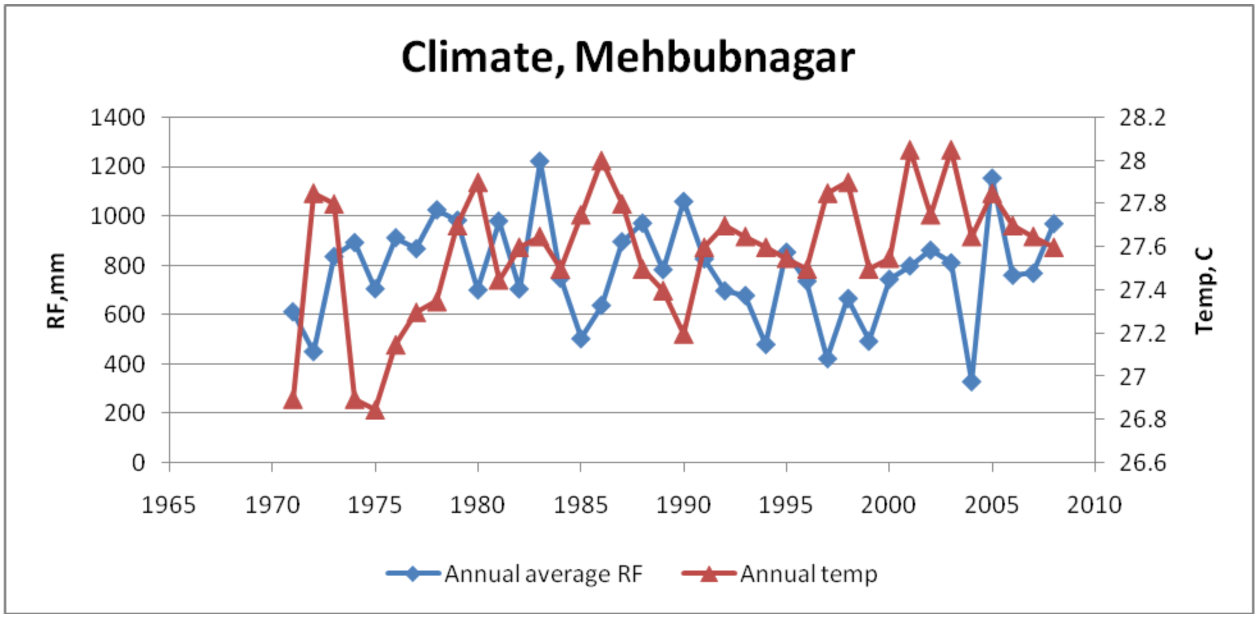
Decadal variation in monthly, seasonal and annual maximum temperature at Mahabubnagar															
YEAR	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Winter**	**Summer**	**Annual**
1971-1980	30.2	33.1	36.5	39.2	39.6	34.7	32.0	30.9	31.8	31.7	30.1	29.3	31.7	38.4	33.3
1981-1990	30.0	33.3	36.5	39.2	39.9	35.1	31.6	30.6	31.7	31.5	30.2	29.2	31.6	38.5	33.2
1991-2000	30.5	33.3	37.2	38.9	39.5	34.7	31.6	30.5	31.8	31.8	30.9	29.7	31.9	38.5	33.3
2001-2008	31.2	34.0	37.1	38.8	39.9	34.9	31.8	30.3	31.5	32.0	31.5	31.0	32.6	38.6	33.7

From the above tables a steady rise of the temperature can be observed. The decadal minimum temperature of winter, summer and yearly has been increased by 0.8, 0.6 and 0.4 degree C. While the maximum decadal temperature of winter, summer and annual has increased by 0.9, 0.2 and 0.4 degree C. Therefore it is obvious from the above tables that the surface temperature is increasing slowly and after 2000 the rate of rising has been increased sharply.



Graph 5.38 Annual mean temperature of Mahbubnagar

The above graph of annual mean temperature from 1970 clearly reveals that there has been a gradual increase in the annual mean temperature. There was an increase of 0.7 degree C of air temperature from 1970 till 2009, about 2.6 percentages. After 1990 the increase of mean temperature was significant but after 2000 the condition was severe. The maximum mean temperature (28.1 degree C) was observed twice between the years 2000 to 2005. But after 2005 the severity was reduced slightly. The decadal moving average also shows an increase of 0.4 degree C in the last three decades.



Graph 5.39 Climate of Mahbubnagar

The above graph of temperature and rainfall of Mahbubnagar shows that there is direct relationship between rainfall and temperature. The change in rainfall was followed by a change in temperature in the next year.

Let the temperature (T) is dependent on the variable rainfall (r) , the relation is :

T= -.00023r + 27.7

	Coefficients	*Standard Error*	*t Stat*
Intercept	27.76496	0.195537	141.9937
X Variable 1	-0.00023	0.000244	-0.94685

With 95% confidence level

Therefore the change in rainfall has an inverse effect in the change of temperature.

The major source of irrigation is tube well. The net area irrigated is 167000 ha and gross area irrigated is 211000 ha. The source of irrigations are (2005-06)(area, ha)

Table 5.7 Source of irrigation in Mahbubnagar

Canals	21000
Tanks	11000
Dug wells	18000
Bore/tube wells	111000
Others	6000

According to the well census(2005-06) the total number of Dug well is 91809 and Shallow tube well is 76837. The number of deep tube well is very less so it is not considered. The total number of wells dried is about 129 till 2005. The ground water level of this region varies from 2.22 m to 23.68 m.

Table 5.8 The available ground water resource (MCM)

Net annual ground water availability	1430.22
Net annual draft	885.77
Balance resource	544.45
Stage of ground water development	62%

The entire district lies in Krishna river basin. The district is covered by eight major watersheds viz., Magnur vagu basin, Musi basin, Upper Krishna basin, Dind basin, Tungabhadra basin, Okachetty basin, Kagna basin and Lower Krishna basin. The Krishna and Tungabhadra are two principal rivers that flow through the district. The Krishna river flows through Gadwal, Atmakur,Wanaparthy, Alampur and Achampet mandals whereas Tungabhadra meanders through Taluks of Gedwal and Alampur. River Dindi, a tributary of Krishna traverses through Kalwakurthi and Achampet areas and Koilsagar is another tributary to Krishna river. Peddavagu and Chinnavagu are small tributaries to Krishna. The water divide runs in west-north west to east and south west through the catchment of Krishna and Tungabhadra rivers. The water divide separate the Krihna and Koilsagar basins in the North East-South East districts.

The total net area irrigated by the different sources in 2005-06 stood at 167000 ha., out of which the area irrigated by the ground water resources was 129000 ha., which constitutes 77.2% to net area irrigated. Area irrigated by surface water is 38000 ha., which accounts for 22.8% to the total irrigated area.

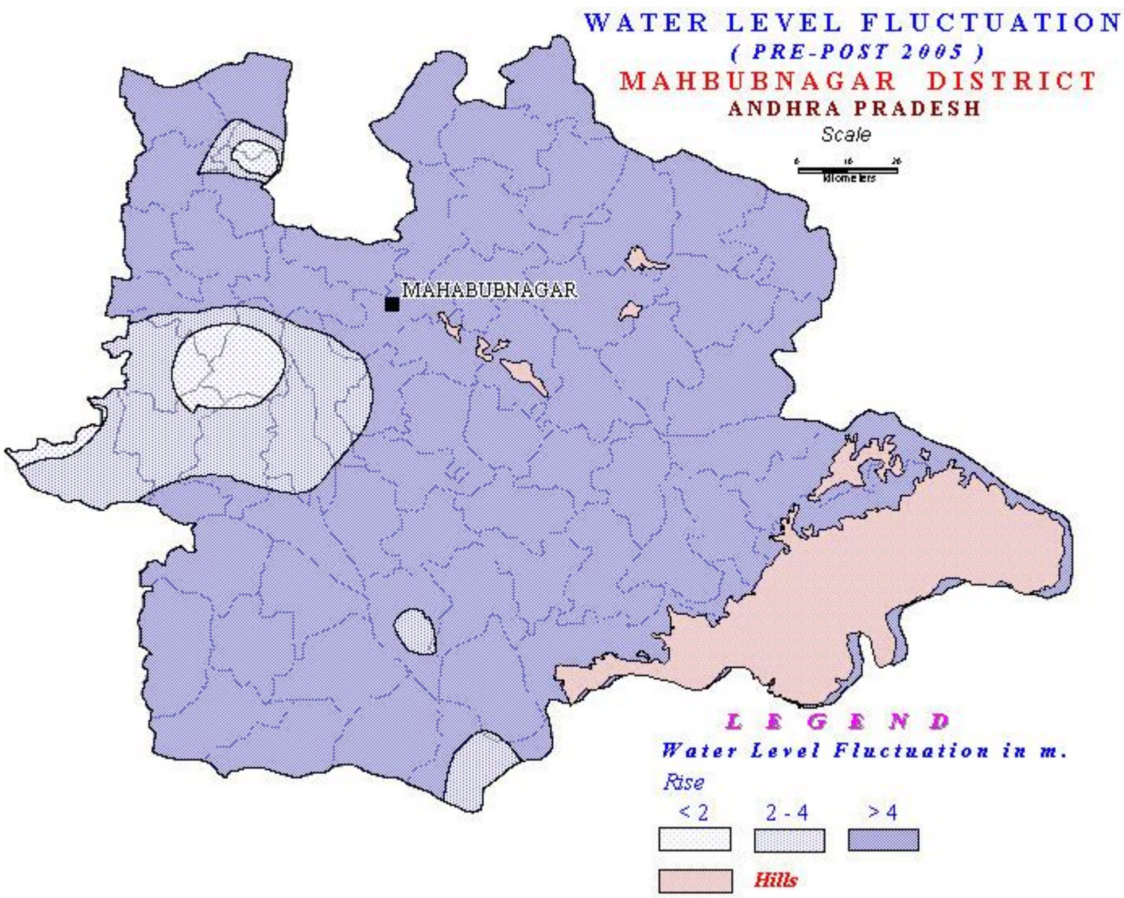


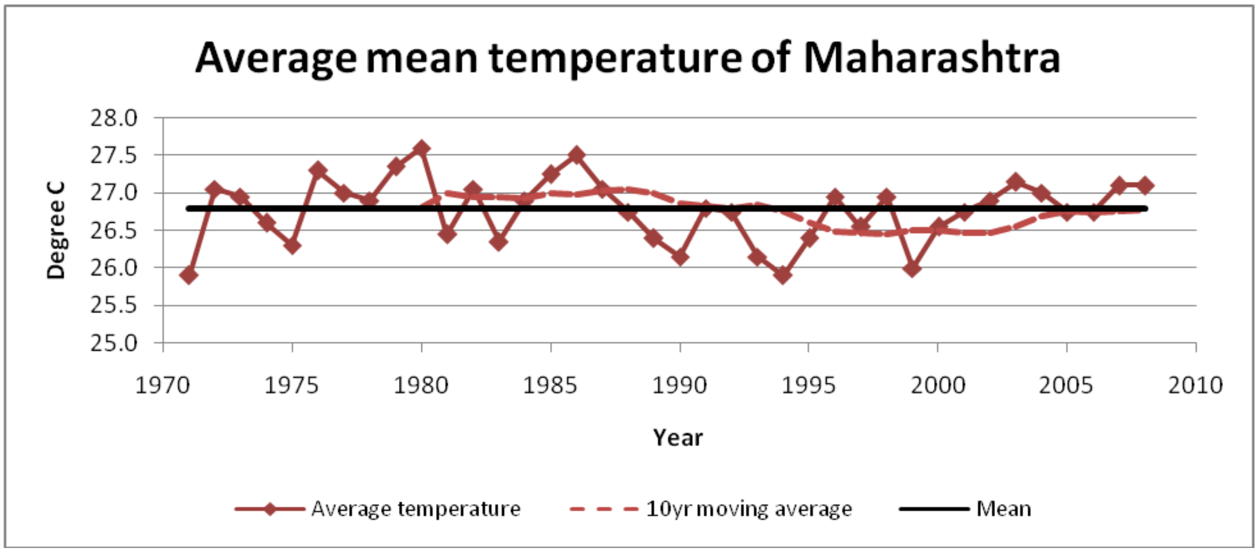
Figure 5.3 Water level fluctuation, pre post monsoon

***Water level fluctuation*:** Fluctuations in the water level between pre and post-monsoon period of 2005 is reflected by the rise all over the district (below fig).The rise of water level of >4 mt is witnessed in the entire district, leaving small pockets, where water level rise is between 2-4 m. Less than 2 m is observed in parts of Dhanwada and Narayanpet mandals. Less fluctuation is observed in the areas where the water levels are comparatively shallow during pre monsoon and the gradient of the slope is less.

An analysis of water level data, collected by C.G.W.B shows annual ‘fall’ is in 27 wells, constituting 39% of the wells, with range from 0.0125 (Amrabad) to 0.41m/yr (monsoon). During post monsoon period, fall is observed in 35% of the wells ranging from 0.1 m to 0.72 m/yr (Kothakonda). It is observed that 28% wells show rising trend and 72% of wells show declining trend.

ii) Maharashtra

The average temperature of Maharashtra is about 26.5 ° C. The middle and the eastern border of Maharashtra remain hotter than the other areas. The summer temperature reaches up to 40 degree C and the winter temperature nearly 10 degree C.



Graph 5.40 Temperature of Maharashtra

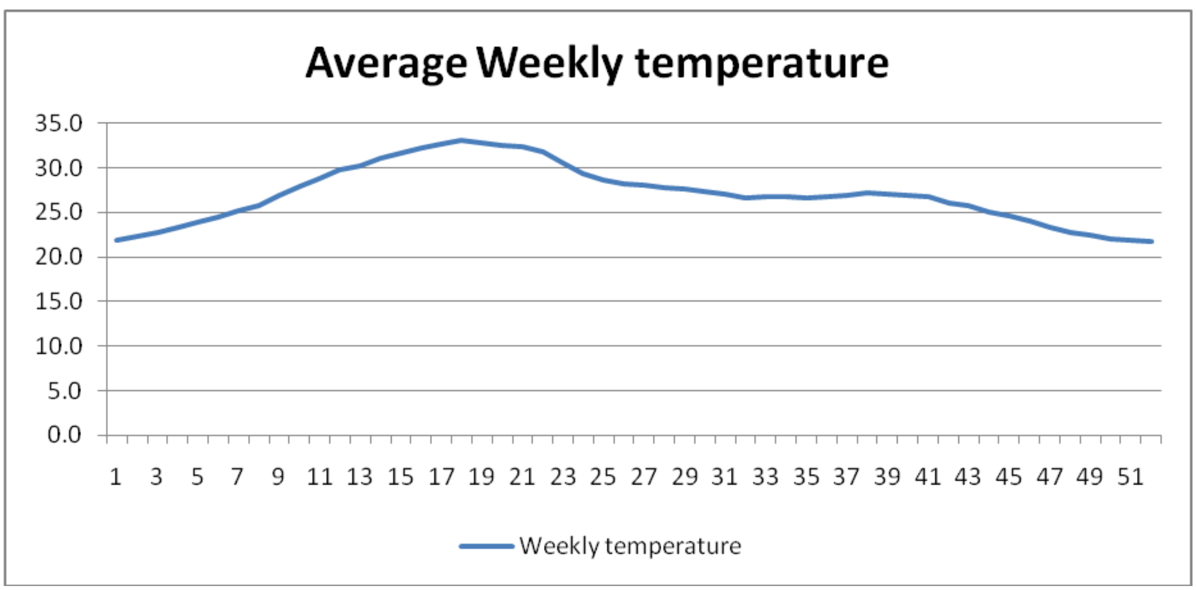
The above graph shows that the average temperature ranges between 26 to 27 degree C. Gradually the deviation of temperature from the mean has been reduced with colder period during 1990- 2000 and after that there is a slow rise in the temperature. The decadal moving average also shows a decreasing trend 2000 but after that there is a increasing trend of temperature.

Ground water: This phenomenon of water shortage and scarcity in the face of normal rainfall appears to have become a normal feature in Maharashtra and is indicative of a serious depletion of water levels in the Ground Water Aquifers in various part of the State.

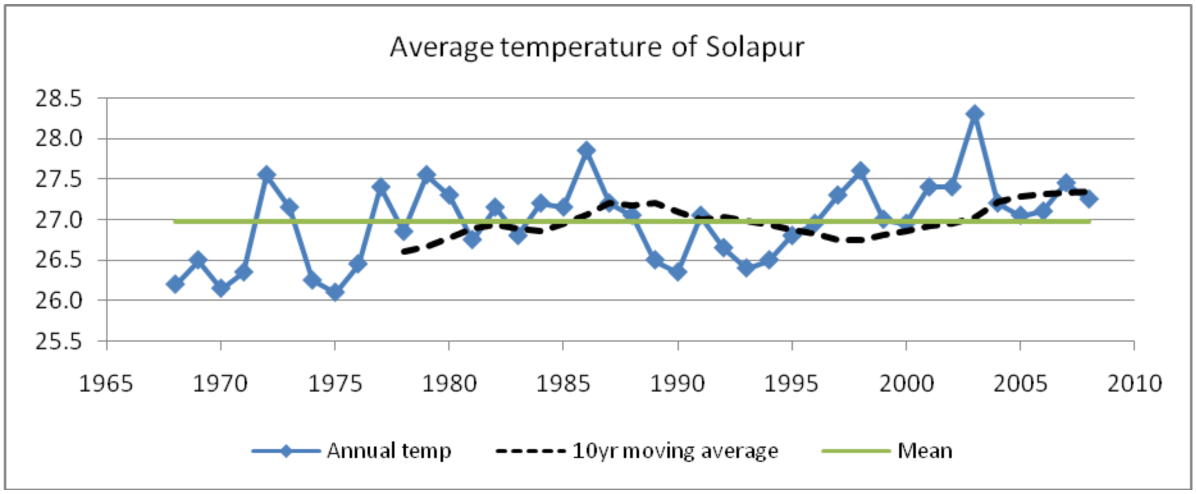
In the year 2003-04, the Government of Maharashtra notified that 71 Talukas in the State were facing water scarcity. Of these 71 Talukas 4 Talukas of Sinnar, Suragana, Devala, and Latur had received more than 100% of the Normal rainfall during the year. Similarly, it was noticed that the Talukas of Sangamaner, Akola, Sangola, Bhokardhan, Ashti, Parli, Renapur, and Nilanga had received more than 80% of normal rainfall that year.

ii.a) Sholapur

The mean temperature of Sholapur is about 27 degree C. The bove graph of weekly temperature chows that the highest temperature is in the month of May. The summer season started on the month of April and it lasts till June last week. From October the temperature started going down and minimum temperature occurs on the month of January.



Graph 5.41 Average weekly temperature



Graph 5.42 Average temperature of Sholapur

The yearly average temperature as shown in the above graph is increasing gradually from the last two decades. The average yearly temperature of Sholapur is nearly 27 degree C. After 1995 the deviation of the temperature from the mean has increased by 2.5 percentages from the mean. The decadal moving average also showed a similar trend of gradual rise for the last 10 year. The decadal average temperature increased by nearly 0.7 degree C from the 1970s level.

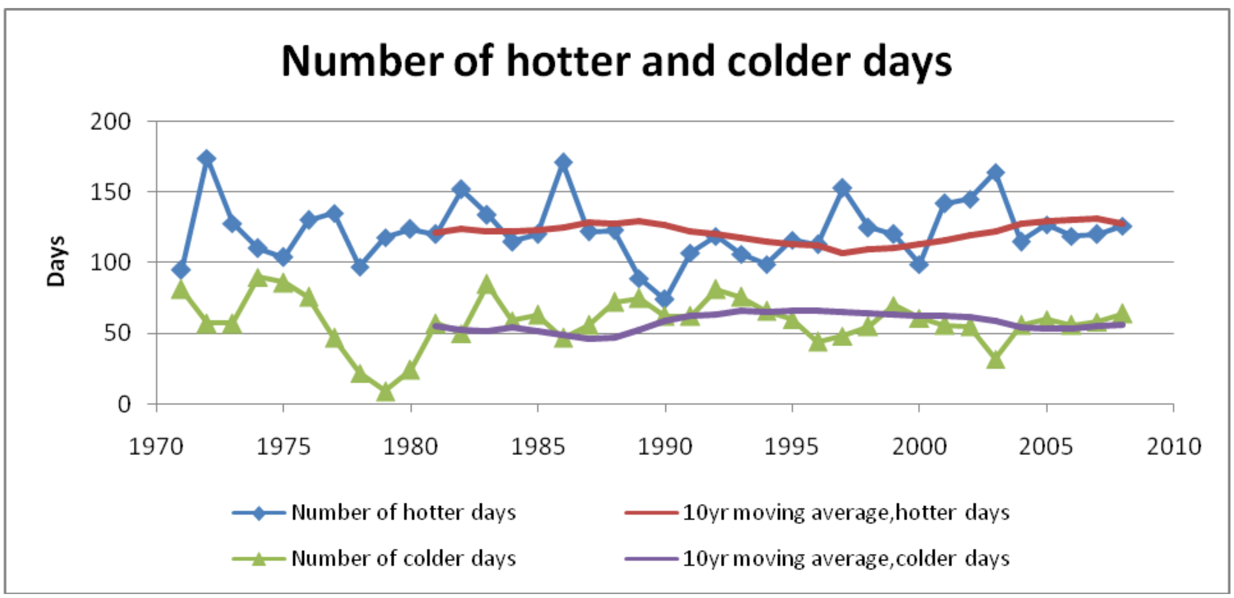
Table 5.9 Decadal variation of minimum temperature

Decadal variation in monthly, seasonal and annual minimum temperature at Sholapur															
YEAR	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Winter**	**Summer**	**Annual**
1971-1980	14.1	16.8	20.4	24.0	24.7	23.5	22.4	21.7	21.4	19.9	17.0	13.8	15.4	23.0	20.0
1981-1990	14.6	16.2	19.9	23.4	25.1	23.6	22.6	21.9	21.7	19.7	16.1	14.3	15.4	22.8	19.9
1991-2000	14.1	16.2	20.3	23.2	24.6	23.6	22.7	22.1	21.7	20.2	16.8	13.4	15.2	22.7	19.9
2001-2008	14.9	16.9	20.5	24.6	25.4	24.0	23.2	22.3	22.1	19.9	16.3	13.9	15.9	23.5	20.3

Table 5.10 Decadal variation of maximum temperature

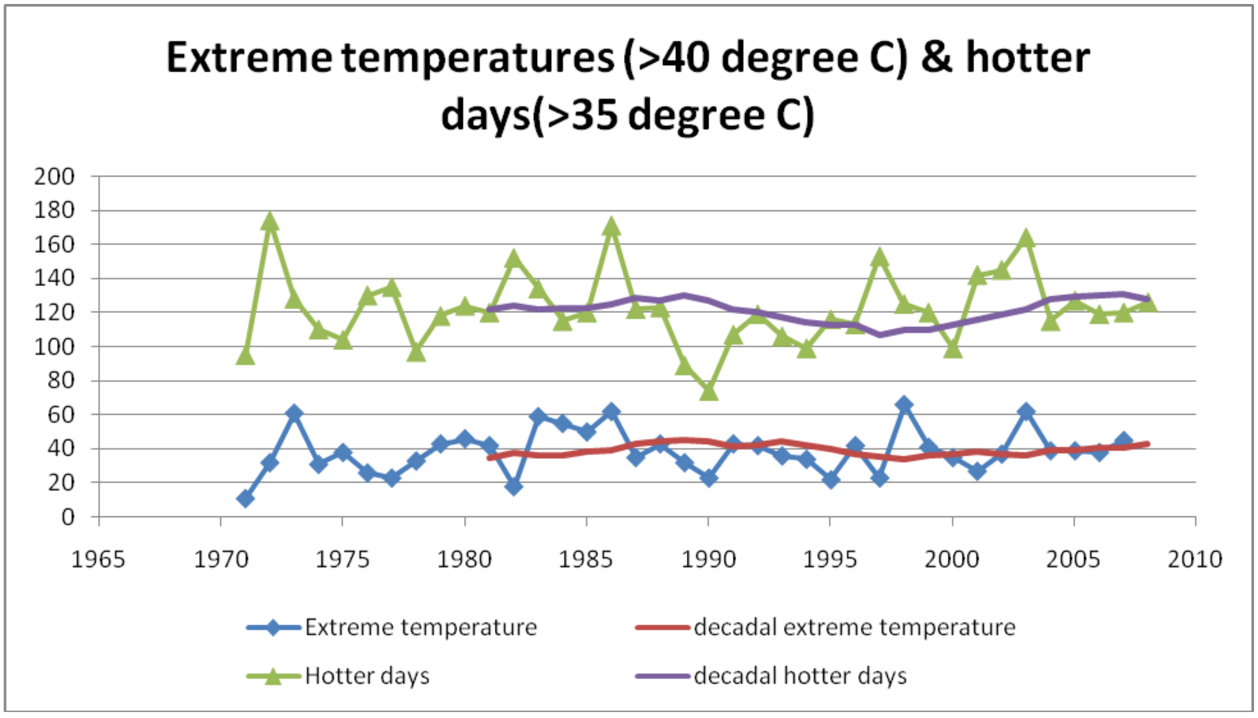
Decadal variation in monthly, seasonal and annual maximum temperature at Sholapur															
YEAR	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Winter**	**Summer**	**Annual**
1971-1980	30.6	33.5	37.2	39.9	40.0	35.1	32.7	31.2	32.2	32.6	31.0	29.9	32.0	39.0	33.8
1981-1990	31.0	34.0	37.4	40.2	40.4	35.1	32.6	31.8	32.4	32.6	31.3	30.2	32.5	39.3	34.1
1991-2000	30.7	33.4	37.6	39.8	40.2	35.5	32.4	31.6	32.4	32.2	31.1	30.0	32.1	39.2	33.9
2001-2008	31.5	34.7	37.7	40.3	40.5	35.5	33.3	31.6	31.9	32.8	32.2	31.4	33.1	39.5	34.4

From the above tables can be observed that there was a decrease in temperature after 1980s till 2000. But after 2000 there was a small rise in the temperature. However overall there was a increase in the decadal temperature.



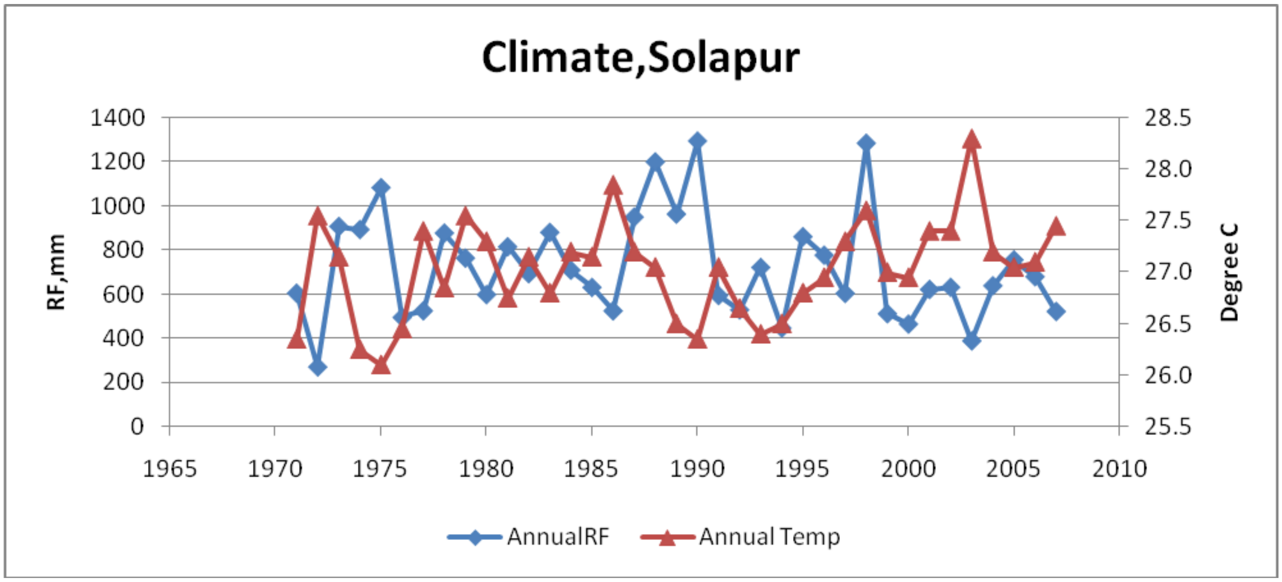
Graph 5.43 Number if hotter and colder days in Sholapur

The winter, summer and annual minimum temperature showed a deviation of 0.5, 0.5 and 0.3 degree C. The winter, summer and annual maximum temperature also showed a rise of 1.1, 0.5 and 0.6 degree C. Therefore a sharp increase in surface temperature has been observed after 2000 and it ultimately increases the overall effect of high temperature. The number of hotter days and colder days has not showed any significant changes from the 1970 level. There was a comparatively colder climate during the 1980s and 1990s period. But after 2000 the climate turns comparatively hotter than before. The decadal moving average shows that after 2000 the number of hotter days increased by nearly 12 percentages and the number of colder days decreased by nearly 11 percentages from the year 2000 level.



Graph 5.44 Extreme temperature events in Sholapur

Temperature > 40 degree C here is considered as extreme because normally above this temperature it is difficult for plant and as well as human being to maintain their livelihood.The number of hotter days with extreme temperature (>40 degree C) has been nearly same for the past 30 years. During 1980-1985 the number of extreme temperature crossed 50 and again on 1998 and 2003 it crossed the limit of 50 days. But considering the decadal moving average of the extreme temperature it can be observed that there has been a increase in the extreme days after 2000. But still the increment of the number of extreme days is not very significant.



Graph 5.46 Climate of Sholapur

The surface temperature is dependent to the annual rainfall. A year with high rainfall is followed by a year with lower temperature. There is a clear relationship between the rainfall and temperature.

Let Y be the temperature and X be the rainfall
y= -0.00068X+27.515

	Coefficients	*Standard Error*	*t Stat*
Intercept	27.51555	0.239142	115.0594
X Variable	-0.00068	0.000315	-2.14324

R square value 0.116

The above relation shows that the rainfall and temperature is inversely related to each other. One unit increase in rainfall after 27.5 unit of temperature will bring a decrease of 0.00068unit of temperature.

5.2. Cropping pattern of the study area

i) Cropping pattern change of Andhra Pradesh

District level data were collected from the period of 1970 till 2005 and from that the state level data was constructed. Andhra Pradesh is one of the top producers of rice. From the tables it is observed that the rice acreage has reduces still the production increased due to high yield. The wheat area has also increased without increase in yield.

Table 5.11 Cropping pattern of Andhra Pradesh

	Area (000 ha)				Production (000 tons)				Yield (ton/ha)			
Crops	1970-79	1980-89	1990-99	2000-04	1970-79	1980-89	1990-99	2000-04	1970-79	1980-89	1990-99	2000-04
Rice	3501.1	3701.5	3839.1	3390.1	5549.1	8037.8	9726	9945.7	1.6	2.2	2.5	2.9
Wheat	21.6	14.1	10.7	12	13.4	9.1	7.5	8.6	0.6	0.6	0.7	0.7
Sorghum	2421.7	1757.3	932.4	617.9	1234.6	1049.9	678.9	623.6	0.5	0.6	0.7	1
Pearl millet	554.2	403	147.9	110.8	298.5	259	118.2	101.2	0.5	0.6	0.8	0.9
Maize	290.5	311.7	351.7	571.9	386.6	551	977.6	1812.8	1.3	1.8	2.7	3.2
Cereals	7841.1	6866.8	4411	4836.5	8147.1	10337.1	9339.6	12619.7	1	1.5	1.9	2.6
Chickpea	68.8	52.6	111.7	327.9	23.3	19.8	77.8	355.4	0.3	0.4	0.7	1.1
Pigeon pea	197.3	277	343.8	473.3	41.6	64.5	109.3	198.9	0.2	0.2	0.3	0.4
Pulse	1381.7	1453.5	1606.9	1982.1	378.1	600.2	697.6	1102.4	0.3	0.4	0.4	0.6
Groundnut	1375.8	1731.4	2180.6	1673.9	1131.5	1514.2	1967.1	1367.7	0.8	0.9	0.9	0.8

Sesame	201.3	150.6	173	160.2	33.6	22.8	36.8	32.5	0.2	0.2	0.2	0.2
Sugar cane	141.4	150.2	215	285.2	1128.7	1107.6	1519.9	1607.2	8	7.4	7.3	6
Cotton	362.4	504.7	904.7	989.6	48.4	123.5	242	296	0.1	0.3	0.3	0.3

The acreage and the production of sorghum and pearl millet have been decreased constantly after 1970s with a small increase in yield. The overall cereal acreage has also decreased but the production increases a slight amount. The increase in yield of cereals is observed from the above table. The cash crops like sugarcane and cotton has been increased constantly from the 1970s level with the increase in the production of pulses. Looking at the growth rate of rice during the 1990-2005. The CGR of the acreage of crops in the below table shows that the acreage areas of most of the cereal crops has been decreased and that of oilseed and other cash crops has been increased. The total CGR of cotton has been the highest of about 10.32. The acreage of pulse crop like chick pea and pigeon pea has been increased while in oilseed the acreage of groundnut has increased and that of sesame has decreased. The acreage of fruits and vegetables and that of sugarcane has also been increased. During the first period of 1970-90 there was an increase in the rice, maize, pigeon pea, pulses, ground nut, sugarcane and cotton. Similarly there was a decrease in the acreage of wheat, sorghum, millets, chick pea and sesame. Some other crops and fruits and vegetables are not taken into account due to unavailability of data. There could also be a possibility that the cereal area are now captured by vegetables and fruits as the fruits and vegetables require less time and gives higher return.

The change in market condition and change of weather has been the most prominent cause for the increase in acreage of cash crop and pulses and that of decrease in cereals. The yield of the all the crops has been increasing every decade. During the last decade the yield of sugarcane has been decreased because there was a decrease in the production. The market price of the commodities also influences the farmer to maintain the crops and apply more fertilizers to receive better yield. The increasing market price of cash crop and other crops led to the shifting of cereals to non cereal based agriculture. The decrease in rainfall and depleting ground water level also helped to shift from cereal based farming which needs more irrigation to non cereal based crops for lesser irrigation requirement. Introduction of improved variety of seeds also motivate the farmers to adapt the new seeds.

Table 5.12 Changing cropping pattern of Andhra Pradesh

	Compound growth rate of area of crop			**Compound growth rate of production**			**Compound growth rate of yield of crop**		
Crops	1970-79 to 1980-89	1980-89 to 1990-99	1990-99 to 2000-2004	1970-79 to 1980-89	1980-89 to 1990-99	1990-99 to 2000-2004	1970-79 to 1980-89	1980-89 to 1990-99	1990-99 to 2000-2004
Rice	0.558	0.366	-1.761	3.775	1.925	0.320	3.198	1.578	2.098
Wheat	-4.216	-2.720	1.734	-3.792	-1.969	2.063	0.489	0.941	0.294
Sorghum	-3.156	-6.142	-5.708	-1.607	-4.266	-1.207	1.593	1.923	4.854
Pearl millet	-3.136	-9.538	-4.041	-1.408	-7.547	-2.194	1.690	2.437	1.230
Maize	0.705	1.216	7.191	3.609	5.901	9.222	2.896	4.465	2.090
Finger millet	-1.318	-4.329	1.324	2.409	-1.010	4.394	3.837	2.287	4.646
Cereal	-2.648	7.821	16.635	-1.621	14.683	24.234	0.926	6.664	6.568
Chick pea	3.449	2.184	4.672	4.484	5.420	8.932	1.116	2.929	4.242
Pigeon pea	0.508	1.008	3.043	4.730	1.514	6.756	4.208	0.497	3.654
Pulse	2.326	2.333	-3.708	2.957	2.651	-5.060	0.519	0.323	-1.587
Groundnut	-2.861	1.397	-1.090	-3.799	4.895	-1.751	-1.091	3.369	-0.596
Sesame	0.608	3.650	4.118	-0.189	3.215	0.802	-0.890	-0.126	-2.791
Sugarcane	3.367	6.010	1.290	9.825	6.956	2.923	6.765	0.747	1.344

Cotton	0.558	0.366	-1.761	3.775	1.925	0.320	3.198	1.578	2.098

After 1970s there were introduction of high yielding varieties of seed which helps to increase the yield. In present situation the main focus in on drought resistance variety and short duration crops.

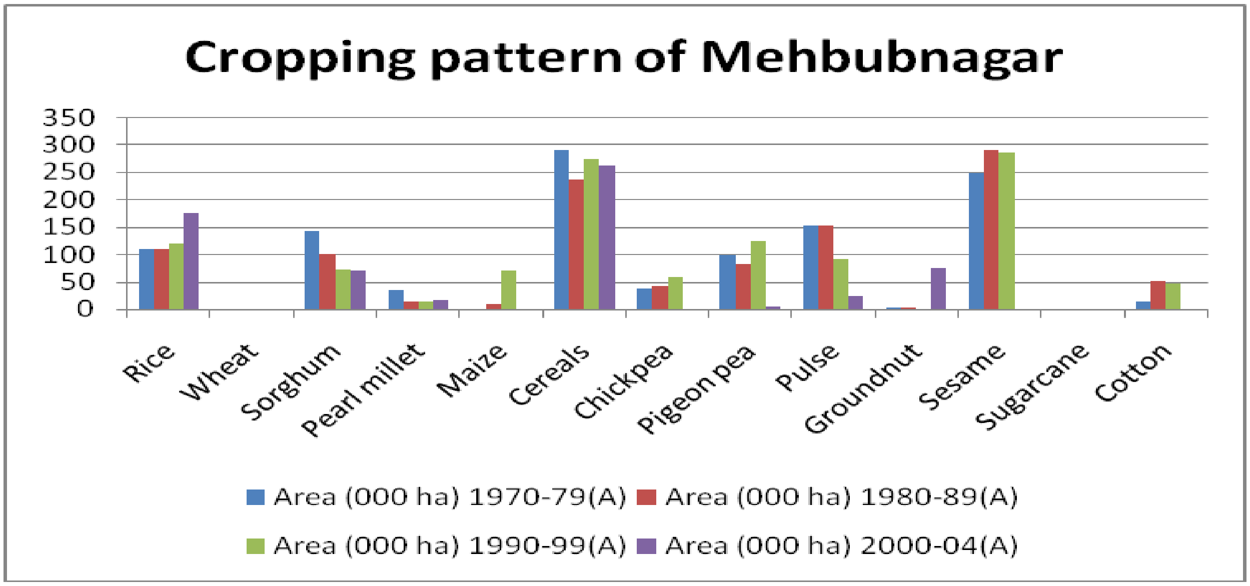
i.a) Cropping pattern of Mahbubnagar

In Mehbuubnagar the predominant crop was rice, sorghum, wheat, sesame and pigeon pea. The area under sesame is consistently higher than any other crops. After 1980s there was a sharp decrease in the area under the crop sorghum and pearl millet which reduce the area under cereal crops. Simultaneously there was a increase under the area of maize. After 1990s the area under chickpea and pigeon pea showed a sharp rise thus increasing the area under pulse crops. The area under maize also showed a high rise consistently after 1970s. The cotton area also shows a high increment after 1980s.

Table 5.13 Cropping pattern of Mahbubnagar

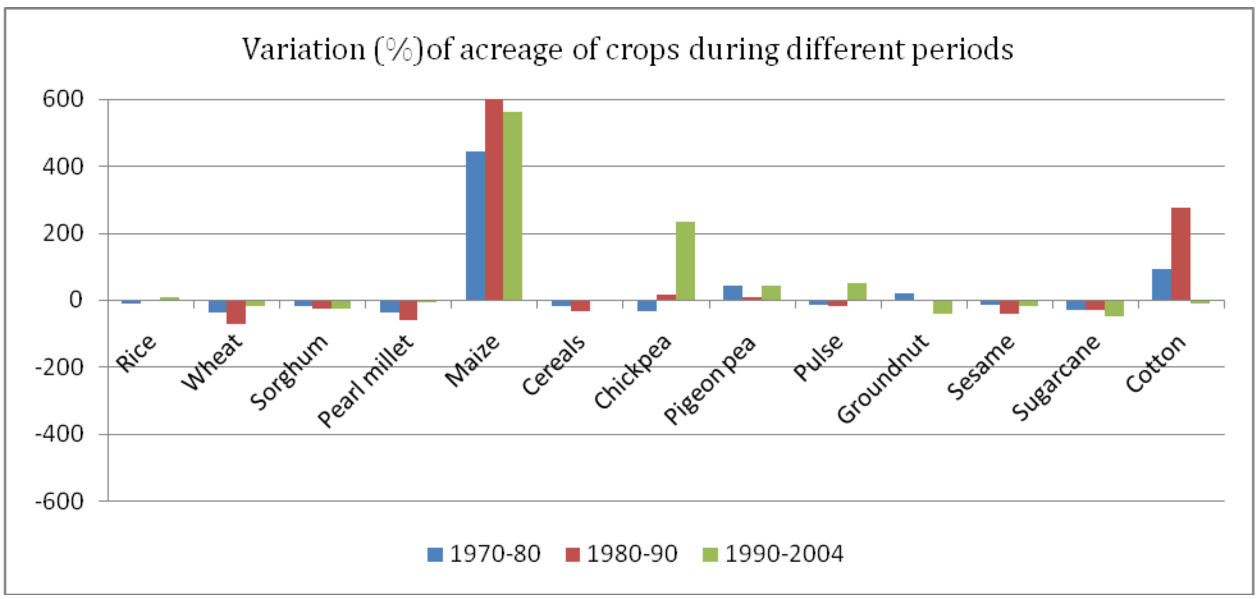
	Area (000 ha)				Production(000 tons)				Yield(kg/ha)			
	1970-79(A)	1980-89(A)	1990-99(A)	2000-04(A)	1970-79(P)	1980-89(P)	1990-99(P)	2000-04(P)	1970-79(Y)	1980-89(Y)	1990-99(Y)	2000-04(Y)
Rice	109.49	110.95	119.39	175.36	180.96	218.437	280.326	1408.854	1652.754	1968.77	2347.986	109.49
Wheat	0.85	0.26	0.21	0.73	0.55	0.289	0.126	548.8722	647.0588	1120.155	588.785	0.85
Sorghum	143.49	100.94	72.02	70.57	70.023	61.3695	52.142	413.0576	475.5136	618.7051	711.5258	143.49
Pear	36.4	14.6	13.7	16.9	11.8	6.18	7.32	294.	325.	421.	534.	36.4

l millet	3	8	0	9	6	5	8	0464	5559	4364	8905	3
Maize	0.38	10.54	69.74	0.1	0.828	31.064	120.524	1428.571	2178.947	2948.088	1728.19	0.38
Cereals	2.55	2.95	9.90	381.149	395.16	372.1748	524.122	588.8117	762.2935	1054.561	1465.641	2.55
Chickpea	37.66	41.61	58.81	1.17	0.97	1.234	10.178	303.1088	380.3922	418.873	1028.496	37.66
Pigeon pea	99.62	81.95	124.89	3.96	6.05	9.015	22.436	150.7997	160.6479	216.639	381.4738	99.62
Pulse	152.91	152.41	92.19	22.552	22.404	21.17063	39.426	193.4482	224.8991	258.3294	315.6757	152.91
Groundnut	2.17	1.30	1.06	75.95	91.72	109.594	79.094	595.4528	599.83	719.0783	857.9269	2.17
Sesame	249.10	291.27	286.37	0.27	0.15	0.116	0.186	107.5697	69.12442	89.57529	175.4717	249.10
Sugarcane	0.13	0.09	0.05	0.95	0.69	0.534	0.189	5277.778	5307.692	5680.851	3937.5	0.13
Cotton	14.00	52.87	46.55	0.98	3.46	9.22	11.054	133.8798	247.1429	174.4065	237.4855	14.00



Graph 5.46 Acreage of different crops in Mahbubnagar

The production of cereals has increased from the 1970 to 1990 periods. But after that there was a slow decrease in the cereal acreage as well.



Graph 5.47 Variation of acreage during different periods

The compound annual growth rate of the crops showed a similar trend of decrease in area and production of wheat, sorghum, pearl millet and sugarcane. Simultaneously there was an increase in the maize, pulses and cotton acreage and production. After

1990s there is a significant increase in the chickpea acreage and production being a CAGR of 35.17. The yield of almost all the crops has shown a positive increase for every period with only exception of wheat, maize and sugarcane. For wheat and sugarcane the area and production also showed a negative growth rate. Therefore the yield decrease may led to less acreage of these two crops or may be due to less management of this crop the yield reduced for every year.

Table 5.14 Change in growth of different crops in Mahbubnagar

Crops	Change in Area			Production			Yield		
	1970-80	1980-90	1990-2005	**1970-80**	**1980-90**	**1990-2005**	**1970-80**	**1980-90**	**1990-2005**
	CAGR			CAGR			CAGR		
Rice	-1.274	0.133	1.053	0.315	1.900	3.628	1.609	1.765	2.548
Wheat	-4.378	-11.239	-2.636	-2.792	-6.232	-11.183	1.659	5.641	-8.779
Sorghum	-1.396	-3.456	-4.709	-0.078	-1.311	-1.616	1.418	2.667	1.408
Pearl millet	-4.508	-8.691	-0.978	-3.531	-6.303	2.452	1.023	2.615	3.464
Maize	18.432	39.410	30.994	23.539	43.689	21.371	4.312	3.069	-7.346
Cereal	-4.061	1.454	18.898	0.362	-0.597	5.012	2.616	3.299	4.815
Chick pea	3.671	1.003	5.067	-1.857	2.436	35.178	2.297	0.968	13.692
Pigeon pea	-1.560	-1.933	6.204	4.329	4.069	13.912	0.635	3.035	8.419
Pulse	1.830	-0.033	-6.930	-0.066	-0.565	9.289	1.518	1.395	2.905
Groundnut	-1.445	-5.031	-2.820	1.905	1.796	-4.552	0.073	1.830	2.554
Sesame	1.433	1.576	-0.242	-5.708	-2.538	6.978	-4.326	2.626	10.082
Cotton	6.699	14.210	-1.802	13.445	10.297	2.626	6.322	-3.426	4.509
Sugarcane	-3.202	-3.190	-9.155	-3.147	-2.530	-13.790	0.057	0.682	-5.102

The yield of any particular crop depends on the following factors such as irrigation, fertilizer application, producers price and climatic factor. There may be many factors which affects the yield of a crop. But for simplicity and availability of data, only few factors are considered.

Table 5.15 Change in various parameter of crop practice

Crops	Change in yield			Change in fertilizer			Change in irrigated area			Change in producers price		
	1970-80	**1980-90**	**1990-2005**	**1970-80**	**1980-90**	**1990-2005**	**1970-80**	**1980-90**	**1990-2005**	**1970-80**	**1980-90**	**1990-2005**
	CAGR			CAGR			CAGR			CAGR		
Rice	1.61	1.77	2.55	1.76	6.78	8.27	-0.87	0.20	-0.98	7.48	7.90	6.200
Wheat	1.66	5.64	-8.78	2.23	5.34	8.26	-3.50	-9.77	0.50	7.81	8.55	8.023
Sorghum	1.42	2.67	2.02	2.01	7.8	9.56	-13.10	5.50	1.49	2.96	11.24	6.837
Pearl millet	1.02	2.61	3.46	1.01	6.89	10.47	-13.82	4.33	-20.82	2.63	10.42	8.321
Maize	4.31	3.07	-7.35	2.75	5.78	6.9	24.98	10.53	20.67	6.24	8.27	6.348
Cereal	2.62	3.30	4.81						0.00			
Chick pea	2.30	0.97	13.69	0.98	7.57	8.76	-20.57	20.95	44.72	12.49	10.31	9.454
Pigeon pea	0.63	3.04	8.42	2.33	8.01	11.01	0.00	0.00	-0.22	11.50	10.32	9.632
Pulse	1.52	1.40	2.91	2.19	3.57	12.56	-20.57	25.89	38.30	12.67	9.94	18.935
Groundnut	0.07	1.83	2.55	3.02	6.98	9.76	5.42	1.64	-0.48	11.46	6.86	6.183

Sesame	-4.33	2.63	10.08	0.62	4.6	7.9	-	0.96	12.82	7.51	8.55	7.700
Cotton	0.06	0.68	-5.10	1.25	6.89	12.05	16.16	9.72	-1.76	7.00	12.74	8.706
Sugar cane	6.32	-3.43	4.51	0.35	5.98	8.56	0.83	-9.33	3.19	4.51	14.84	19.44

Table 5.16 Periodic correlation of yield with other variables

			Correlation with yield				
	Year	Average yield (kg/ha)	Irrigated Area	Producers Price	Fertilizer uses	Temp.	Rainfall
Rice	1970-79	1408.85	0.650	0.590	0.808	0.496	0.807
	1980-89	1652.75	0.854	0.291	0.445	-0.637	0.486
	1990-99	1968.77	0.682	-0.202	0.348	-0.064	0.419
	2000-04	2347.99	0.707	-0.195	0.730	-0.144	-0.053
Wheat	1970-79	548.872	-0.807	0.354	0.440	0.296	0.170
	1980-89	647.059	-0.193	-0.318	-0.252	0.108	0.065
	1990-99	1120.16	0.196	-0.491	-0.261	-0.419	0.170
	2000-04	588.785	-0.830	0.284	-0.194	0.826	0.634
Sorghum	1970-79	413.058	-0.614	-0.561	0.631	-0.095	0.657
	1980-89	475.514	0.460	0.065	0.111	0.075	-0.185
	1990-99	618.705	-0.212	-0.034	-0.645	-0.338	0.323
	2000-04	711.526	-0.046	0.675	0.268	0.084	0.883
Pearl millet	1970-79	294.046	0.046	-0.357	0.003	-0.528	0.169
	1980-89	325.556	0.220	-0.299	-0.099	0.251	0.145
	1990-99	421.436	-0.435	0.329	0.055	-0.446	0.228
	2000-04	534.891	0.773	-0.679	0.932	-0.164	0.407
Maize	1970-79	1428.57	0.802	0.018	-0.788	-0.124	-0.661
	1980-89	2178.95	0.638	0.465	0.376	-0.404	-0.075

	1990-99	2948.09	0.428	0.830	0.348	0.454	-0.588
	2000-04	1728.19	-0.353	-0.474	0.029	0.804	0.202
Chickpea	1970-79	303.109	0.422	0.250	0.613	-0.167	0.594
	1980-89	380.392	0.487	-0.838	-0.478	0.049	0.380
	1990-99	418.873	-0.176	0.008	-0.246	-0.464	0.072
	2000-04	1028.5	0.131	0.494	-0.545	0.895	0.467
Pigeon pea	1970-79	150.8	0.000	0.101	-0.048	-0.234	0.116
	1980-89	160.648	0.000	-0.180	0.174	0.446	-0.278
	1990-99	216.639	0.057	0.603	0.619	-0.079	-0.232
	2000-04	381.474	-0.806	-0.062	0.576	-0.605	0.088
Pulse	1970-79	193.448	0.252	0.257	0.160	-0.501	0.542
	1980-89	224.899	-0.189	0.123	0.224	0.149	-0.072
	1990-99	258.329	-0.751	0.388	-0.048	-0.243	0.312
	2000-04	315.676	0.759	0.722	0.089	-0.096	-0.253
Groundnut	1970-79	595.453	0.505	0.607	0.185	-0.250	0.611
	1980-89	599.83	0.535	0.412	-0.114	-0.509	0.518
	1990-99	719.078	0.198	-0.356	-0.283	-0.542	0.727
	2000-04	857.927	0.117	-0.257	0.137	0.115	-0.544
Sesame	1970-79	107.57	0.000	-0.206	-0.392	-0.319	-0.284
	1980-89	69.1244	0.000	0.121	-0.147	0.210	-0.509
	1990-99	89.5753	-0.037	-0.360	0.120	-0.343	0.221
	2000-04	175.472	0.471	-0.196	-0.065	0.286	-0.542
Sugarcane	1970-79	5277.78	-0.284	0.018	-0.017	-0.469	-0.016
	1980-89	5307.69	0.489	-0.004	-0.203	-0.111	0.182
	1990-99	5680.85	0.230	-0.079	-0.422	-0.405	0.382
	2000-04	3937.5	-0.684	0.458	-0.116	0.396	-0.213
Cotton	1970-79	133.88	0.782	0.924	0.835	0.051	0.758
	1980-89	247.143	-0.848	-0.724	-0.644	0.038	0.404
	1990-99	174.407	-0.399	-0.403	-0.080	-0.410	0.448
	2000-04	237.485	-0.772	0.320	0.532	-0.077	0.015

From the table of compound annual growth rate it can be observed that the decrease in the sorghum yield because the producer's price growth rate was less compared to other crops. Again the growth rate of irrigated area under sorghum was also less compared to other crops. Therefore the rabi sorghum may has been decreased after 1990s. Similarly the maize yield as well as acreage has increased significantly due to increase in irrigated area, fertilizer application and comparatively better producers price. The correlation between rainfall and yield of maize are negative after 1990s. After 1990s the rainfall has been decreased compared to 1980s. This increased the irrigation requirement of the crop. Therefore the yield of maize crops can be predicted to be dependent on rainfall. The increase in pulses yield and acreage has been consistent from the last three decades. The irrigated area, fertilizer and producers price has also shown a positive growth rate. The irrigated area has shown a high growth rate of for pulses. The correlation also showed a negative relation after 2000. Therefore similar to other crops the pulse yield has increased significantly due to increase in irrigated area, fertilizer application and producers price. The cotton acreage has decreased after 1990 with a high increase in irrigated area and producers price. The correlation between rainfall and yield are also very less of about .015 as after 2000 the rainfall has also decreased. But the fertilizer application has increased significantly for the last period means that the cotton yield for the last period was increased due to high increase in the fertilizer application which is due to less rainfall and high producers price. For all the crops the temperature is negatively correlated with the yield. This means that the increase in temperature will increase the yield. But the temperature has been increasing gradually after 1990s. Therefore it reflects that there is no significant relationship between temperature and change in yield.

ii) Cropping pattern of Maharashtra

The main crops of Maharashtra are coarse cereals, pulses and cotton. The compound growth rate of the crops shows that the acreage of groundnut, wheat, sesame and potato has been decreased significantly from the 1970s level. The acreage of maize, pulses, mustard, fruits and vegetables and onion has been increased significantly. But overall the acreage of cereal has been decreased from 1980s and the acreage of oilseed and pulses has been increased gradually.

Table 5.17 Cropping pattern of Maharashtra

Crops	Area (000 ha)				Production (000 tons)				Yield (ton/ha)			
	1970-79	1980-89	1990-99	2000-04	1970-79	1980-89	1990-99	2000-04	1970-79	1980-89	1990-99	2000-04
Rice	1407.05	1497.55	1529.95	1517.48	1758.47	2174.91	2432.863	2283.26	1.249757	1.452312	1.590159	1.504639
Wheat	1020.55	954.24	805.26	742.08	752.5	849.18	999.678	960.68	0.737348	0.889902	1.241435	1.294577
Sorghum	6173.22	6504.93	5583.97	4846.18	3472.93	4747.74	5117.774	3658.28	0.56258	0.729868	0.916512	0.754879
Pearl millet	1698.16	1760.59	1817.19	1520.14	568.86	738.21	1271.995	1017.32	0.334986	0.419297	0.699979	0.669228
Maize	52.79	86.72	205.62	365.5	65.04	116.68	247.265	628.612	1.232052	1.34548	1.202534	1.719869
Cereals	10690.76	11050.63	10238.1	9247.34	6855	8812.99	10378.92	8759.918	0.641208	0.79751	1.013754	0.947291
Chick pea	393.16	520.74	714.46	770.76	130.85	216.91	414.37	427.42	0.332816	0.416542	0.579976	0.554544
Pigeon pea	614.11	771.4	1023.81	1058.72	331.35	482.94	598.75	711.84	0.539561	0.626057	0.584825	0.672359
Pulse	2682.93	2863.14	3360.411	3506.76	900.11	1175.12	1745.35	1837.424	0.335495	0.410431	0.519386	0.523966
Groundnut	826.44	747.38	623.18	426.6	550.42	694.69	678.417	461.5	0.666013	0.9295	1.088637	1.08181

Sesame	**156.3556**	**226.75**	**191.03**	**124.06**	**35.27**	**50.83**	**43.883**	**33.2**	**0.225576**	**0.224168**	**0.229718**	**0.267612**
Sugarcane	**246.58**	**296.23**	**475.67**	**525.78**	**1997.24**	**2662.73**	**4060.564**	**3254.678**	**8.099765**	**8.988725**	**8.536515**	**6.19019**
Cotton	**2438.71**	**2651.08**	**2886.58**	**2343.58**	**197.18**	**245.06**	**392.432**	**340.538**	**0.080854**	**0.092438**	**0.135951**	**0.145307**

The highest acreage is for the crop sorghum compared to any other crops while the yield of rice and wheat are comparatively better than other crops. Pulse crops are always having a very important position in Maharashtra. The acreage under sesame has reduced while the sugarcane acreage has been increased substantially.

Table 5.18 Change in cropping pattern of Maharashtra

Crops	Change in yield			Area			Production		
	1970-80	1980-90	1990-2005	1970-80	1980-90	1990-2005	1970-80	1980-90	1990-2005
	CAGR			CAGR			CAGR		
Rice	0.625	0.214	-0.117	2.148	1.127	-0.903	1.513	0.911	-0.787
Wheat	-0.670	-1.683	-1.160	1.216	1.645	-0.567	1.898	3.385	0.601
Sorghum	0.525	-1.515	-2.004	3.176	0.753	-4.683	2.637	2.303	-2.734
Pearl millet	0.362	0.317	-2.518	2.640	5.592	-3.141	2.270	5.258	-0.640
Maize	5.089	9.017	8.565	6.018	7.799	14.259	0.885	-1.117	5.245
<u>Cereal</u>	0.332	-0.761	-1.443	2.544	1.649	-2.394	2.205	2.428	-0.964
Chick pea	2.850	3.213	1.089	5.184	6.687	0.444	2.269	3.365	-0.639
Pigeon pea	2.307	2.871	0.480	3.839	2.173	2.502	1.498	-0.679	2.013
Pulse	0.652	1.614	0.611	2.702	4.035	0.737	2.036	2.382	0.126
Groundnut	-1.000	-1.801	-5.270	2.355	-0.237	-5.355	3.390	1.593	-0.090
Sesame	3.787	-1.700	-5.980	3.722	-1.459	-3.907	-0.063	0.245	2.205
Sugarcane	1.851	4.850	1.441	2.918	4.310	-3.111	1.047	-0.515	-4.487
Cotton	0.838	0.855	-2.933	2.198	4.821	-2.006	1.348	3.933	0.955

After 2000 most of the cereal crops showed decrease in their growth rate except maize. The legume crops like groundnut and sesame also showed a similar trend in acreage and production and as well as yield. The increase in the acreage of pulses and sugarcane has been significant. Here other cash crops and fruits and vegetable are not considered due to data accessibility problem. The significant decrease in the cereal and legume crop and cotton for the last period may be substituted by an equal growth rate of fruits and vegetables. Looking towards the yield it can be observed that yield of almost all the crops has been increased significantly except sugarcane from the last decade. The yield has been increased for all the crops particularly due to increased use of inorganic fertilizer and using better technology like better seed variety and farm mechanization. The cropping pattern has been slowly shifted from the cereal based to non-cereal based mainly pulses, oilseeds and vegetables. The shifting of cropping pattern is mainly due to market forces. The price of pulses has been increased more than any other crops in the last decade. But still there are may be other reasons for the shifting of cropping pattern like change in climate, change in availability of input etc. Overall it can be inferred that the cereal area is reducing with an increase of cash crop and pulses and increase in yield of nearly all crops.

ii.a) Sholapur cropping pattern

Cereal crops are the predominant perennial crop of this region. During the 1970s the focus was more on cereals and oilseed crops. But later on as it is observed below that the sesame and groundnut compounded growth rate has been decreased considerably and shifted toward annual crop like sugarcane. Among cereals the only increase can be observed in the maize area and production. The yield for paddy has decreased from the previous level while for wheat and maize it has increased. Among pulses the chick pea acreage has been increased more compared to pigeon pea. The sugarcane acreage and as well as production has been increased significantly from the initial level. The acreage of fruits and vegetables also increased from the initial level. The yield of almost all the crops has been increased due to increase of fertilizer application and irrigation. Due to green revolution after 1960s there was a tremendous focus to improve the crop yield by applying fertilizers in order to make India self sufficient in food production. As a result during 1970s and 1980s the yield increased nearly at a double rate. But increase of yield is also limited due to soils own capacity. The yield cannot be increased indefinitely and it is shown in the below table the growth rate of yield has decreased slowly. The overall growth rate is still positive for all the crops. The shifting of crops here is from cereal based to cash crops mainly sugarcane due to producers price and requirement of less rainfall and less management.

Table 5.19 Cropping pattern of Sholapur

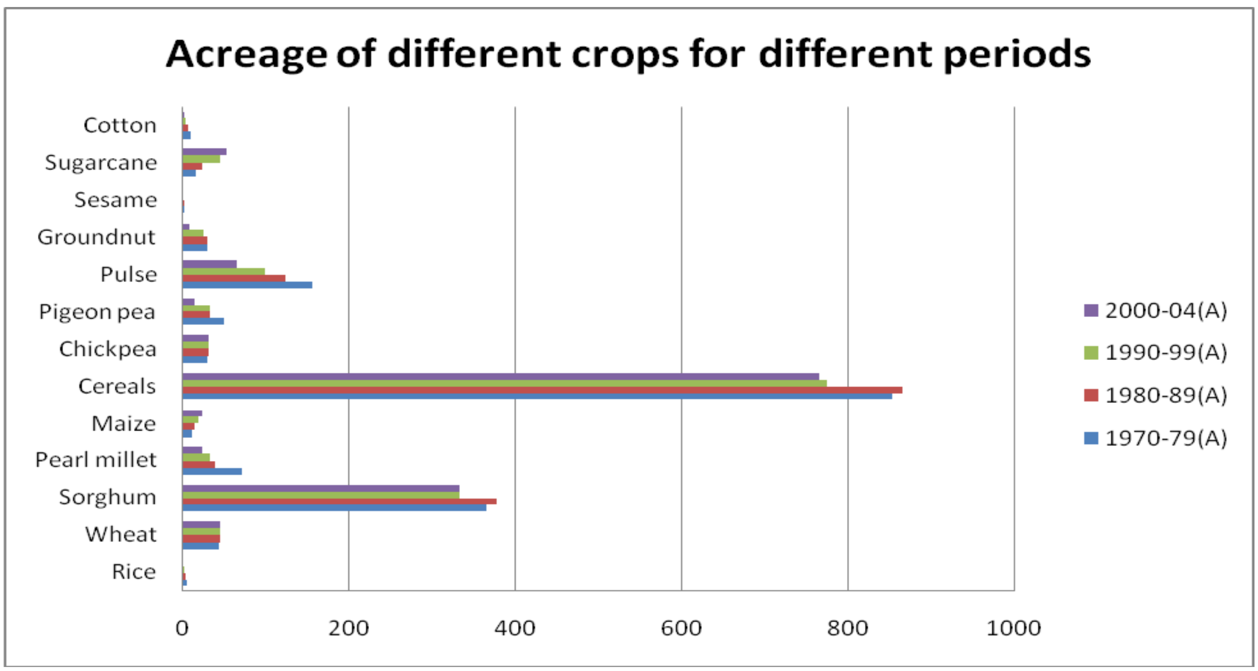
	Area (000 ha)				Production(000 tons)				Yield(kg/ha)			
	1970-79(A)	1980-89(A)	1990-99(A)	2000-04(A)	1970-79(P)	1980-89(P)	1990-99(P)	2000-04(P)	1970-79(Y)	1980-89(Y)	1990-99(Y)	2000-04(Y)
Rice	5.64	4.1	3.16	0.94	8.22	5.58	3.16	0.94	1457.45	1360.98	1000.00	1000.00
Wheat	44.74	45.49	45.41	46.78	35.59	43.18	52.2	50	795.49	949.22	1149.53	1068.83
Sorghum	364.905	378.395	334	332.7	117.21	132.585	157.75	115.87	814.37	710.37	694.82	503.70
Pearl millet	71.5	40.24	33.84	25.22	12.65	12.66	14.19	11.14	176.92	314.61	419.33	441.71
Maize	12.34	16.03	20.23098	24.36	17.9	22.11	28.75603	28.91	1450.57	1379.29	1421.39	1186.78
Cereals	852.17	864.75	774.18	765.38	314	339.92	416.56	323.38	368.47	393.08	538.07	422.51
Chickpea	30.43	32.63	32.53	32.12	9.18	13.07	17.07	14.5	301.68	400.55	524.75	451.43
Pigeon pea	49.96	33.71	33.56	15.16	10.78	11	7.99	4.94	215.77	326.31	238.08	325.86
Pulse	156.	124.	99.4	65.9	36.2	40.4	36.9	26.1	231.	325.	371.	396.

	42	24	9		4	7	6	44	68	74	49	72
Ground nut	30.29	30.81	26.26	9.24	18.88	39.28	31.99	8.24	623.31	1274.91	1218.20	891.77
Sesame	3.57	3.3	0.904062	0.4	0.76	0.58	0.266912	0.12	212.89	175.76	295.24	300.00
Sugarcane	16.72	24.02	45.33	53.01701695	139.23	228.93	381.338	392.5622449	8327.15	9530.81	8412.49	7404.46
Cotton	10.47	6.94	3.91	3.426180133	2.33	1.68	1.011	0.837186257	222.54	242.07	258.57	244.35

Table 5.20 Change of cropping pattern of different crops in Sholapur

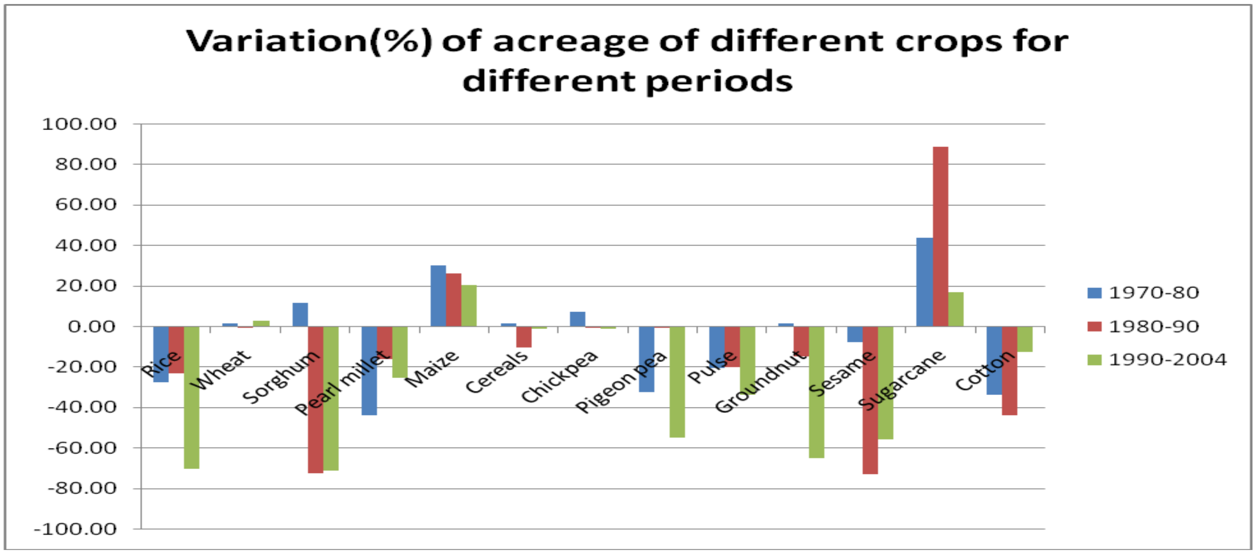
Crops	Change in Area			Production			Yield		
	1970-80	**1980-90**	**1990-2005**	**1970-80**	**1980-90**	**1990-2005**	**1970-80**	**1980-90**	**1990-2005**
	CAGR			CAGR			CAGR		
Rice	-3.14	-2.57	-15.90	-3.80	-5.53	-15.90	-0.68	-3.04	0.00
Wheat	0.17	-0.02	0.43	1.95	1.92	-0.61	1.78	1.93	-1.03
Sorghum	0.36	-1.24	-0.06	1.24	1.75	-4.31	-1.35	-0.22	-3.17
Pearl millet	-5.59	-1.72	-4.11	0.01	1.15	-3.40	5.93	2.91	0.75
Maize	2.65	2.35	2.69	2.13	2.66	0.08	-0.50	0.30	-2.54
Cereal	0.15	-1.10	-0.16	0.80	2.05	-3.55	0.65	3.19	-3.39
Chick pea	0.70	-0.03	-0.18	3.60	2.71	-2.30	2.88	2.74	-2.13
Pigeon pea	-3.86	-0.04	-	0.20	-3.15	-6.64	4.22	-3.10	4.59

			10.73						
Pulse	-2.28	-2.20	-5.71	1.11	-0.90	-4.83	3.47	1.32	0.94
Groundnut	0.17	-1.59	-13.86	7.60	-2.03	-17.62	7.42	-0.45	-4.36
Sesame	-0.78	-12.14	-11.00	-2.67	-7.47	-10.79	-1.90	5.32	0.23
Cotton	-4.03	-5.58	-1.87	-3.22	-4.95	-2.66	0.84	0.66	-0.80
Sugarcane	3.69	6.56	2.26	5.10	5.24	0.42	1.36	-1.24	-1.81



Graph 5.48 Acreage of different time period in Sholapur

The above graph shows that the acreage of cereals has been decreased sharply after 1980s. A consistence decline in the sorghum and pearl millet has been observed while maize showed a opposite trend..



Graph 5.49 Variation of acreage of different crops for different crops in Sholapur

The variation graph shows that after 1980s there was a significant change in the cropping pattern. The shifting was from cereals to sugarcane and other crops like cash crops and fruits and vegetables. The only cereal crop that has positive growth rate is maize. The negative variation for rice, sorghum, groundnut, pigeon pea and sesame are more in comparison to other crops for the last period. Chickpea and wheat has maintained a constant acreage level with increase in yield. Another significant change has been observed for the acreage of sugarcane and a small increase in the wheat acreage

Table 5.21 Changing of different parameters of crop production in Sholapur

Crops	Change in yield			Change in fertilizer doses			Change in irrigated area			Change in producers price		
	1970-80	**1980-90**	**1990-2005**	**1970-80**	**1980-90**	**1990-2005**	**1970-80**	**1980-90**	**1990-2005**	**1970-80**	**1980-90**	**1990-2005**
	CAGR			CAGR			CAGR			CAGR		
Rice	-0.68	-3.04	0.00	3.617	4.67	5.7	-6.04	-0.46	-50.50	7.48	7.90	6.200

Wheat	1.78	1.93	-1.03	3.194	6.53	8.97	0.37	1.82	4.55	7.81	8.55	8.023
Sorghum	-1.36	-0.22	-4.49	2.976	6.78	8.98	1.02	0.54	-7.77	2.96	11.24	6.837
Pearl millet	5.93	2.91	0.75	4.11	5.87	9.012	-4.07	3.63	-11.60	2.63	10.42	8.321
Maize	-0.50	0.30	-2.54	3.73	5.83	10.12	-1.58	-5.21	-	6.24	8.27	6.348
Cereal	0.65	3.19	-3.39				0.15	0.57	-4.05			
Chick pea	2.88	2.74	-2.13	4.62	5.24	6.75	1.57	7.61	-0.07	12.49	10.31	9.454
Pigeon pea	4.22	-3.10	4.59	5.26	4.92	8.76	9.64	-4.30	-	11.50	10.32	9.632
Pulse	3.47	1.32	0.94	4.77	5.82	9.289	2.51	5.12	-0.73	12.67	9.94	18.935
Groundnut	7.42	-0.45	-4.36	2.98	5.24	6.44	11.53	0.01	-16.48	11.46	6.86	6.183
Sesame	-1.90	5.32	0.23	2.356	6.53	8.76	2.66	0.00	-	7.51	8.55	7.700
Cotton	1.36	-1.24	-1.81	4.32	6.91	8.13	-4.82	-4.29	2.42	7.00	12.74	8.706
Sugar cane	0.84	0.66	-0.80	3.49	5.19	9.19	5.27	6.99	-6.32	4.51	14.84	19.44

Table 5.22 Correlation of yield and other parameters in Sholapur

			Correlation with yield				
	Year	Average yield	Irrigated Area	Producers Price	Fertilizer uses	Temp.	Rainfall
Rice	1970-79	1457.45	0.70	0.61	0.71	-0.09	0.27
	1980-89	1360.98	0.03	-0.12	-0.53	0.07	-0.10
	1990-99	1000.00	-0.39	0.74	0.51	0.16	0.07
	2000-04	1000.00	0.47	-0.88	0.04	-0.62	0.35
Wheat	1970-79	795.49	0.76	0.68	0.51	0.34	0.60
	1980-89	949.22	0.26	0.59	0.34	-0.58	0.88
	1990-99	1149.53	-0.02	0.21	0.68	0.15	0.20
	2000-04	1068.83	0.98	-0.83	-0.67	-0.94	0.85
Sorghum	1970-79	814.37	0.82	-0.18	0.66	0.21	0.50
	1980-89	710.37	0.34	0.38	0.37	-0.26	0.73
	1990-99	694.82	-0.77	0.28	0.35	0.08	0.41
	2000-04	503.70	1.00	-0.52	-0.31	-0.96	0.63
Pearl millet	1970-79	176.92	-0.19	-0.50	0.17	0.28	0.20
	1980-89	314.61	-0.56	0.05	0.09	-0.76	0.50
	1990-99	419.33	-0.19	0.03	0.17	0.11	0.27
	2000-04	441.71	-0.05	-0.35	-0.02	-0.41	0.37
Maize	1970-79	1450.57	0.71	0.36	0.76	-0.35	0.22
	1980-89	1379.29	0.57	-0.52	-0.52	-0.03	-0.28
	1990-99	1421.39	0.09	0.59	0.43	0.24	0.19
	2000-04	1186.78	-0.03	0.07	-0.90	-0.72	0.92
Chickpea	1970-79	301.68	0.55	0.47	0.26	0.55	0.76
	1980-89	400.55	0.61	0.46	0.33	-0.39	0.86
	1990-99	524.75	0.43	0.52	0.57	0.40	0.22
	2000-04	451.43	0.98	0.06	-0.26	-0.94	0.60
Pigeon pea	1970-79	215.77	0.53	0.58	0.66	0.52	0.28
	1980-89	326.31	-0.13	0.45	0.36	-0.27	0.62

	1990-99	238.08	-0.09	0.28	0.44	0.56	0.32
	2000-04	325.86	0.84	-0.68	-0.25	-0.91	0.40
Pulse	1970-79	231.68	0.78	0.74	0.82	0.23	0.48
	1980-89	325.74	0.25	0.47	0.35	-0.55	0.85
	1990-99	371.49	0.20	0.57	0.59	0.43	0.30
	2000-04	396.72	0.95	-1.00	-0.27	-0.97	0.59
Groundnut	1970-79	623.31	0.22	0.36	0.36	0.38	0.42
	1980-89	1274.91	0.68	0.23	0.69	-0.27	0.70
	1990-99	1218.20	0.52	0.07	-0.09	0.42	0.64
	2000-04	891.77	0.61	-0.97	-0.18	-0.79	0.54
Sesame	1970-79	212.89	0.44	0.76	0.73	0.06	0.31
	1980-89	175.76	0.15	-0.51	-0.16	0.25	-0.69
	1990-99	295.24	0.10	0.15	0.48	0.01	0.13
	2000-04	300.00	-0.51	0.91	0.40	1.00	-0.67
Sugarcane	1970-79	8327.15	0.67	0.44	0.63	-0.07	0.24
	1980-89	9530.81	-0.72	-0.87	-0.80	-0.02	-0.42
	1990-99	8412.49	0.83	0.55	0.49	0.23	0.29
	2000-04	7404.46	0.53	-1.00	0.12	-0.88	0.20
Cotton	1970-79	222.54	-0.02	0.48	0.71	-0.35	-0.16
	1980-89	242.07	0.20	0.40	-0.08	0.40	0.41
	1990-99	258.57	0.49	0.53	0.77	-0.40	-0.48
	2000-04	244.35	0.33	-0.12	0.11	-0.21	-0.25

The correlation of yield and other variables clearly shows a relation of yield and rainfall amount. In case of rice crop the yield reduced slightly and showing a positive correlation with rainfall and irrigated area and negative correlation with producers price. The growth rate of producers price was less in the last period when compared to other periods. The irrigation area under rice was reduced due to decrease in rainfall. The fertilizer application of fertilizers and price increase although increased but unable to increase the yield due to constrain in irrigation and rainfall. For sorghum crop, high correlation is observed with irrigation and rainfall. The yield decrease is simultaneously with irrigation and rainfall decrease. In case of sugarcane the acreage has been increased significantly, but the yield has been decreased for the last period. During 1990s the sugarcane acreage has increased by more than 80 percentages. And after that the increase in acreage is even more than 15 percentages. The main driving force behind the increase in the acreage of sugarcane is the producers price. The growth rate of producers price is nearly 14.84 percentages for the year 1990s and even 19.4 percentages for the years after 2000. But the yield has been decreased after 1990s due to decrease in the irrigated area and rainfall. For most of the crops the yield has been negative after 2000 while there is a sharp increase in the yearly temperature of Sholapur. The correlation also shows negatively related with the yield. Therefore the yield is presumed to be significantly related with the irrigated area and producers price. The relation yield and rainfall and temperature are also significant for some of the crops. The price affects the intension of the farmers to apply fertilizers and maintain good agriculture practice. Here only few crops has been considered which restrict the implication of the obtained relation of yield with other factor. The acreage of fruits and vegetables has increased from the last few years due to high demand and high price.

5.3 FARMERS PERCEPTION ABOUT VILLAGE AND CLIMATE CHANGE

The four villagers of the study area are Dokur, Aurepalli in Mahbubnagar district of Andhra Pradesh and Shirapur, Kalman in Sholapur district of Maharashtra. The study area has been divided into two different groups. The first group is based on the input usage in agriculture and the second group is based on the drought resistance capacity of the village. According to the resource based on the village, agriculture practice, livelihood activities, climatic condition, adaptive capacity of the villagers and farmers perception the classification of high input and drought resistance region has been made. Dokur and Kalman are considered under low drought resistance villages while Aurepalli and Shirapur are considered under high drought resistance villages. In case of input usage, Aurepalli and Shirapur are considered as high input usage area while Dokur and Kalman are considered as low input usage area.

i) Demography of the villages

Dokur is small village of an area of 3395 acre in the Mahbubnagar district of Andhra Pradesh. This village is under the Devarkadra block. This village is among the six village level study village of ICRISAT for the past three decades. At present the gross cropped area is nearly 3038 acre and the irrigated area is nearly 630 acre. The village is suffering with continuous drought of 5 years for the last ten years and it makes the lives of the villagers more vulnerable to nature. The literacy level of this village is nearly 47% among them the males were more literate than the female. The numbers of large farmers are decreasing slowly as the nuclear families are increasing. At present nearly 40% of the population belongs to small household group while nearly 25% belongs to landless group. The medium household group comprises of nearly 19% and large household are nearly 15%.

Kalman is a village situated in the North Sholapur block of Sholapur district in Maharashtra state. The geographical area of this village is about 7563 acre in which net cropped area is about 4625 acre. The main source of irrigation is well and tube wells. The irrigated area is about 520 acre. This village is among the six village level study village of ICRISAT for the past three decades. The literacy level of this village is nearly 68 percentages and the male literacy percentage is more than the female literacy rate. The landless farmer consists of nearly 28 percentages which has decreased over a period of time. The dominant amount of percentages is about 51 percentages of small households which has increased over the last two decades. The medium households consist nearly 17 percentages, nearly unchanged over past decades.

Aurepalli village has 4022 acre geographic area in the Madgul block of Mehbubnangar district of Andhra Pradesh. The net cropped area is nearly 2472 acre and gross cropped area is nearly 2583 acres. This village is among one of the six village level study village of ICRISAT for the past three decades. This region comes under the semi arid region of India. The irrigated area of this village is nearly 693 acres. The main source of irrigation at present is bore wells. The average family size is about 4.5 per households and literacy level of this village is about 44 percentages. The literacy level among male is higher than the female literacy by nearly 20 percentages. The maximum percentage of house hold comprises of small and medium house hold.

Shirapur is a village in the Mohol block of Sholapur district in the state of Maharashtra. The total geographic area of this village is nearly 3355 acre and the net cropping area is nearly 2105 acre. The irrigated area is nearly 1750 acre. The main benefit of this region is facility of canal irrigation which helps them to less dependent on monsoon. The literacy rate of this village is nearly 62 percentages where the male literacy rate is more than the female literacy rate. This village is nearly 30 km away from the Sholapur main town. There are nearly 51 percentages of small households, 22 percentages of landless house hold, 19 percentages of households and 8 percentages of large households.

Table 5.23 Demography of the study villages

	Input area/Drought resistance				Input area /Drought resistance			
Demographic features	Low		Low		High		High	
	Dokur(AP)		Kalman(MH)		Aurepalli (AP)		Shirapur (MH)	
	Number	Farmers Perception *	Number	Farmers Perception *	Number	Farmers Perception *	Number	Farmers Perception *
Geographic area	3395 acre		7563 acre		4022 acre		3355 acre	
Landless HH	133	-1 (9)	198	-1 (11)	131	-1 (14)	138	-1 (18)
Small HH(0-2 ha)	212	1 (18)	357	1 (16)	315	2 (27)	306	1 (28)
Medium HH (2-4 ha)	106	1 (12)	119	0	250	2 (21)	116	0
Large HH (>4 ha)	80	-2 (25)	26	-1 (19)	70	-2 (24)	42	-1 (17)

*{-2 major decrease (>20% decrease),-1 minor decrease (<20% decrease), 0 no change, 1 minor increase (<20% increase), 2 major increase (>20% increase)}

According to the farmers perception the number of landless household has been decreased due to increase of income from non-farm sources. The large household also gets divided into smaller ones due to separation of lands among the offspring's.

Therefore the number of nuclear family has been increasing gradually. The livestock population has also been decreasing because of high cost of maintenance. Even though the overall population has decreased but still now peoples are using cross breed cattle's because of the emergence of few private milk collection centres.

Although there is slight increase in female cows of hybrid variety but overall there is a decrease in the livestock population. This happen primarily because the increasing maintenance cost of the livestock and increasing feed prices. Except in Shirapur the number of cattle population has been decreased in al other villages. In Shirapur increase of hybrid varieties of cattle has been observed.

Table 5.24 Livestock population of the study villages

Livestock population	Input area/Drought resistance				Input area /Drought resistance			
	Low		Low		High		High	
	Dokur		Kalman		Aurepalli		Shirapur	
	Number	Farmers Perception*	Number	Farmers Perception*	Number	Farmers Perception*	Number	Farmers Perception*
Cattle	67	-1 (13)	750	-1 (10)	204	-1 (17)	1240	1 (16)
Buffaloes	224	-1 (8)	840	-1 (12)	399	-2 (24)	750	1 (10)
Goats	2840	0	1100	0	646	1 (8)	738	0
Sheep	4783	1 (9)	580	1 (5)	3430	1 (19)	127	-1 (12)
Poultry	2790	1 (15)	130	1 (8)	1340	1 (7)	845	-1 (5)

*{-2 major decrease (>20% decrease),-1 minor decrease (<20% decrease), 0 no change, 1 minor increase (<20% increase), 2 major increase (>20% increase)}

ii) Livelihood of the study villages

The distribution of occupation is summarized in the below table. In Kalman and Shirapur, both from Maharashtra more than 60 percentages of villagers primary occupation is agriculture and for Shirapur particularly agriculture has been increased within the last 7 years. A sugar factory was established in 2003 just within a range of 3 km from the village. This reduced the transportation cost of the farmers and also created a ready market for the sugarcane. Therefore nearly 60-70 percentages of the farmer shifted to produce sugarcane from other crops. This increased the agriculture dependency of the villagers.

The labour sector consist of farm and non-farm labour. The farm labour has been decreased and the nonfarm labour has been increased substantially, therefore labour sector has been increased overall. In Dokur and Aurepalli, both in Andhra Pradesh, the labour sector growth is significant than the villages in Maharashtra.

Table 5.25 Primary occupation of the study villages

Primary occupation	Input area/Drought resistance				Input area /Drought resistance			
	Low		Low		High		High	
	Dokur		Kalman		Aurepalli		Shirapur	
	Share in (%)	Farmers Perception*	Share in (%)	Farmers Perception*	Share in (%)	Farmers Perception*	Share in (%)	Farmers Perception*
Agriculture	32	-1 (19)	63	0	46	-1 (15)	64	1 (6)
Labor	26	2 (22)	19	1 (15)	23	1 (18)	12	1 (9)
Business	7	1 (10)	3	0	3	1 (13)	1	1 (8)
Service	0	0	7	1 (8)	0	0	5	1 (10)
Caste	16	1 (16)	6	1 (4)	24	2 (35)	5	0
Others	19	1 (11)	2	0	4	1 (6)	12	1 (8)

*{-2 major decrease (>20% decrease), -1 minor decrease (<20% decrease), 0 no change, 1 minor increase (<20% increase), 2 major increase (>20% increase)}

The reason behind this is reducing agriculture dependency and increase migration. The caste based occupation i.e. sheep rearing, toddy cultivation and other small physical works have been increased significantly. The toddy cultivation particularly increased highly in Aurepalli and Dokur as it has a high demand in the village and nearby villages with high price.

iii) Source of irrigation of the study villages

The source of irrigation is one of the most important factors that helped an area to become less dependent on rainfall and turn it less vulnerable. In Dokur the source of irrigation has showed a major shifting from tank, wells to bore well. Presently about 99 percentages of irrigated land is under bore well. Due to reduction in rainfall from the last 10 years all the wells in Dokur has dried up and even the tank water is not being used for irrigation. Presently the villagers decided not to use the tank water so that the ground water level could go up. The water table has been changed drastically by nearly 165 ft within the last 30 years. The main reasons for this are decreasing rainfall and increase number of bore well. For Kalman the main source of irrigation is wells consistently for the last few decades. Recently for the last few years there is an increase in the number of bore wells. In Aurepalli about 95 percentages of the area is irrigated by bore well and only nearly 5 percentages area is by dig well. The major source has been shifted from wells to bore wells. The tank and wells are now totally dried up and the only source of irrigation is bore well. The depletion of ground water level and the increase in number of bore well are vice versa reason to each others. Due to depletion of ground water table villager depends more on bore wells. Again the bore well helps in exploitation of groundwater level. In Shirapur the major source of irrigation is canal from last 12 years after 1996 from when the canal has been functioning. Very less amount of wells and bore wells are there for irrigation. The canal water supply has some restricted time period. So the canal water is not available for throughout the years. The farmers collect the water from the canal during the available period and store it in the wells. So the actual source of irrigation is the canal. Due to proper availability of water Shirapur is under low drought resistance area. The canal is supposed to continue till Kalman within the next few years.

Table 5.26 Source of irrigation in the study villages

Source of irrigation	Input area/ Drought resistance				Input area/ Drought resistance			
	Low				High			
	Dokur		Kalman		Aurepalli		Shirapur	
	Area (%)	Perception*	Area (%)	Perception*	Area (%)	Perception*	Area (%)	Perception*
Canal	0	0	0	0	0	0	65	1 (78)
Tank	0	-2 (60)	0	0	0	-1 (15)	0	0
Well	1	-2 (70)	85	-1 (10)	2	-2 (80)	20	0
Bore well	99	2 (80)	15	1 (15)	98	2 (85)	15	1 (7)

*{-2 major decrease (>20% decrease),-1 minor decrease (<20% decrease), 0 no change, 1 minor increase (<20% increase), 2 major increase (>20% increase)}

iv) Cropping pattern of the study villages

The major kharif crops for Dokur village before last decade was sorghum, millet and ground nut. Presently for the last few years all those has been shifted to mainly castor and pigeon pea and cotton to some extent. The main reasons for this according to the villagers are decrease and erratic rainfall and high market value of castor

Table 5.27 Cropping pattern of low input and low drought resistance villages

Input area/ Drought resistance						
Low				Low		
Crops	Dokur			Kalman		
	Area (%)	Magnitude of change in area*	Average yield(kg/ha)	Area (%)	Magnitude of change in area*	Average yield(kg/ha)
Kharif						
Paddy	16	0	2460	0	0	0
Cotton	6	1(19)	400	0	0	0
Castor	28	2(35)	650	0	5	0
Jowar	3	-1(9)	350	0	0	0
Sorghum	7	-2(24)	360	0	0	0
Pigeon pea	0	0	0	38	2(24)	350

Sunflower	0	0	0	25	1(10)	140
Maize	0	0	0	3	0	1059
Blackgram	0	0	0	2	0	170
Groundnut	0	0	0	10	-1(12)	51
Vegetable	0	0	0	10	2(25)	-
Mixed crop						
Castor + Pigeon pea	40	0	250	0	0	0
Pigeon pea + others	0	0	0	12	2(22)	110
Rabi						
Paddy	39	-1(12)	2350	0	0	0
Groundnut	11	1(9)	550	0	0	0
Ragi	3	-1(17)	340	0	0	0
Bajra	4	-1(18)	345	0	0	0
Sorghum	31	-1(19)	380	76	-2(26)	650
Wheat	0	0	0	3	-1(13)	750
Chickpea	0	0	0	3	1(10)	520
Sunflower	0	0	0	5	1(9)	130
Vegetable	0	0	0	4	2(21)	3500
Mixed crop						
Sorghum +Pigeon pea	4	0		0	0	0
Sunflower + Pigeon pea	0	0	0	4	1(9)	310
Perennial						
Citrus	0	0	0	71	1(11)	0
Grapes	0	0	0	19	-1(9)	1670
Annual						
Sugarcane	0	0	0	49	1(19)	24000
Fruits	0	0	0	51	-1(13)	-

*{-2 major decrease (>20% decrease),-1 minor decrease (<20% decrease), 0 no change, 1 minor increase (<20% increase), 2 major increase (>20% increase)}

. During rabi season previously there were paddy all the area. But now it is shifted to rabi sorghum and groundnut due to water scarcity. Even they adopted new paddy variety of less duration i.e. nearly months in place of six months. Therefore the shifting is towards less water requirement, high resistance to timely water requirement, short duration and high market value crops. Presently for the last few years the farmers in Dokur are facing severe problem due to castor disease and infestation of wild pigs. Even for the last few years the yield of castor and pigeon pea has also been decreased due to above problems and decreased rainfall. The wild pig problem is one of the reason for decrease in acreage of ground nut. In Kalman the major kharif crop is pigeon pea and sunflower. Previously there were safflower, hulga and matki crops which are presently decreased significantly. There is a major increase in the pigeon pea and vegetables acreage in the kharif season. Vegetables required less water and it is a short duration crop, while pigeon pea has a good market value. Although the vegetable acreage is limited but the increase in the last few years is significant. In rabi season there is an increase in the chickpea production and equally decrease in the sorghum production. The probable reason behind this shifting is high market value of pulses and vegetables compared to cereals and less water requirement. Kalman also have perennial and annual crops like grapes and sugarcane. Compared to last 20 years the grape acreage has been increased but for the last few years the acreage has been decreased as well as yield due to change in rainfall distribution. The sugarcane acreage also increased for the last few decades. In 2007 the monsoon arrival was earlier and in 2008 it is extreme delayed by more than 2 moths. Therefore in 2007 the sowing of seeds was normal. The increase in temperature in Kalman region led to early ripening of the crops hence changing the crop duration cycles.

Table 5.28 Cropping pattern of high input and high drought resistance villages

Input area/ Drought resistance						
High				High		
Crop	Aurepalli			Shirapur		
	Area (%)	Magnitude of change in area*	Average yield(kg/ha)	Are a (%)	Magnitude of change in area*	Average yield(kg/ha)
Kharif						
Paddy	13	-1(15)	2560	0	0	0
Cotton	58	2(56)	900	0	0	0
Castor	0	0	0	0	0	0
Millet	5	0	350	0	0	0
Sorghum	4	0	360	0	0	0
Pigeon pea	0	0	0	32	-2(25)	550
Maize	0	0	0	22	2(22)	1550

Black gram	0	0	0	5	-2(26)	-
Matki	0	0	0	5	-2(30)	130
Fodder	0	0	0	21	-	-
Mixed crop						
Castor + Pigeon pea	20	-2(27)	268	0	0	0
Matki + kulthi	0	0	0	15		145
Rabi	0	0	0	0	0	0
Paddy	58	-1(14)	2450	0	0	0
Groundnut	10	1(9)	450	0	0	0
Maize	6	-1(14)	340	3	-1(19)	1458
Bajra	0	0	0	0	0	0
Sorghum	15	0	280		0	0
Wheat	0	0	0	9	-2(24)	1100
Chickpea	0	0	0	3	-2(22)	754
Sunflower	16	2(21)	550	0	0	0
Fodder	0	0	0	5	-	-
Mixed crop						
Sorghum +other crops	0	0	0	80	-2(28)	810
Sorghum + chickpea	0	0	0	2		250
Perennial						
Citrus	0	0	0	0	0	0
Grapes	0	0	0	0	0	0
Annual						
Sugarcane	0	0	0	94	2(70)	26000
Fruits	0	0	0	6	1(15)	-

*{-2 major decrease (>20% decrease),-1 minor decrease (<20% decrease), 0 no change, 1 minor increase (<20% increase), 2 major increase (>20% increase)}

The main kharif crops of Aurepalli village presently are cotton and some mixed crops with pulses. Previously the main kharif crops were sorghum, millet and small amount of paddy. From the last decade there is a significant increase in the cotton acreage. Simultaneously there was reduction in the acreage of the sorghum and millet acreage. The main reason for this is the high market value of the cotton acreage. In rabi season the main crop is still paddy but it has been decreased by more than 10 percentages. Simultaneously there is an increase in the acreage of ground nut and sunflower acreage. In Shirapur the main kharif crop is pigeon pea and maize. The major shifting for Shirapur is increase in the maize acreage. Previously there were practice of some coarse cereals like hulga, safflower, matki etc which has gradually reduced to negligible amount. In rabi season the major crop is sorghum. Significant decrease has been observed in the acreage of wheat, c hickpea and sorghum in the last decade. Nearly 65 percentages of t he village area of Shirapur has been covered by sugarcane which was initially occupied by other cereal crops.

Table 5.29 Change in cropping pattern for different periods in Study villages

	1975-76			2004-05		
	Average size of landholding (ha)	Proportion area under food grain production (%)	Proportion of area under food grain in mixed crop (%)	Average size of landholding (ha)	Proportion area under food grain production (%)	Proportion of area under food grain in mixed crop (%)
Aurepalle	4.4	39	0	2	22.6	5.9
Dokur	2.6	85	40	1.6	32.6	2.9
Shirapur	4.4	83	86	2.9	66.6	0.2
Kalman	8.1	93	99	5.1	52.5	1.2

The main reason behind this shifting is the establishment of the sugar factory within a range of 3 km of Shirapur during 2002-03. This sugarcane factory provides efficient transport and marketing facility to the sugarcane crops. Therefore farmers focused their attention toward growing the sugarcane crops. The canal availability in Shirapur also helped to get timely irrigation for the sugarcane.For all the villages a major shifting as observed was from cereal crops to cash crops. The decrease of cereals with mixed crop has been decreased extremely. Within the four villages the shifting of cereals to other crops is more in case of Dokur and Kalman both of which comes under low input and low drought resistance villages.

v) Climatic perception of the study area villages

Table 5.30 Actual and perceptual change in climate

Change in perception and actual climate	Input area/ Drought resistance				Input area/ Drought resistance			
	Low				High			
	Dokur		Kalman		Aurepalli		Shirapur	
	1970-90	1970-2008	1970-90	1970-2008	1970-90	1970-2008	1970-90	1970-2008
Change in actual annual rainfall (%)	6	-7	9	-10	6	-7	9	-10
Change in perceptual annual rainfall (%)*	0	-2(35)	0	-1(16)	0	-2(23)	-1(9)	-1(15)
Change in actual annual temperature (%)	-0.38	0.45	-0.12	0.56	-0.38	0.45	-0.12	0.56
Change in perceptual annual	0	1(10)	-1	1(13)	0	1(11)	1(6)	1(13)

temperature (%)*								
Change in GWL(%)	295		71		235		47	

*{-2 major decrease (>20% decrease),-1 minor decrease (<20% decrease), 0 no change, 1 minor increase (<20% increase), 2 major increase (>20% increase)}

The affect of climate change has clearly been observed by the farmers of nearly all villages. The perception of the farmer are quite similar to the original change. The change in actual rainfall for the second period (1990-2008) is nearly 7 percentage decrease for two villages in Mahbubnagar and nearly 10 percentage decrease in the two villages of Maharashtra. But the perceptual deviation of actual rainfall in Maharashtra villages is less than the villages of Andhra Pradesh. This is because Dokur is facing continuous drought of more than 4 year in the last 10 years and Aurapalli is also facing 2 years of severe drought in the last 10 years. Beside this the water availability of the Maharashtra villages are higher than the water availability of the Andhra Pradesh villages. The perception of farmers for increased temperature is also similar to the original change. The temperature increase for Sholapur villages is nearly 0.56 degree while for Mahbubnagar district villages are nearly .45 degree. The farmers perception in the Sholapur district villages also realized higher changes compared to farmers of Mahbubnagar district villages. Therefore not only the rainfall but also the ground water depletion creates impact on the farmers perception.

The arrival of monsoon has been deviate by nearly 1.1 percentages in the last period (1990-2008) in the Mahbubnagar district and nearly 3.35 percentages for the Sholapur district. It can be observed that the farmers perception in the Sholapur district villages about delay monsoon is less than the farmers perception in the Mahbubnagar district villages.

Table 5.31 Change in monsoon and monthly contribution

Change in perception and actual monsoon	Input area/ Drought resistance				Input area/ Drought resistance			
	Low				High			
	Dokur		Kalman		Aurepalli		Shirapur	
	1970-90	1970-2008	1970-90	1970-2008	1970-90	1970-2008	1970-90	1970-2008
Average actual deviation of monsoon (%)	-1.5	1.1	-0.5	3.35	-1.5	1.1	-0.5	3.35
Perceptual deviation of monsoon (%)*	0	2(25)	0	1(18)	0	2(24)	0	1(17)
Average contribution of June (%)	13	14	14	13	13	14	14	13
Average contribution of July (%)	20	19	15	17	20	19	15	17
Average contribution of August (%)	23	25	21	19	23	25	21	19
Average contribution of September (%)	20	18	24	24	20	18	24	24

*{-2 major decrease (>20% decrease),-1 minor decrease (<20% decrease), 0 no change, 1 minor increase (<20% increase), 2 major increase (>20% increase)}

The contribution of different months has also changed for the two districts means the rainfall become more erratic than before. The perception of the Sholapur district villages are less compared to the perception of the Mahbubnagar villages because the water availability (ground water) is more in the Sholapur villages. Therefore even though the deviation of monsoon is more, the affect on the crops will be less.

vi) Impact of climate change

Among the different factors that affect livelihood of the villages, climate change is considered to be one of the most important factors because the main source of income for the villagers.

Table 5.32 Cause of livelihood impact

Livelihood impact	Input area/ Drought resistance				Input area/ Drought resistance			
	Low				High			
	Dokur		Kalman		Aurepalli		Shirapur	
	1970-90	1970-2008	1970-90	1970-2008	1970-90	1970-2008	1970-90	1970-2008
Unsustainable production practices	1(9)	1(14)	0	0	1(8)	1(17)	0	1(14)
Climate change	0	2(26)	0	2(21)	0	2(22)	0	1(15)
Unsustainable water management	0	1(17)	1(6)	1(8)	0	1(18)	1(12)	0
Deforestation	0	0	0	0	0	0	0	0
Change in land use	0	0	0	0	0	0	0	0
Demographic pressure	2(23)	2(21)	2(21)	2(23)	2(24)	2(21)	2(23)	2(22)
Poverty	0	-1(18)	1(8)	-1(14)	0	-1(18)	1(6)	-1(10)
Govt. Intervention	1(7)	2(35)	0	0	1(5)	2(24)	0	0

*{-2 major decrease (>20% decrease), -1 minor decrease (<20% decrease), 0 no change, 1 minor increase (<20% increase), 2 major increase (>20% increase)}

In Shirapur and Kalman in Sholapur district the affect of climate change has comparatively lesser impact than the other villages. The main advantage of the The production practices have been improved from the previous due to farm mechanization and adopting improved variety of seeds. In the Dokur and Aurepalli villages of Mehbunagar, the climate changes however has a negative impact on the livelihood and whereas government intervention can be considered as the positive impact on livelihood. Compared to 1970s the awareness about water management has been increased to cop up with consistent drought and scattering rainfall. Continuous increase in the number of bore wells in the Mahbubnagar region led to further depletion of ground water level. The strong Government intervention is one of the major reasons to reduce the poverty level in the village. Sholapur villages is the availability of water for irrigation throughout the year. The Shirapur the canal water is used all the year to provide irrigation for all the year and in Kalman the well water is available most of the time of the year. The population of all the villages has all increased in high rate. But for these two villages of Sholapur the Government intervention is not significant. Various work programs from Government are not applied in this areas. This may be because inefficient panchayat and other political chaos. In all the four villages the poverty ratio has been decreased

vii) Labour availability of the study villages

In all the villages the availability of the farm labour has decreased while nonfarm labour has increased. The way of information flow has also diversified. Previously the only source of information is radio and government offices. Now the television and newspaper serves a very important role in information dissemination. The farmers usually get information about new technologies from the panchayat offices or from the progressive farmers and also from the retailer shops. In some cases ICRISAT also provide information about the new technologies. The cultivable area of Dokur has decreased mainly due to less rainfall and for Aurepalli due to increase of land value the owner prefer to sold the land for non agriculture practices. In Shirapur and Kalman the cultivable area has also decreased a small amount due to increase in the population and small scale industries.

Table 5.33 Labour availability of the study villages

Labour availability	Input area/ Drought resistance				Input area /Drought resistance			
	Low				High			
	Dokur		Kalman		Aurepalli		Shirapur	
	1970-90	1970-2008	1970-90	1970-2008	1970-90	1970-2008	1970-90	1970-2008
Availability of farm labour	0	-2(25)	0	-1(13)	0	-2(22)	0	-1(9)
Availability of non-farm labour	0	1(16)	0	1(15)	0	1(13)	0	1(12)
Information flow	0	1(10)	0	1(12)	0	1(11)	0	1(18)
Cultivable area	0	-2(21)	0	-1(8)	0	-1(16)	0	-1(9)
Farm mechanization	1(4)	1(10)	1(8)	1(13)	1(7)	1(12)	1(9)	1(18)
Irrigation	0	-2(29)	0	1(15)	0	-2(21)	0	2(23)
Govt. Intervention	1(7)	2(35)	0	0	1(5)	2(24)	0	0

*{-2 major decrease (>20% decrease),-1 minor decrease (<20% decrease), 0 no change, 1 minor increase (<20% increase), 2 major increase (>20% increase)}

The irrigated area for the two villages of Mahbubnagar has decreased more than 20 percentages while the irrigated area of the Sholapur villages has increased. The government initiatives are implemented properly in the villages of the Mahbubnagar villages but the Sholapur villages are deprived from it. In the Dokur and Aurepalli villages the employment guarantee scheme which was started in 2006 that promises 100 days employment to the villager has been implemented successfully in this village. For implementing properly the Panchayat is working in a sound manner and it decreases the poverty level of this village. But as easy work are available under the Government schemes the labour are reluctant to work as a farm labour inside the village. In the village the working hour is more than 8 hrs while for working under the scheme the working hour is nearly 6 hr and less intense. Beside that there has been an increase in migration of labour to earn easy money in the nearby cities. Therefore the medium and the large farmers are now facing the problem of labour scarcity in the villages.

Table 5.34 Change in income activities of the study area

Change of occupation	Input area/ Drought resistance				Input area/ Drought resistance			
	Low				High			
	Dokur		Kalman		Aurepalli		Shirapur	
	1970-90	1970-2008	1970-90	1970-2008	1970-90	1970-2008	1970-90	1970-2008
Change in migration *	0	2(26)	0	1(14)	0	1(17)	0	1(7)
Change in Business *	0	2(24)	1(4)	1(9)	1(4)	1(11)	0	0
Change in agriculture land *	1(12)	-2(29)	1(11)	-1(8)	1(13)	-1(9)	1(5)	0
Change in livestock*	1(10)	-1(11)	1(9)	0	1(10)	0	0	2(35)
Change in caste based occupation*	1(7)	1(16)	0	1(4)	0	2(35)	0	0
Change in average HH income *	-1(10)	1(35)	-1(15)	1(45)	-1(11)	1(36)	-1(10)	1(55)

*{-2 major decrease (>20% decrease),-1 minor decrease (<20% decrease), 0 no change, 1 minor increase (<20% increase), 2 major increase (>20% increase)}

There is a significant increase in the amount of migration for Dokur and in Aurepalli to some extent. The main reason of migration is unavailability of job in the villages and with proper remuneration. In Dokur due to continuous drought the farm practice has been decreased substantially which increase the migration amount. Likewise in Shirapur due to proper availability of work the migration is very limited. The livestock has increased by more than 30 percentages in Shirapur village and it is now one of the primary income source. In Aurepalli the caste based occupation particularly sheep rearing and toddy cultivation has been increased by more than 35 percentages for the last few years due to high revenue and lack of other activities for the same caste people. In Dokur also the caste based occupation like sheep rearing as been increased by small amount. The caste based occupation like pottery, hair dresser etc of Kalman and Shirapur has not increased very much due to adequate availability of farm job. The diversification of income sources lead to increase in overall average income of the villages.

viii) Natural resource management

Soil and water conservation measures comes under the natural resource management. Different initiatives has been taken for conservation of natural resources under Government Schemes and individual initiatiatives.

In Andhra Pradesh there is a strong Government initiative for soil and water conservation. In Dokur there is a check dam for harvesting rain water constructed in 2002. One water association was also creates at that time for proper management of the watershed. Beside this the Government also created other job opportunities by constructing small canal, water ponds and silting the check dam. In Aurepalli the bunds was created to avoid soil erosion. During these initiatives the villagers were involved in the Government employment schemes by mean of conservation. Therefore it creates job opportunity and equally it help to conserve soil and moisture. But all the activities were only from Government initiatives for Dokur and in Aurepalli the bund construction was done on farmers own initiatives. In case of Shirapur the canal was constructed during 1996 which is now the major source irrigation in this village. In Kalman there was small initiative by the Government for constructing bund for soil conservation. But the main problem with Government initiatives is the creation of employment in the Sholapur region. Even for the structures constructed by Government as a part of employment generating activities, the villagers do not get proper employment. Most of the time the government works depends on the contractors. Therefore including the villagers in the works are also depends on the interest of the contractor. There is a serious lacking in the Government approach for the implementation of the schemes.

Table 5.35 Causes of changing practice of low input and low drought resistance villages

Changing practice	Input area/ Drought resistance							
	Low				Low			
	Dokur				Kalman			
	Rank according to preference				Rank according to preference			
	Due to Change in RF	Due to Change in Temp	Due to Change in GWL	Due to Change in Market situation	Due to Change in RF	Due to Change in Temp	Due to Change in GWL	Due to Change in Market situation
New bore well	2	4	1	3	2	3	1	4
Deepening of the existing well	2	4	1	3	1	4	2	3
Adoption of sprinkler/drip set	1	3	2	4	1	4	2	3
Change in cropping pattern	2	4	3	1	3	4	2	1
Change in number of irrigation	1	3	2	4	1	4	2	3
Change in livestock rearing	2	3	4	1	2	4	3	1
Change in growing rain fed crop	1	3	2	4	2	4	3	1
Change annual crop to perennial crop	2	3	4	1	2	4	3	1
Alternate occupation(migration)	2	4	3	1	2	4	3	1

The ranking is done on 1-4 scale, 1= most important and 4= least important

To improve the natural resource quality and creating proper employment a bottom approach could be appreciable. Also there is a lacking of awareness about the consequences of improper management of soil and water. If villagers are fully aware about the need of conservation then community action could be a efficient solution for the land and water conservation.

Table 5.36 Causes of changing practice of high input and high drought resistance villages

Changing practice	Drought resistance/ Input area							
	High				High			
	Aurepalli				Shirapur			
	Rank according to preference				Rank according to preference			
	Due to Change in RF	Due to Change in Temp	Due to Change in GWL	Due to Change in Market situation	Due to Change in RF	Due to Change in Temp	Due to Change in GWL	Due to Change in Market situation
New bore well	1	4	2	3	2	4	1	3
Deepening of the existing well	2	4	1	3	2	3	1	4
Adoption of sprinkler/drip set	1	4	2	3	1	4	2	3
Change in cropping pattern	2	4	3	1	2	4	3	1
Change in number of irrigation	1	3	2	4	1	4	2	3
Change in livestock rearing	2	3	4	1	3	2	4	1
Change in growing rain fed crop	1	4	2	3	2	4	3	1
Change annual crop to perennial crop	2	3	4	1	2	4	3	1
Alternate occupation(migration)	2	4	3	1	2	4	3	1

The ranking is done on 1-4 scale, 1= most important and 4= least important

From the above table of farmers choice, it can be observed that the main cause behind every new initiative is change in market situation and after that change in climate. Change in GWL is also an effect of climate change in the region. As because climate is an uncontrollable variable, a proper knowledge on other adaptive technologies can help to combat the affect of climate change. A sound information flow regarding the climate change and market will always be useful to create suitable situation in the village to improve their livelihood.

ix) Institutional Involvement

Among all the institutional involvements the self help groups of women has shown a significant increase in the last decades. The SHG groups are engaged mostly for saving and disbursing loans. Beside it there is an increase of milk collection centres.

Table 5.38 Institutional involvement

Institutional involvement	Input area/ Drought resistance				Drought resistance/Input area			
	Low				High			
	Dokur		Kalman		Aurepalli		Shirapur	
	1970-90	1990-2008	1970-90	1990-2008	1970-90	1990-2008	1970-90	1990-2008
Farmers cooperative	Yes(1)	Yes(1)	No	Yes(1)	Yes(1)	Yes(3)	Yes(1)	Yes(2)
Milk collection centre	No	Yes	No	Yes(3)	No	Yes(4)	No	No
SHGs	No	Yes(33)	No	Yes	No	Yes(41)	No	Yes
Panchayat	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Secondary School	No	Yes	No	yes	Yes	Yes	Yes	Yes
Health centre	No	No	No	No	No	No	No	Yes
Veterinary hospital	No	No	No	No	No	No	Yes	Yes

Banks (Regional, rural, cooperative and private)	No	Yes	No	Yes	No	Yes	Yes	Yes
Electricity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Telephone	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The access to formal credit institute has been increased after 1990s. The secondary school was established during the 1970- 1990 period. But Health centres and veterinary centres are only present I Shirapur village. The veterinary centre facilitates the dairy farming and now dairy in one of the major source of income for the Shirapur villagers.

x) Barriers to adaptation

The main barriers to adaptation among all the above mentioned point is lack of awareness and lack of strong Governance. In all the study villages there are formal sources of Information services but the farmers are not fully aware about the source of information. Often the farmers feel reluctant to go the Krishi Vigyan Kendras which is a official extension service provide. But recently the second generation farmers are more aware of the information procedures. The other informal source of information providers are the progressive farmers, the traders and the retailers. Although there are formal source of credit services the villagers often be indecisive to approach to them due to high documentation. The agriculture land practices has been reduced which is one of the main source of income for the villagers. The shortage of land mainly happening because of reducing rainfall help to increase in fallow (particularly in Dokur) and increase of land price (Aurepalli) motivate them to sale their land for other than agriculture practices.

Table 5.38 Barriers to adaptation

Barriers to adaptation	Reasons
1. Lack of information	Lack of extension advise
2. Lack of access to formal financial services	Procedures for formal credit from banks; Depend on informal credit and SHG
3. Shortage of labour	NREGS, shift from farm to non-farm sources of income
4. Shortage of land	Sale of land, population increase, increase of fallow due to less rainfall
5. Decrease of GWL	Increased competition of water
6. Lack of Governance	Implementation of the Government schemes

The depletion of GWL also forced them to move toward deeper wells and bore wells, which ultimately increase the competition for irrigation water. Migration is one of the significant changes in most of the low drought resistant villages. Due to migration there is shortage in the labour availability in the agriculture land. The other promising reason is the NREGA scheme which provides 100 days of job guarantee to the villagers. This job has high wage rate with less effort and ultimately increase the overall wage demand from the labour side. With the increasing cost of production the medium class farmers are unable to afford the cost. This government intervention is highly significant in Dokur and Aurepalli. But in the Sholapur villages due to weak intervention of Government the labour are not getting proper remuneration and ultimately select migration as a last option.

xi) Adaptation strategy of the study villages

Different household villagers have different level of activities to cope up with climate change. The large households are the least effected class for the drought situation. They have their own saving and enough tangible and intangible assets which they can sell during failure of crops. Often the large households have more than one source of income.

Table 5.39 Adaptation strategy according to household segments of low input and low drought resistance area (Dokur and Kalman)

Household	Main coping strategy
Landless H	Seasonal migration to city, Government employment scheme(only for Andhra Pradesh villages)
Marginal H	Work as labour, lending money
Medium H	Lending money, selling of limited stocks
Large H	Reducing expenses, selling of stock, practice livestock

For drought situation the landless labour also used to migrate unless adequate work is available in the villages. As they have very limited assets and belongings migration is the only and easy way to earn livelihood. In Andhra Pradesh as the government intervention is dominant the landless labours can earn livelihood by employment guarantee scheme. But in Maharashtra villages the Government intervention is weak. Therefore the employment schemes are not implemented properly in those villages. The marginal farmers during crop failure often lend money from formal and informal source of institutes and also sometime works as labour in others field. Even in some cases they also prefer to migrate in nearby cities. In both the area the worst affected households are the medium households. They often lend money and sell the limited stock. But as they have some lands of their own, they usually do not prefer migration. The social prestige also resists them to go for labour during crop failure. So there are very limited options for the medium farmers.

The adaptation strategies can be classified according to intervention in different level. For the farm level intervention various method and practices has been adapted by the farmers. Shifting of crops and moving toward high yield variety is one the most common strategies they adapted.

Table 5.40 Adaptation strategy according to household segment of high input and high drought resistance area (Aurepalli and Shirapur)

Househo ld	Main coping strategy
Landless H	Seasonal migration to city, Government employment scheme(only for Andhra Pradesh)
Marginal H	Work as labour, lending money, seasonal migration
Medium H	Lending money, selling of limited stocks
Large H	Own saving, own irrigation facility, Reducing expenses, selling of stock

In Dokur the adaptation of short duration paddy crop and in Aurapalli the adaption of high yielding variety of cotton seeds showed the actual farm level intervention. The Government intervention is sounding in Dokur and Aurepalli (both in Mahbubnagar) villages. The NREGS i.e. National Rural Employment Guarantee Scheme is implemented successfully in the villages. But the implementation of this scheme is very limited in Kalman and Shirapur (both in Sholapur) villages. Although other schemes like Public Distribution System (PDS), Indira Awash Yojana (IAY) and other pension schemes are implemented in both the districts. Business activities has been increased in the Dokur and Aurapalii region which developed into a successful entrepreneurship in many cases. Dairy farm is one of the most common adaptation strategies in the Shirapur village. In almost all the villages the population of hybrid cattle’s has been increased with increase in milk collection centres. Beside this there is a significant growth in private milk collection centres and private poultries. This livelihood activities provide similar sidewise livelihood option to the villagers.

Table 5.41 Adaptation strategy on different intervention levels of the low input and low drought resistance villages (Dokur and Kalman)

Farm level	Change in cropping pattern, high yielding crop varieties (short duration crops)
Institution level	Milk dairy for diversification(less for Dokur) and loans, PDS shop and NREGS (for AP only) , Co-operative and banks for crop loans, small business
Technological level	Micro irrigation(for Dokur), deepening of existing bore wells, setting of new bore wells, check dams(for Dokur), water pond (for Dokur)
Social level	SHG for microfinance facilities, migration to nearby towns or cities(more in AP), increase of small business

The adaptation for the technology level is very limited. Various adaptation strategies has been observed in the form of irrigation in the Dokur and Aurepalli villages. The number of sprinklers and drip sets has been increased appreciably in those villages. While in the Kalman and Shirapur villages, may be as because they are not facing acute water problem, the adoption of micro irrigation is very limited. The soil and water harvesting structure was constructed with Governments own initiatives. Individual awareness is not sufficient to initiate the soil conservation practices in the villages.

In social level the main adaptation strategy undertaken by the villagers is migration. The migration status of Dokur and Aurepalli has been raised significantly. But in Shirapur and Kalman the migration status is not very alarming

Table 5.42 Adaptation strategy on different intervention levels of the high input and high drought resistance villages (Aurepalli and Shirapur)

Farm level	Change in cropping pattern, hybrid seeds (Hybrid cotton)
Institution level	Private dairy farm (Shirapur), PDS shop and NREGS(for AP) for BPL card holders(for Sholapur), Co-operative and banks for crop loans
Technological level	Micro irrigation(more in Aurepalli), deepening of existing bore wells, setting of new bore wells, water harvesting structures (canal for MH), dams
Social level	SHG for microfinance facilities, migration to nearby cities and towns (more in AP), increase of small business

. Although the migration activities brings more income for the villagers but it has negative consequences for the health aspect and food security aspect. In all the villages the social boundaries are very strong. Therefore community initiatives are very limited. The only dominant community activity are the women groups i.e. the SHG groups which are engaged mostly in small saving and loan disbursement activities.

xii) Coping mechanism

The main difference between adaptation and coping is the duration of effect. Adaptation comes when the farmers change their livelihood practice entirely due to prolong effect of climate change. But as far the study does not reveal any direct relation of shifting practice and climate change. Therefore coping mechanism is more suitable definition for the present study context.

The first sign of increase of climatic variability for the farmers is the change in the monsoon arrival. The sowing and harvesting of most of the crops depends on the arrival and departure of monsoon. Therefore farmers often shift their sowing and harvesting dates with the change of the monsoon arrival. Even the fertilizer application is also related with the monsoon arrival. Shifting of the dates of agriculture operation is the first coping mechanism that farmers perceive.

Table 5.43 Coping mechanism

Coping mechanism	Input area/ Drought resistance			
	Low		High	
	Dokur	Kalman	Aurepalli	Shirapur
Loans	**4**	**4**	**4**	**5**
Migration for nonfarm activity	**2**	**8**	**3**	**8**
Shift to new crop suitable to new climate pattern	**8**	**9**	**8**	**9**
Partial sale of assets	**3**	**3**	**3**	**4**
Increase of mixed crops	**5**	**7**	**8**	**6**
Change in date of operation	**1**	**1**	**1**	**1**
Use previous cash saving	**2**	**2**	**2**	**2**
Reduce consumption expenditure	**3**	**3**	**3**	**3**
Sale of livestock	**7**	**5**	**6**	**4**

Ranking in 1to 10 scale , 10= Least preferred, 1= Most preferred

During occurrence of drought the large as well as small farmers are forced to use their previous savings to sustain their livelihood. For the small farmers the savings are very limited and therefore they choose for sometimes to sale their assets and later on sale their livestock if situation become more difficult. The landless labour often choose migration as the most preferable option during unavailability of adequate wage jobs inside the villages. Assessing credit is one of the preferable options for the small farmers. Although there are difficulties to avail loan from formal sources but they still manage to get it from the informal sources. The shifting of cropping practices and adapting new varieties is not directly related to climae change. There are various factors that affect the shifting of crop. Among them market and irrigation plays a very important role. But in some regions like Dokur the farmers has adopted short duration variety of paddy crop due to decrease in the rainfall. Even the number of sprinklers and drips has been increased in the Mahbubnagar villages in the last decade.

6. Conclusion

The observed changes in climate for the last three decades showed a significant change in amount of total precipitation and annual average temperature. The maximum rainfall amount has also been decreased from the past and the minimum winter and as well as maximum temperature has been increased. The deviation of rainfall from the mean has also increased from the 1970s level. The depletion of ground water level in the villages is also quite alarming as it is one of the main sources of irrigation for Dokur, Aurapalli and Kalman villages. The decadal rainfall data in almost all regions showed significant decrease in the annual rainfall. The cropping pattern of the whole Mahrashtra and Andhra Pradesh has gradually shifted from cereal to non cereal crops. The decrease in rainfall, the change in irrigated area and the market value of the crops are the dependent variable for the shifting of the cropping practice. The village level cropping pattern also has been shifted to less rainfall required crops, shorter duration and high yield variety crops. The cereal area has also decreased in all the villages and transformed to non cereal crops. The main reason for this is the scattering rainfall and the market price. The market value of the pulses and other cash crops has increased more than the cereal crop which stimulates the shifting of cropping pattern.

The analysis of farmers' perceptions of climate change indicates that most of the farmers in the study are aware that temperature is increasing and the level of precipitation is declining. In all the villages the overall village economy is growing due to increase in the livelihood options. Migration has been the most adaptable practice in the drought villages. Government initiatives has also been significant in the villages of Andhra Pradesh. Various water and soil conservation practices has initiated by the Government and in some places it is very successful. Increase in the livestock particularly hybrid cattle is another observed changes in the study villages. In Shirapur livestock is now one of the primary occupations. Even in Aurepalli village few medium to large farmers has started their own dairy farm to collect milks. Although Self Help Groups has increased appreciably still social boundaries are very strong in the villages.

The main sources of information for the villagers are the progressive farmers, the traders and retailers.

As the cereal crops is decreasing and non cereal crops has increasing the only negative effect it could impose is upon the food security of the nation. Therefore proper initiative to maintain the cereal crops in one side and extensive research on the drought resistance crops could maintain the food security. The Government initiatives are effective in the Andhra regions but not so effective in the Maharashtra regions. So a bottom up approach could help to create more job opportunities and soil and water conservation in the villages. Awareness to the villagers could also encourage them for natural resource conservation by individual initiatives. For community action and mass awareness the SHG groups could be helpful. A prior knowledge to monsoon arrival and weather and also the various Government schemes running for that region, the new varieties suitable for that region can help the farmers to plan for their next crops. Other initiatives that could be beneficial to combat with climate change includes implementation of effective crop insurance policies, facilities for credit and infrastructure for off farm activities, conducting research on crop varieties and livestock species that are better suited for dry region, encouraging social networking and investment in irrigation.

ANNEXURE

Defining key conceptual terms

This section defines the concepts and terms used in climate change impact assessments and adaptation used for climate risk management.

Atmosphere is the blanket of air that surrounds the earth, moving both horizontally and vertically and thus causing variation in weather and climate. It absorbs energy from the sun, recycles water and other chemicals and works with electrical and magnetic forces to provide the moderate climate. The atmosphere also protects the earth from high-energy from high energy radiation.

Weather is the current atmospheric condition in a given place. This includes variables such as temperature, rainfall, wind or humidity. Anyone looking outside can see if it is raining, windy, thermometer or just feeling it. Weather is what is happening now, or likely to happen tomorrow or in the every new future.

Climate is average weather for a given place or a region. It defines typical weather conditions for a given area based on long-term averages. For example, on average, Andhra Pradesh is expected to sunny in May, rainy in July and cold in January but there may be annual deviation. Although an area's climate is always changing, the changes do not usually on a time scale that is immediately obvious to us. We can observe how weather changes from day to day but subtle climate changes are not as readily detectable. Weather and climate take similar elements into account, the most important of which are air temperature and humidity, type and amount of cloudiness and precipitation, air pressure, and wind speed and direction. A change in one weather element can produce changes in regional climate.

Climate variability refers to the climatic parameter of a region varying from its long-term mean. Every year in a specific time period, the climate of a location is different. Some years have below average rainfall, some have average or above average rainfall. These changes are result from atmospheric and oceanic circulation, caused mostly by differential heating of the sun or earth. The atmosphere and ocean circulate in three dimensions and each acts on the other. The atmosphere moves faster than the ocean, but the ocean stores a large amount of heat and releases it slowly over a long periods. Thus, the ocean acts as a memory in this circulation. These atmosphere-ocean circulation cause climate to vary in seasons or year to year time period.

Climate change is attributed to both natural and human activities. Variation in climate parameters generally attributed to natural causes. However because of changes in the earth's climate since the pre-industrial era, some of these changes are now considered attributable to human activities.

Enhanced greenhouse effect is considered the result of human activities that have increased atmospheric concentrations of green house gases and aerosols since the pre-industrial era. The atmospheric concentrations of key green house gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). They reached their highest recorded level in 1990s, primarily due to combustion of fossil fuels, agriculture, and land-use changes.

The increase in surface temperature in the northern hemisphere during the twentieth century is considered greater than for any century in the last 1000 years. Statistics show the global mean surface temperature increased by 0.6±0.2°C, the number of hot days in a year increased in many places and the number of cold days decreased in nearly all land areas (IPCC, 2001).

Carbon dioxide concentrations globally averaged the surface temperature and sea level are projected to rise in the future. Various climate model projections predicted that the average surface temperature would increase with a range of 1.4 to 5.8 °C between 1990 and 2100. Thos is about two to ten times larger than the observed warming during the twentieth century. Similarly, the average global precipitation is projected to increases during the twenty-first century but at regional level, there will be both increase and decreases ranging from 5 percent to 20 percent.

Adaptation is a process by which strategies to moderate, cope with, and take advantage of the consequences of climate events are enhanced, developed and implemented.

Adaptation baseline is the current adaptations that are already in place.

Adaptive capacity is the ability of a system to adjust its characteristics or behavior in order to expand its coping range under existing climate variability or future climatic conditions. There is a difference between adaptive potential, which is a theoretical upper limit of response based on expertise and anticipated developments within the planning horizon of the assessment, and adaptive capacity, which is existing information, technology and resources of the system under consideration.

Climate change vulnerability is the degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes.

Coping range is the range of climate where the outcomes are beneficial or negative but tolerable. Beyond the coping range, the damages or losses are no longer tolerable and a society is said to be vulnerable.

Risk is the result of interaction of physically defined hazards with the properties of the exposed systems, i.e. sensitivity or vulnerability. Risk can also be from the combination of an event, its likelihood and its consequences. Risk equals the probability of climate hazard multiplied by a given system's vulnerability.

Socio-economic vulnerability is aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of harmful perturbations.

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