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CLIMATOLOGY

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IMPACT OF CLIMATE CHANGE ON THE PRODUCTION OF RICE AND POTATO IN PASCHIM MEDINIPUR DISTRICT, WEST BENGAL

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Abstract

Climate change might be a major concern to human being since it affects so many economic sectors as well as different aspects of human life. Climate change is projected to have serious implications for their crops because irrigation facilities are not available sufficiently although rice is rainfed crop but potato cultivation is fully dependent on irrigated water. The study is focused on the impact analysis of climate change particularly the change in temperature and rainfall on the yield of rice and potato. Paschim Medinipur District of West Bengal is such a drought prone area where more than 80% people are dependent on agriculture. The cultivation of rice and potato is adversely affected not only by an increase and decrease in all overall amounts of rainfall but also by shifts in the timing of rainfall during the period of 2004-2005, 2007-2008 and 2010-2011. The result reveals that an integrated farming system was considered one of the most important adaptations to cope with the climatic vagaries. Changing the timing of sowing, planting, harvesting; to take advantages of the changing duration of growing season and associated heat and moisture level was another options. Farmers have developed a wide range of management practices such as intercropping, crop rotation, rainwater harvesting etc.

Introduction

Climate change is one of the most important global environmental challenges of the present century. Global warning has been in increasing trend since the 1980, although the earth's average surface temperature has increased by about 1.2 to 1.4 ^{0}F in the last 100 years (Mendelshon, 2007). Climate change might be a major concern to human being since it affects so many economic sectors as well as different aspects of human life. Negative impacts of climate change on the agricultural sector will be especially dangerous since it is directly related to food security and human health.

Paschim Medinipur District of West Bengal is such a drought prone area where more than 80% people are dependent on agriculture. Around 60% of total agricultural land is rainfed and it is highly vulnerable to climate change particularly in monsoon season. More than 80% of total farmers' in this district are small and marginal and thus, having less capacity to cope with climate change impacts on agriculture. At present, paddy as cereal crop in kharif season and potato as cash crop in rabi season are the two most important staple food in this region. In most agro-climatic regions, farmers have compelled to stop to cultivate such crops which are the best suitable for that regions. Climate change is projected to have serious implications for there crops because irrigation facilities are not available sufficiently although rice is rainfed crop but potato cultivation is fully dependent on irrigated water.

Our main concern is to assess the impact of climate change particularly the unevenness and variability of rainfall and fluctuating temperature on these two staple crops. We are also trying to analyse the perception of farmers about the impact of climate change, the adoption strategies adopted by them to cope with these climatic vagaries. Before the impact analysis, we must know about the climate change and the agricultural system of this District.

Climate Change

According to IPCC, “Climate change refers to a change in the state of the climate that can be identified by change in the mean or variability of its properties and that persists for extended periods, typically decades or longer”. Climate change is evident from the observations of increase in global average air temperature, sea surface temperature, variability in precipitation, extreme weather events, widespread melting of snow and ice, storm surges and coastal flooding. The unprecedented change in the monsoon related rainfall is expected to have severe impact on the hydrological cycle of this area and thus, changing the pattern, frequency and intensity of extreme rainfall events (flood and drought).

Agricultural System

The key characteristics of the agricultural system of this area that could influence its vulnerability to climate change are (i) the high level of subsistence type agriculture with very small holdings; (ii) majority of agricultural practices particularly in kharif season and rainfed, (iii) unevenness, seasonality and variability of rainfall mainly control the crop yield, (iv) maximum thrust on food cropping, not on cash cropping; (v) irrigation facility is not sufficient.

Study area

Paschim Medinipur District (21^0 36’35”N – 22^0 57’ 10” N to 86^0 33’50” E – 88^0 12’ 40” E) is located in the extreme South Western part of West Bengal. The average attitude is 39 m above M.S.L. The total geographical area is 928.53 ha. The area is served by the river Kangsabati, Silabati, Subarnarekha etc. and the soil mainly red lateritic and sandy loam type. The total population are 5943300 (2011) of which the no. of cultivators are 456650 (2011) and no. of agricultural labourers are 616181 (2011). The District headquarters is Medinipur (22^0 25’N and 87^0 19’E).

Methodology and Data Base

The study is focused on the impact analysis of climate change particularly the change in temperature and rainfall on the yield of rice and potato. The related data were collected from Government published records and documents, climatic and agricultural departments and administrative offices. For perception analysis of farmers, a multi-stage random sampling design was employed for the selection of the sample respondents across various economic, age and racial classes. The total sample constitutes 300 respondents of 20 mouzas of 10 C.D. Blocks. The required information for the study was collected using pre tested structured questionnaire schedule. The collected data were tabulated and statistically analysed to interpret the result. Descriptive statistics were used to assess farmer's perceptions.

Analysis and Results

It is evident that physical impact of climate change are seen as, (i) increase in the average temperature by 2^0C – 4^0C; (ii) changes in rainfall (both distribution and frequency) during pre-monsoon, monsoon and post-monsoon seasons, (iii) decrease in the no. of rainy days by more than 15 days, 9iv) an increase in the intensity of rain by 1-4 mm/day, (v) increase in the frequency and intensity of cyclonic and hail storms, (vi) improper onset of monsoon, (vii) increasing long dry spell etc. Table 1 shows the distribution of mean seasonal temperature and rainfall of the study area.

Rice in kharif season and potato in rabi season are the two most important staple crops in this region. We can say that the economy of this area depends on these two crops. All the climatic vagaries impose negative impact on the production of both rice (rainfed) and potato (irrigated water fed). Table.2 represents the agriculture land use in the District. Most of the areas of the district are largely dependent on rainfall for irrigation. Any change in rainfall pattern poses a serious threat to total agricultural system.

The cultivation of rice and potato is adversely affected not only by an increase and decrease in all overall amounts of rainfall but also by shifts in the timing of rainfall. For instance, the yield of rice is sufficient in the year of 2004-05, 2007-08, 2010-11 due to the right timing and distribution of rainfall. On the other hand the rice yield is poor in the year of 2003-04, 2005-06, 2008-09 because of improper onset of monsoon, long dry spell, intense rainfall in 2-3 days or flooding. The cultivation of potato in rabi season also hampers due to the unpredicted rainfall (2005-06), hail (2006-07), outbreak of diseases (2008-09) etc. Even the amount of moisture and temperature in the soil will be affected by changes in factors such as precipitation, run off and evaporation.

Table 1. Distribution of mean seasonal temperature (°C) and rainfall (mm)

Year	Season wise distribution of temperature			Season wise distribution of rainfall		
	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post - monsoon
2000	27.5	29.13	22.75	75.75	279.50	11.25
2001	27.88	28.75	22.88	90.75	281.50	44.75
2002	27.88	29.25	22.63	55.75	328.00	32.00
2003	28.50	29.12	22.12	50.75	207.25	130.50 **
2004	29.75 *[t]	31.25 *[t]	22.50	22.75 *[r]	275.00	43.50
2005	28.5	29.88	22.50	56	254.50 *[r]	91.50
2006	28.63	29.25	23.13	48.5	297.75	12.75
2007	27.75	29.25	19.00	54.5	476.75 *[rr]	115.25 *[rr]
2008	27.37	28.87	23.12	51.00	398.25	24.50
2009	27.39	28.33	23.22	76.50	200.50 *[r]	20.75
2010	29.88 *[t]	32.50 *[t]	22.75	41.50 *[r]	192.75 *[r]	29.50
2011	28.5	31.13 *[t]	22.75	41.50 *[r]	192.75 *[r]	29.50

(Source : Indian Meteorological Department- Alipore, Kolkata)

N.B. *[t] = increasing temperature from normal.

*[r] = decreasing rainfall from normal.

*[rr] = flood situation.

** = increasingly rainfall in post monsoon period from normal.

Table 2. Agricultural land use of the District (2012).

Agricultural land use	Area (000 ha)	Cropping intensity (%)
Net sown area	558.70	168
Area sown more than once	379.94	
Gross cropped area	938.64	

(Source : Department of Agriculture, Govt. of West Bengal).

Gross irrigated area	428.12	46.11
Rainfed area	510.52	54.98

(Source: Department of Agriculture, Govt. of West Bengal).

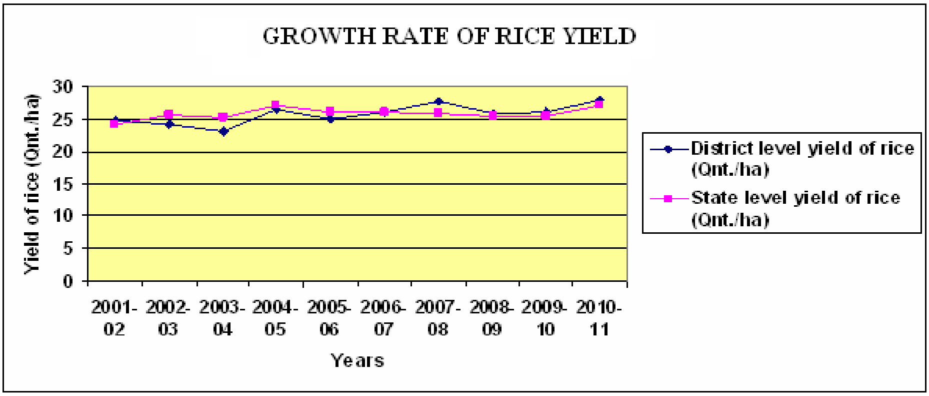

Fig. 1. Growth of Rice

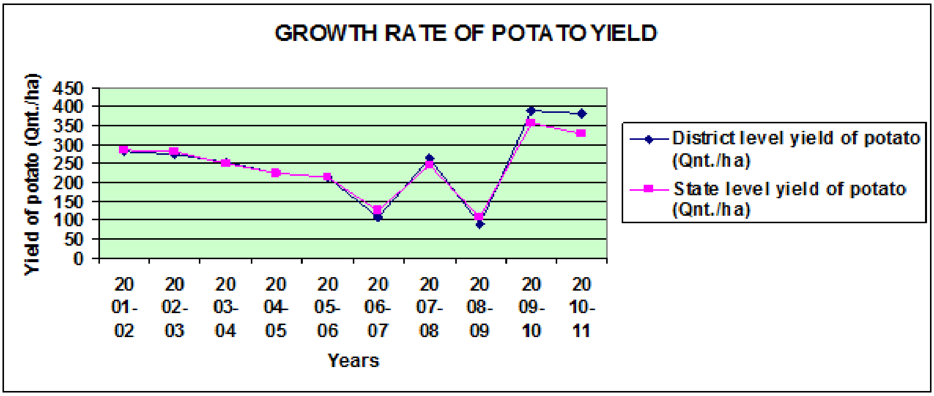

Fig. 2. Growth of Potato

Table 3. Represents status of irrigation facilities available in the study area during 2012.

Irrigation status	Area (000 ha)	% to total geographical area (928.53 ha)
Net irrigated area	82.4	8.87

The multivariate regression analyses between changes in temperature, rainfall and yield of rice and potato show the positive relation in case of positive changes and negative relation in case of negative changes (+1 in the case of temp. and yield of rice, +0.82 in the case of rainfall ; - 0.48 in case of rainfall and potato etc.). Besides other agricultural technologies it is evident that supply response of food production is greatly influenced by the irrigation facilities. It is however, true that now with over 54.98% of rainfed areas under rainfall is still one of the most important factors determining average yield . Due to the vagaries in rainfall in 2008-09 1856.7 thousand tonnes of rice production, nearly 515.42 thousand tonnes were produced in the areas without irrigation.

Table 4. Yield characteristics of rice and potato

Year	Rice Area ('000 ha) Production ('000 Tonnes) Yield (Qnt. /ha)				Remarks	Potato Area ('000 ha) Production ('000 Tonnes)				Remarks
	Area	Production	Yield (Dist. level)	Yield (State level)		Area	Production	Yield (Dist. Level)	Yield (State level)	
2001-2002	580.3	1441.1	24.83	24.12		47.1	1335.4	283.52	284.57	
2002-2003	642.1	1551.8	24.18	25.58		67.1	1841.8	274.49	282.51	
2003-2004	651.4	1508.2	23.15	25.23	Delay in monsoon	61.1	1547.5	253.27	250.32	
2004-2005	655.3	1736.8	26.50	27.14		56.7	1268.7	223.76	225.14	
2005-2006	654.0	1629.6	24.92	25.94	Long dry spell	71.3	1519.6	213.13	215.24	Unpredicted rainfall
2006-07	692.4	1798.8	25.98	25.93		79.4	843.7	106.26	123.84	Deep tog and more rainfall
2007-08	650.2	1798.8	27.67	25.73		70.7	1874.4	265.12	247.04	
2008-09	718.9	1856.7	25.83	25.33	Lesser rainfall	63.6	557.3	87.63	106.77	Out break of diseases
2009-10	674.3	1756.5	26.05	25.47		62.7	2448.1	390.45	357.68	
2010-11	616.7	1718.6	27.87	27.08		64.7	2482.4	383.68	328.31	

Source: Department of Agriculture, Govt. of West Bengal

Farmers' perception about the impact of climate change on rice and potato production: The farmer's perception on the climate change was assessed using open ended as well as closed and perceptive as well as conceptual type questions. Most of the farmers did not know the concept of climate change as such directly but they expressed through the effects or changes of different climatic phenomena that occurred compared to the earlier years or based on their elder's experiences. The perceptions of the farmers are organized and tabulated (Table.5) in the following.

Table 5. Farmer's perception on the impact of climate change

Impact factors	Perception in %			
	Small farmers	Medium farmers	Large farmers	Total farmers
Reduction in yield	84.27	79.58	65.13	76.33
Reduction in net income	89.26	81.63	62.15	77.68
Pest and disease out break	75.34	72.67	69.25	72.42
Seasonal variation in rainfall	98.26	92.56	96.25	95.69
Crop failure	96.25	94.26	74.56	88.36
Shifting of seasons	74.56	76.68	72.48	74.57
Change in other climatic phenomena such as deep fog, hail, cyclones etc.	96.25	92.45	95.36	94.69
No idea	2.56	3.26	13.56	6.46

The results of the above table reveal that the farmers of all categories are suffered by the impact of climate change but the worst impact imposes on the small and medium farmers because of their dependence on climatic phenomena particularly on rainfall hazards. Large farmers can cope with the changing pattern to some extent due to their capacity to avail agricultural technologies and better economy.

Table 6. Farmer's perception of climate

Climatic events	Perception of farmers (%)		
	Increased	Decreased	No Change
Temperature	96.17	0	3.83
Rainfall	16.25	73.50	10.25
Occurrence of drought	61.00	5.00	34
Late onset of monsoon	85.00	0	15
Early withdrawal of monsoon	76.00	0	24
Long dry spell	86.00	0	14
Uneven distribution of rainfall	98.00	0	2
Unpredictable rainfall	84.00	6.00	10
Other climatic hazards	83.00	0	17

The result indicates that most of farmers perceived that the distribution of the temperature had significantly increased. By contrast almost all said that the rainfall level had continuously decreased. The majority of respondent believed the uneven distribution and unpredictable behaviour of climatic phenomena.

Table 7. Reasons for reduction in yield and net revenue

Impact factors	Perception of total farmers (%)
1. Change in seasonal pattern of temperature	56
2. Change in seasonal pattern of rainfall distribution	92
3. Soil erosion and fertility	12
4. Out break of pests and diseases	78
5. Other climatic hazards, such as fog, hail, cyclones etc.	62
6. No idea	8

The respondent farmers are highly concerned about the reduction of yield and net income because crop yield sustains their lives. The seasonal increase in temperature and seasonal variation of rainfall, and other climatic hazards such as deep fog, hail and cyclones etc. mainly are responsible for low yield rate. They mostly perceived that the outbreak of pests and diseases occurred due to these climatic changes. It is clear that most of the farmers are very much conscious about the lowering yield rate and the reduction of their annual income.

Thus, we can say that the impact of climate change on agricultural production are considered into main three ways, such as:

(i) direct effects on rainfed yields through changes in temperature and rainfall;

(ii) indirect effect on irrigated yields from changes in temperature and in water available for irrigation and

(iii) autonomous adjustments to area and yield due to the use of agricultural technology, price effects and changes in trade system.

The direct and indirect effects of climate change on agriculture play out through the economic systems, altering prices, production productivity, food demand and ultimately human well-being.

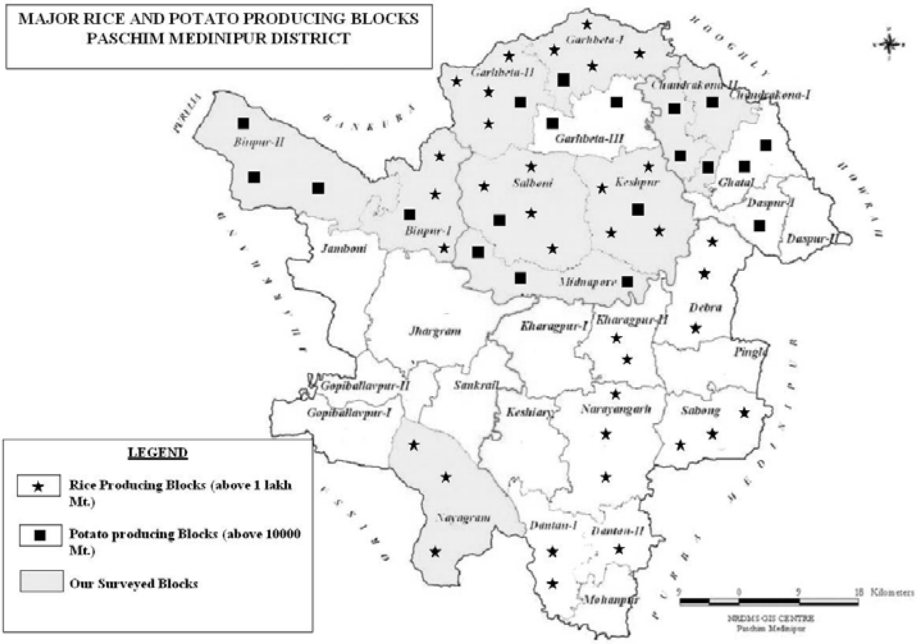

Fig. 3. Major Rice and Potato production blocks in Medinapur District

Adaptive measures and strategies: It is now urgent need to recognize the climatic change and variability issues holistically through various adaptive measures particularly what the farmers want. Proper use of latest improvements in agricultural technologies and right time weather forecasting system can enhance the agricultural productive and meet the future challenges of climate change in this region.

Farmer's perception on adaptive measures: Various adaptation strategies being used by the farmers in response to challenge climatic changes. The result reveals that an integrated farming system was considered to be one of the most important adaptations to cope with the climatic vagaries. Changing the timing of sowing, planting, harvesting; to take advantages of the changing duration of growing season and associated heat and moisture level was another options. Farmers have developed a wide range of management practices such as intercropping, crop rotation, rainwater harvesting etc. But even now the agricultural insurance is not so popular among farmers most probably due to their unconsciousness.

Table 8. Major adaptation strategies to mitigate the impact of climate change

S #	Adaptations	Farmers perception (%)			
		Small farmers	Medium farmers	Large farmers	Total farmers
1	Integrated / mixed farming system	94.35	75.27	61.19	76.94
2	Use of short duration crop varieties	45.23	46.68	33.59	41.83
3	Change in cropping pattern	62.57	44.23	28.11	44.97
4	Change in time of farm operation	74.02	65.81	55.73	65.19
5	Soil conservation techniques	35.32	46.27	55.29	45.63
6	Crop rotation	83.42	71.57	65.19	75.39
7	Inter cropping	81.22	73.42	63.56	72.73
8	Increase the use of organic manners	47.13	45.67	16.23	36.34
9	Use of stress tolerant seeds	10.56	20.32	30.45	20.44
10	Use of water conservation techniques	70.21	61.35	55.53	62.36
11	Shifting of other occupations	85.58	76.29	25.63	62.50
12	Borrowing	86.74	59.45	10.41	52.20
13	Insurance	12.32	15.52	35.39	21.08
14	Reduce expenditure of consumer goods	65.35	51.21	5.29	40.62

Recommendations

In order to reduce the adverse impacts of climate change on agriculture, few adaptive actions need to be taken at various levels. These strategies will have to be based on sustainable land use practices which are better suited for the local climatic variability.

1. Care management of resources like soil, water etc. taking up all possible measures to increase water resources and reserves at all levels taking the advantages of local relief.
2. Focus should be given on the stress tolerant local varieties of seeds.
3. Changes in the cropping pattern and cropping sequence if necessary. Focus to given on sustainable agriculture techniques like mixed cropping, intercropping etc.
4. change in the land use pattern considering relief and soil depth and water availability of the area.
5. Close monitoring of weather elements and their impact on standing crops to bring the situation under control.

6. An early warning system should be put in place to monitor changes in pest and disease profiles and predict new pest and disease out breaks.
7. The agriculture credit and isurance system must be made more comprehensive and responsible to the needs of small farmers particularly.
8. Substitute employment opportunities outside the agricultural sector such as fishing, poultry farming can improve the economy of the farmers.
9. Awareness among the farmers about the nature and extent of weather changes is very essential.
10. Transportation, distribution and market integration to provide the infrastructure to supply food during crop failures.

Conclusion

This research clearly reveals that the climatic variations have significant impact on the production of both rainfed as well as irrigated crops. The small and medium farmers are most affected due to the poverty and lesser ability to cope with the climatic changes. Agriculture is still the main source of income and provides a fundamental contribution to welfare and socio-economic development of this region. Thus, climate change can be viewed as one of the most critical environmental problems to confront us as it is most immediately linked to human well-being, development and economic growth.

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ANNUAL AND SEASONAL MOISTURE VARIABILITY AND ASSESSMENT OF AGRICULTURAL EFFICIENCY OF CROPS IN JHARKHAND STATE, INDIA

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Abstract

Agricultural productivity may be enhanced by using additional irrigational and bio-chemical inputs. Sometimes these methods may trigger other problems such as soil erosion, water logging, salinity/alkalinity etc., which are detrimental for agricultural sector. Instead, Index of moisture adequacy (Ima), a derived parameter of water balance helps in the identification of crop suitability, ideal length of growing period and agricultural potentiality of any region. In the present study water balance is carried out for seven IMD weather stations of Jharkhand and Ima indices were estimated. The analysis revealed that soil moisture status in the study region is highly suitable to support high water requiring crops during kharif season and highly to moderately suitable for less water requiring crops during rabi season. Almost entire State is highly efficient for agriculture during kharif, efficient during rabi and moderate to less efficient during zaid (summer) season. On the basis of annual moisture status, entire State comes under efficiently suitable zone for agriculture except Jamshedpur region which comes under moderately efficient zone.

Keywords: Index of moisture adequacy (Ima), crop suitability, water balance and soil moisture

Introduction

For the ever-growing population size, the problem of food security is posing a big challenge for the governments, researchers, policy makers and planners. Past experiments towards improving agricultural productivity have indicated that advanced irrigational and bio-chemical inputs have increased the crop productivity to a large extent (Hussain, 2001). But at the same time these methods have triggered the problems such as soil erosion, water logging, salinity/alkalinity etc., which are detrimental for agricultural sector (Haider, 1998; Stigter, 1995; Pal, 2001).

Hence, it is essential to search for sustainable methods by which agricultural efficiency and productivity may be enhanced without damaging the ecological environment. In this context, the concept of agro-climatic regionalization is gaining significant recognition and applicability since it emphasizes the sustainable approach in the selection of suitable crops, cropping pattern, crop scheduling etc. in relation with the existing climatic conditions. Several studies have already indicated that the growth and development of plants, incidence of pests and diseases, droughts and floods etc. are directly related to climatic variables especially temperature and moisture and hence they play a crucial role in determining success or failure of a particular crop (Subramaniam, 1987; Montheith, 1999).

Further, earlier studies indicated that excessive moisture as well as extreme water deficiency conditions during the critical growth period reduce crop production and are injurious to crop (Pochop *et al.,* 1975; Zaidi *et al.,* 2004). Likewise, studies have also indicated that agricultural production can be improved, if adequate water is provided whenever soil moisture storage depletes to a certain extent (Ram Mohan and Subrahmanyam, 1983). Further, Victor and his associates (1991) suggested that the prosperity of agriculture in terms of yields will be achieved if the selection of crops and cropping system be adjusted with the water availability period and the crop growth period.

Under rain fed conditions successful crop growth period coincides with the period when soil moisture is adequately available to meet the atmospheric water demand. Soil moisture adequacy depends upon soil type, vegetation type upon the soil and amount of precipitation. The maximum amount of moisture that soil can hold is known as field capacity. During rainy season, if rain is sufficient to make soil reach its field capacity, there is no dearth of water for the crops and it is the ideal period of crop growth if moisture factor is crucial for crop success. During this period, actual evapotranspiration (AE) equals potential evapotranspiration (PE). But due to limitation of soil water availability during rainless period, AE remains lower than the PE as crops utilize available soil moisture in its root zone (actual evapotranspiration) to meet the atmospheric water need or PE (maximum amount that can be evaporated if there is no water scarcity). This imbalance causes water stress to the crops and hampers crop growth, vigour and yields. Supplemental irrigation may be adopted to protect crops from water stress. In absence of irrigation, low water requiring crops or drought resistant type of crops may be grown. Again, all the crops do not require equal and/or high amount of water throughout the growing period. Hence, depending upon the soil moisture adequacy, crop suitability may be assessed. Keeping this in view an attempt is made in the present paper to evaluate the normal monthly soil moisture adequacy over Jharkhand State, based on which agricultural efficiency of the State is determined.

Study Area

Jharkhand State (Figure 1) occupies a total geographical area of 79.7 km^2 in India, which is bounded between 21° 58' N to 25° 18' N latitudes and 83° 22' E to 87° 57' E longitudes. Physiographically, the State is a plateau with undulating topography. The total population of the State is 32,988,134 persons (Census, 2011). The total cultivable land in the State is 38.00 lakh hectares, net sown area is 25.75 lakh hectares (67.7 per cent) and irrigated land is only 3.01 lakh hectares which is 7.9 per cent of the total cultivable land (www.agri.jharkhand.gov.in). Therefore, agriculture is almost rain fed. *Kharif* is the main cropping season which coincides with the southwest monsoon season during which the State receives about 80 per cent of the annual rainfall. The principal *kharif* crops grown in the State are paddy, maize, pulses (*arhar,* black gram*,* green gram*,* and *Kurthi)*, oilseeds (groundnut, sesamum, sunflower, and *surguja)* and other millets like jowar, bajra and ragi.

During rabi (following *kharif*) season, the land is occupied with pulses (gram, lentil, and peas), wheat, oilseeds (mustard, linseed, sasslower, and sunflower) and maize crops.

Methodology and Data Collection

Soil moisture adequacy index derived through water balance technique (Thornthwaite and Mather, 1955) has been adopted to evaluate agricultural efficiency of Jharkhand State. To compute water balance, mean monthly temperature and rainfall data were collected for the available time span (50 to 100 years) of seven representative IMD stations of Jharkhand (Figure 1).

From the water balance analysis, average monthly Index of Moisture Adequacy (IMA), which is the percentage ratio of Actual Evapotranspiration (AE) and Potential Evapotranspiration (PE) have been calculated as follows;

$$IMA= (AE/PE)*100$$

IMA provides an accurate assessment of status of existing moisture availability conditions over time. The understanding of which is beneficial for the assessment of agricultural efficiency, climatic crop suitability, agro climatic regionalization, adoption of appropriate cropping pattern, preparation of crop calendar, identification of length of crop growing periods, irrigation scheduling etc. of a particular region. Successful studies have been pursued using IMA as a parameter for assessing length of crop growing period (Sarma and Lakshmi Kumar, 2006; and Hema Malini and Tesfaye, 2013; and demarcation of agro climatic regions (Hema Malini and Pampa Choudhury, 2010). For the analysis, monthly Ima values have been classified and categorized into crop suitability classes as follows.

Table 1. General Categorization of Crop suitability Classes

IMA%	Suitability classes
Above 80	Highly suitable (HS)
60 to 80	Moderately suitable (MS)
40 to 60	Slightly suitable (SS)
Below 40	Not suitable (NS)

To determine the agricultural efficiency zones based on moisture suitability, average values of Ima have been used for determining overall agricultural efficiency. Similarly, Ima values have been averaged for the respective months of a particular agricultural season to assess seasonal evaluation of agricultural efficiency of Jharkhand State. Since October month is the end of *kharif* and the beginning of *rabi* season, the Ima value of October is included in both *kharif* and *rabi* season.

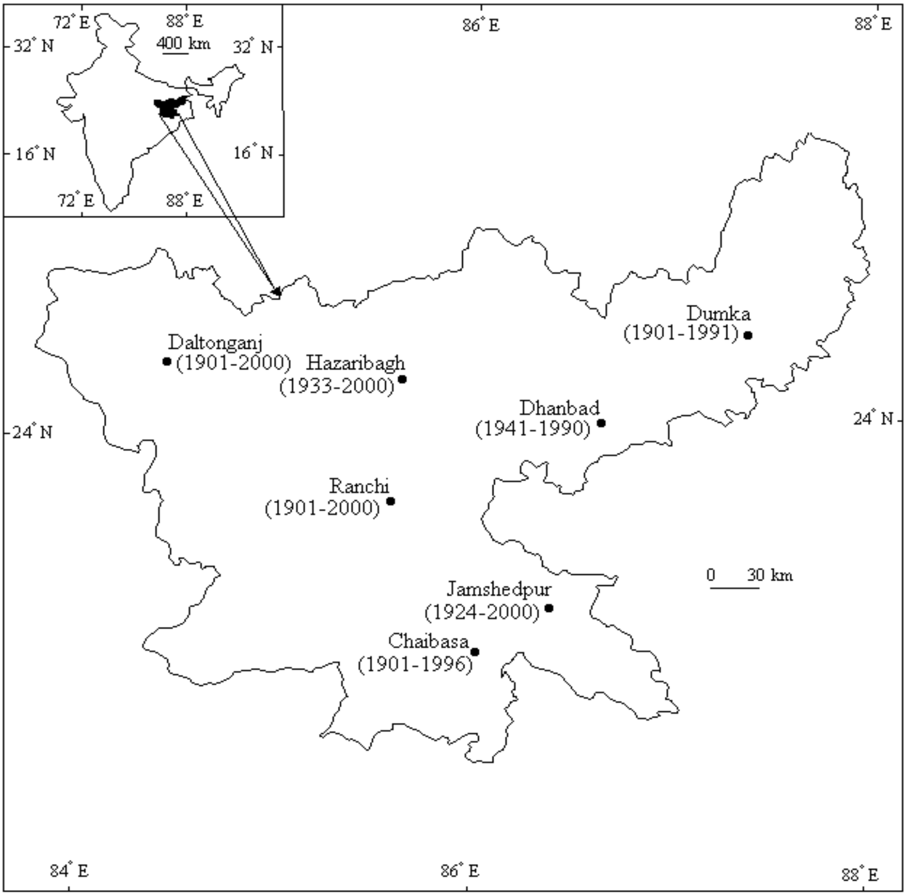

Fig. 1 - Location of Jharkhand and representative IMD stations

Table 2. Classification Scheme of Agricultural Efficiency Zones

Agricultural Efficiency Zones	IMA %
Highly Efficient (HE)	Above 90
Efficient (E)	75 to 90
Moderately Efficient (ME)	50 to 75
Less Efficient (LE)	25 to 50
Not Efficient (NE)	Below 25

Results and Discussions

Water requirement, availability and length of growing period

The crop water requirement (PE) is defined as the amount of water needed climatically to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by the various crops to grow optimally. The crop water need mainly depends on the climate, crop types and length of growing period. Generally, in a sunny and hot climate crops need more water per day than in a cloudy and cool climate. Further, paddy and sugarcane require more water than millet. Again, some crops may be harvested only in 30 to 45 days such as radish and hence, require comparatively less water than crops that have long growing periods and are harvested after 90 to 150 days such as paddy and millet or 270 to 365 days like sugarcane (www.fao.org). Actual evapotranspiration (AE) on the other hand, is defined as the quantity of water available in the crop root zone that is actually lost to atmosphere by evaporation and transpiration. If Actual evapotranspiration fulfil the demand of atmospheric water need (PE) crops grow effectively, otherwise they grow unproductively.

To understand the water need and water availability of the study region monthly values of AE and PE have been computed. The monthly differences between these have been diagrammatically represented in Figure 2. The analyses indicated that during March to October PE values are maximum (100 to 180 mm) in all places of Jharkhand, while AE equals PE only from June to October months. This implies that between June and October crops which need high temperature and high water may be grown because of high amount of climatic water availability. However, in absence of irrigational facilities, crops would suffer water stress conditions greatly during March to May months, as AE could supply only the amounts between 50 and 90 mm due to higher amounts of PE. Again, during November to February, due to prevalence of cold conditions, PE falls down significantly and ranges roughly between 70 and 30 mm, while AE values are found between 60 and 20 mm. In these months although the difference between PE and AE is small, less amount of PE and AE may support the growth of low temperature and less water requiring crops and may suffer with water stress conditions slightly during their growth period.

Further, the analysis of PE and AE for agricultural seasons namely *Kharif* (June to October), revealed that total PE values ranges between the minimum of 664 mm and the maximum 859 mm at all the representing stations during *kharif* (June to October) season. In this season, AE values are almost equal to PE. Thus, during *kharif* season Jharkhand State receives ample water to meet the atmospheric demand. The water requirement of paddy, maize, peanut, millets ranges between 450 and 800 mm and the total length of growing period of these crops range between 90 and 150 days (www.fao.org), and hence, these crops may be grown in the *kharif* season successfully in the State.

During rabi (October to March) season, total PE values range between the minimum of 249 mm and the maximum 345 mm (Jamshedpur) and AE values range from the minimum of 227 mm and the maximum 289 mm. This implies that during rabi season, thermal potential (PE) of Jharkhand State is low. Therefore, less temperature and less water requiring crops such as peas, beans, lentil, wheat, cabbage, tomato, onion, potato etc. (www.fao.org) may be grown. During zaid (March to May) season PE ranges from a minimum of 440 mm to the maximum of 516 mm and AE from the minimum 157 mm to the maximum 220 mm. This indicates that atmospheric water requirement is higher than that of the actual water availability. Thus, without irrigational support crop cultivation is not possible climatically in this season. If irrigation is available, high water requiring crops which needs 450-500 mm of total water during their complete life span and has crop growth period of about 90 days, may be grown.

Crop Suitability based on Moisture Adequacy

In order to accurately assess the monthly water adequacy status of Jharkhand, the Ima values have been computed. Based on general classification of crop suitability classes (Table 1) crop suitability of Jharkhand (Table 3) has been derived. The analysis revealed that five to nine months of Jharkhand are highly suitable, one to four months are moderately suitable, one to two months are marginally suitable and two to three months are not at all suitable for agriculture.

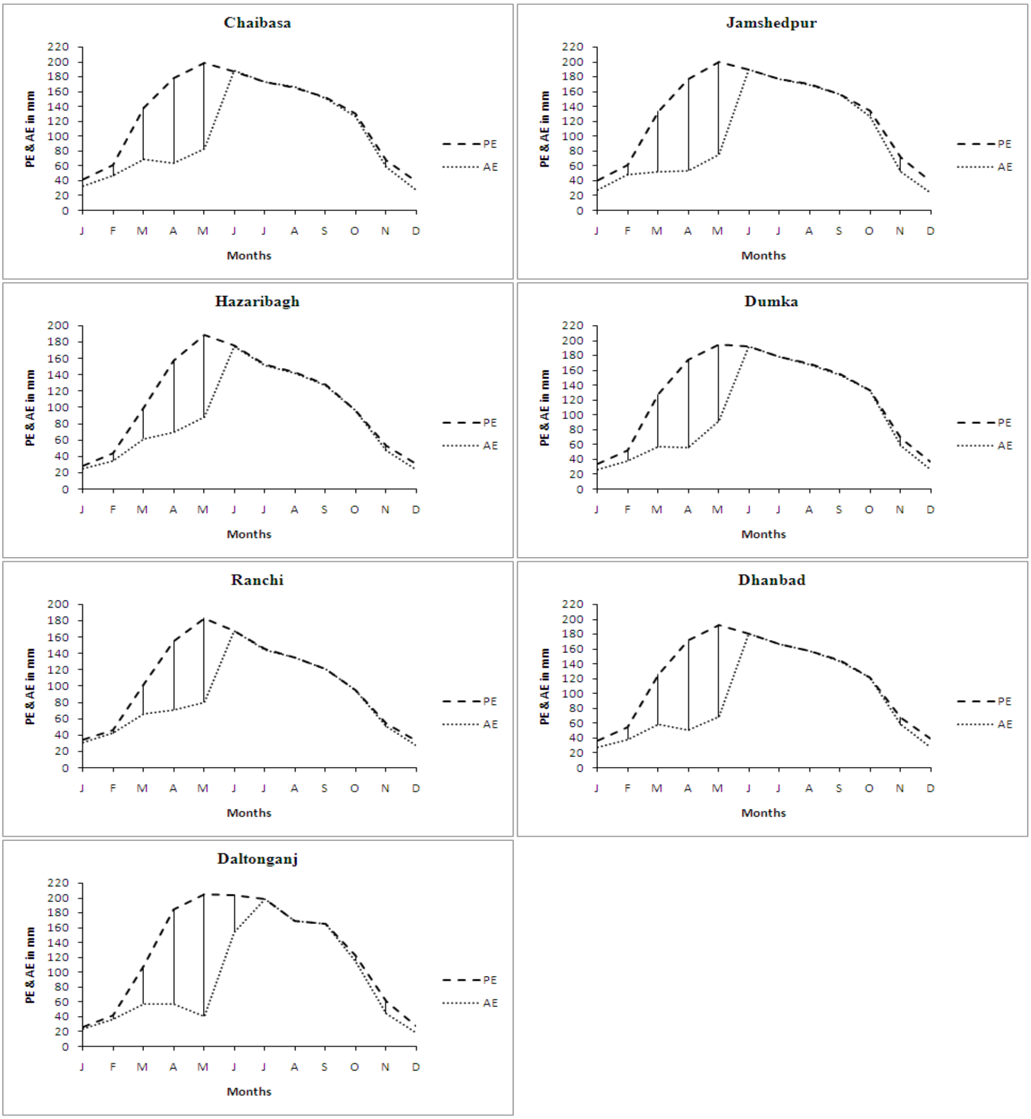

Fig. 2 Crop moisture need vs availability periods of Jharkhand

Since crops are grown according to agricultural seasons, seasonal analysis of crop suitability is attempted. The study indicates that all the five months of the *kharif* season are highly suitable for crop cultivation throughout Jharkhand, except for Daltonganj where June month is moderately suitable. During *rabi* season, all five months over Ranchi and Hazaribagh regions are highly suitable, Daltongonj region has three months with highly suitable conditions and two months with moderately suitable conditions, over Chaibasa, Dumka and Dhanbad region two months are highly suitable and three months are moderately suitable while Jamshedpur has one month with highly suitable conditions and four months with moderately suitable conditions. During *zaid* season, Ranchi and Hazaribagh regions has one month with moderate conditions while two months are slightly suitable, while all three months are not suitable over Jamshedpur region.

Table 3. IMA and Crop Moisture Suitability of Jharkhand

Stations	Months /Seasons											
	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
	Kharif *Rabi* *Zaid*											
Chaibasa	100 (HS)	100 (HS)	100 (HS)	99 (HS)	97 (HS)	85 (HS)	69 (MS)	78 (MS)	75 (MS)	49 (SS)	35 (NS)	41 (SS)
Jamshedpur	100 (HS)	100 (HS)	100 (HS)	100 (HS)	95 (HS)	73 (MS)	62 (MS)	70 (MS)	79 (MS)	39 (NS)	31 (NS)	38 (NS)
Ranchi	100 (HS)	100 (HS)	100 (HS)	100 (HS)	100 (HS)	93 (HS)	82 (HS)	91 (HS)	91 (HS)	65 (MS)	46 (SS)	44 (SS)
Hazaribagh	100 (HS)	100 (HS)	100 (HS)	100 (HS)	100 (HS)	90 (HS)	80 (HS)	89 (HS)	81 (HS)	63 (MS)	45 (SS)	47 (SS)
Dhanbad	100 (HS)	100 (HS)	100 (HS)	100 (HS)	100 (HS)	85 (HS)	69 (MS)	73 (MS)	69 (MS)	46 (SS)	29 (NS)	35 (NS)
Dumka	100 (HS)	100 (HS)	100 (HS)	100 (HS)	100 (HS)	84 (HS)	72 (MS)	76 (MS)	73 (MS)	45 (SS)	32 (NS)	47 (SS)
Daltonganj	76 (MS)	100 (HS)	100 (HS)	100 (HS)	95 (HS)	74 (MS)	70 (MS)	92 (HS)	90 (HS)	54 (SS)	31 (NS)	20 (NS)

Agricultural Efficiency Zones

In order to evaluate agricultural efficiency, scheme shown as Table 2 has been followed. The computed average values and the respective agricultural efficiency zones have been shown in Table 4.

Table 4. Agricultural Efficiency Types of Jharkhand

Stations	Annual	Type	Seasonal					
			Kharif	Type	*Rabi*	Type	*Zaid*	Type
Chaibasa	77	E	99	HE	81	E	42	PE
Jamshedpur	74	E	99	HE	76	E	36	PE
Ranchi	84	E	100	HE	91	HE	52	ME
Hazaribagh	83	E	100	HE	88	E	52	ME
Dhanbad	76	E	100	HE	79	E	27	PE
Dumka	77	E	100	HE	81	E	41	PE
Daltonganj	75	E	94	HE	84	E	35	PE

The findings revealed that the based on annual moisture availability, crop cultivation can be efficiently carried out in most of the regions of Jharkhand except in Jamshedpur, which is moderately efficient. During *kharif* season, entire State is highly efficient for crop cultivation. While, the central parts (Ranchi) of the State is highly efficient, and the remaining parts are not that efficient during *rabi* season. During *zaid* season central parts of the State are moderately efficient and the remaining areas are less efficient.

Conclusion

Based on the study it may be concluded that moisture status of the State significantly varies seasonally. *Kharif* season has ample moisture and thus may support crops like paddy, maize, peanut, millets etc without any water stress conditions all over the State. Crops such as peas, beans, lentil, wheat, cabbage, tomato, onion, potato etc. may be grown during *rabi* season, but crops may suffer water stress especially during December to February except in the central parts of the State, while inadequate moisture conditions hampers cultivation of crops during *zaid* season. From the study, it may also be concluded that central parts of Jharkhand are agriculturally more efficient than remaining parts especially during *rabi* and *zaid* seasons. In order to improve the agricultural efficiency of the State during *rabi* and zaid, irrigational facilities should be created and drought resistant and early maturing crops may be adopted.

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GREEN AND BLUE ROOFS: A SIGNIFICANT SOLUTION TO URBAN ENVIRONMENTAL PROBLEMS

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Abstract

Rooftops are, in general, a less utilized resource of urban areas. Whether they are sloping or flat, large or small, industrial or residential, the possibilities for urban greening, energy production, air cleaning, and faunal habitat that they behold are limitless. The present paper is dealing with major urban environmental problems. A 'Green roof' or 'Living roof' is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane while 'Blue Roof' is the term coined to refer to systems that focus on rainwater collection on roof-tops by using catchment pools, rain barrels and more discreet water-hungry plantings. The study aims to explain the Concept, Meaning and Components of Green and Blue roofs, highlight the Significance of Green roofs as Solution to various urban environmental problems and to assess the Level of Roof-top utilization in Patna M. Corporation based on empirical study and primary level sample survey.

Keywords: Rooftop resource, urban greening, rain water harvesting, green and blue roofs.

Introduction

A healthy ecosystem is the one that has the ability to maintain its structure (organization) and function over time in face of external stress. But the ever increasing density of hard, concrete impermeable surface in the urban areas in the form of roads and buildings has changed the flow of energy and matter through the urban ecosystem creating many problems, especially environmental problems. In developed countries, the level of urbanization is still rising and expected to reach 83% in 2030 (United Nations, 2002; Antrop, 2004). Cropland, grassland and forests are displaced by the impervious surfaces of streets, driveways and buildings greatly intensifying storm water runoff, diminishing groundwater recharge and enhancing stream channel and river erosion (Stone, 2004). The present urbanization scenario in India involves an unsustainable use of natural ecosystem and creates numerous problems both within and outside the cities.

The most suitable answer to the recent calls for a more ecological and greener urbanization is the creation of more and more 'Green space'. Unfortunately, the on-going reduction in urban greenery and the large areas of impervious surfaces created mostly by the essential infrastructures is unavoidable. The high price of land makes it a difficult decision for the preservance of ground level green areas in cities. Sparing the costly urban land for trees seems economically unviable to many. Considering the huge amount of unused roof area (about 40-50% of the impermeable surfaces in urban areas (Dunnet and Kingsbury, 2004), green roofs, also known as rooftop gardens or vegetative gardens, may prove to be an interesting alternative. Rooftops, which for a long time were regarded as unusable space, are now being discovered as new landscapes which hold a great potential for environmentally sustainable and productive utilization.

The creation of a 'Green space' on this 'newly discovered landscape' by addition of soil and vegetation layer to the roof surface, thereby converting them to "Green Roofs" can lessen several negative impacts which the rapid increase in built-up areas is having on the urban ecosystem. This paper mainly aims at bringing to light the importance of Green roofs in combating the various environmental problems that plague the urban centres. The basic objectives of this study are to explain the concept, meaning and components of green and blue roofs; to highlight the significance of green roofs as solution to various urban environmental problems; and to assess the level of roof-top utilization in Patna Municipal Corporation.

Methodology

This paper is the result of study of many different research works conducted in other countries in the field of Green roof technology. It uses the data collected by various researchers to highlight that many of urban environmental problems can be mitigated by the wide scale installation of green roofs. The present study incorporates two major components. The first component deals with the conceptual part of Green and Blue roofs. It includes the study of:

I. The concept, meaning and components of Green roofs, and its significance as solution to multiple urban environmental problems
II. The meaning and benefits of Blue roofs.

It is based on secondary and tertiary sources of information, which includes various articles written by researchers of different countries working in this specific field and the websites of government and private agencies engaged in the promotion of green roofs. The second major component is a primary level survey, which explores the level of roof-top utilization in Patna and the scope for implementation of green-roof technology in Indian cities (figure 1).

Green Roofs – Meaning and Components

A Green roof or a 'living roof' is a special kind of environment friendly building roof that is partially or completely covered with vegetation and a growing medium. Within industry, a shift to the term 'green roof infrastructure' is occurring as it implies that putting vegetation on a roof involves more than just piling soil and planting seeds. There are multiple layers below the growing medium such as a root barrier to prevent root penetration through the roof, drainage and irrigation systems for drainage and a waterproofing membrane for protection from leakage etc. Green roofs can be installed on a wide range of buildings, from industrial buildings to private residences. They can be as simple as a 2-inch covering of hardy groundcover or as complex as a fully accessible park complete with trees.

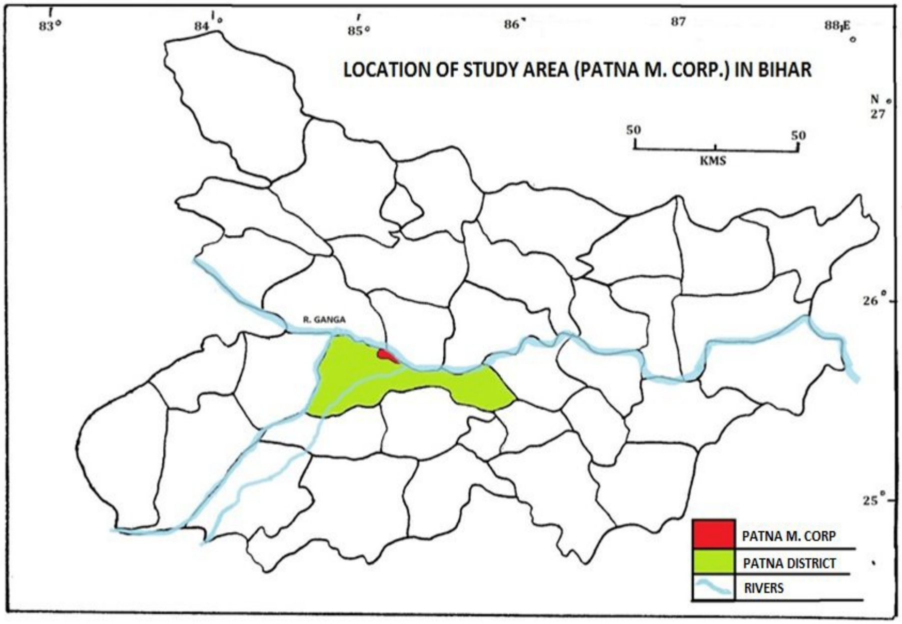

Fig. 1. Location of Patna M. Corporation, Bihar

The main environmental benefits provided by the 'Green roofs' are because of its functioning as 'green space' or ecosystems along with the fact that they utilize the previously unused space of the rooftops. Brief Background of Green Roofs -Roof gardens, the precursors of contemporary green roofs, belong to very ancient times. The earliest documented roof gardens were the hanging gardens of Semiramis (present Syria), considered as one of the seven wonders of the ancient world. Today, similar elaborate roof-garden projects are designed for high-profile international hotels, business centres, and private homes (Oberndorfer, 2007). The modern green roofs originated at the turn of the 20th century in Germany, where the roofs were covered with vegetation to mitigate the damaging effects of the solar radiation on the roof structure. They also served the purpose of fire-retardants. The late 20th century witnessed growing environmental concerns, especially in the urban areas. This created opportunity to introduce progressive environmental ideas, policies and technologies.

Green roof technology was immediately adopted due to its wide scope of environmental benefits and interdisciplinary research led to technical guidelines, the first volume of which was published in 1982 by the Landscape, Research, Development and Construction Society. Germany has been in forefront in the research on green roofs (Mentens, 2005). Since then, the German cities have also introduced many incentive programs to promote green roofs and improve environmental standards. Building law now requires the construction of green roofs in many urban centres (Kohler and Keeley, 2005). Such legal bindings for green roofing have led to a widespread implementation and success of green-roof technology throughout Germany. Not only Germany, many other highly urbanized countries like Japan, Singapore, Belgium, Canada, USA etc. are also now turning to green roofs for solution of their environmental problems.Green roofs are becoming popular in the United States, with roughly 8.5 million square feet installed or in progress as of June 2008.

Components of Green Roof: The basic structure of a green roof includes the following layers: Vegetation, Growing Medium, Filter Membrane, Drainage Layer, Waterproofing/ Root barrier, Insulation and Structural support (Figure 2). This basic green-roof design has been implemented and studied in diverse regions and climates worldwide.

Types of Green Roofs–Generally, there are two main types of green roofs are given in table 1– ‘Intensive Green roofs’ and ‘Extensive Green roofs’ (Figure 3).

i. **Intensive Green Roofs** - The “intensive” green roofs are known for their deep substrates and variety of plantings as green roofs. They have the appearance of conventional ground-level gardens, and they can augment living and recreation space in densely populated urban areas. They typically require substantial investments in plant care. Furthermore, they emphasize the active use of space and carry higher aesthetic expectations

ii. **Extensive Green Roofs –** The “extensive” green roofs have shallower soil and low-growing ground cover. Extensive green roofs are a modern modification of the roof-garden concept. They typically have shallower substrates, require less maintenance, and are more strictly functional in purpose than intensive living roofs or roof gardens.

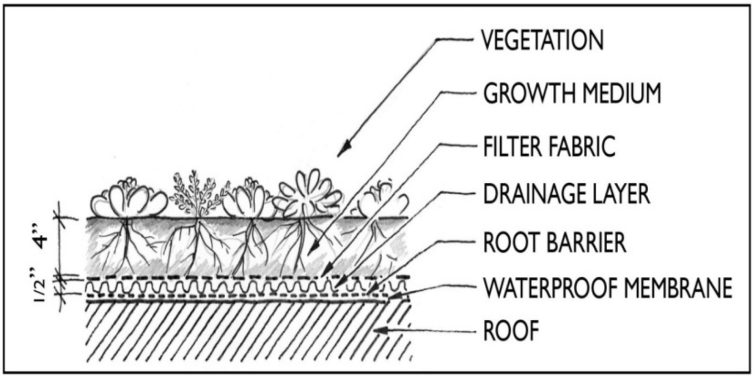

Fig. 2 – Cross-section of extensive Green roof prototype
(Source - *amalthea.kevio.gr/wp.../Tapping-the-potential-of-urban-rooftops.pdf)*

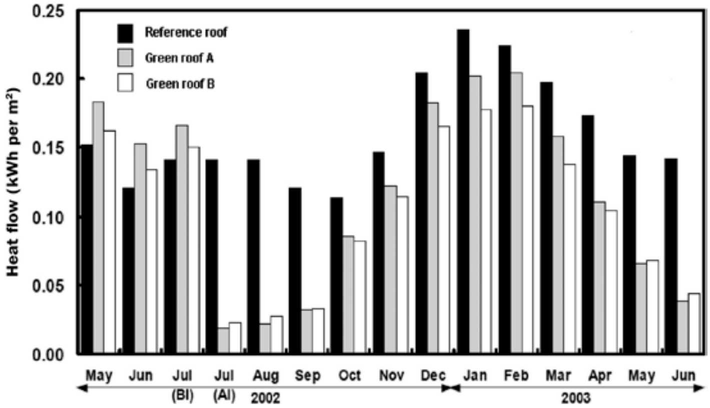

Fig. 3 - Comparison of the average daily heat flow through the green roofs and reference (conventional) roof over two years.

Green roofs were installed in late July 2002. Green roof A has 10 cm of light-colored growing medium; green roof B has 7.5 cm of dark-colored growing medium. Both were installed in Toronto. Abbreviations: AI, after installation; BI, before installation; kWh, kilowatt-hour; W, watt. Graphs are redrawn from Liu and Minor (2005).

Green Roofs as a Solution to Urban Environmental Problems

Roofs which cover about 40-50% of the impermeable surfaces in urban areas (Dunnet and Kingsbury, 2004) are important factor in determining the energy flow in urban areas and causing disturbance in urban ecosystem. These problems can be mitigated to a great extent by altering the superficial properties of the buildings. The main benefits of Green roofs arise from the fact that they replicate nearly all the benefits of ground level green space and in doing so they utilize the previously unused urban space i.e. the rooftops. Thus, the green roofs help in combating the various urban environmental problems without needing the ground level space, which can then be used for other purposes. The major environmental issues, which the green roofs help in tackling, are:

1. Reduction in 'Urban heat island effect'

Due to the reducing green cover and increasingly high percentage of hard and concrete land in the urban areas, most of the incoming solar radiation is absorbed by dark surfaces such as rooftops and pavement in the city and reradiated as long wave radiation or heat. This increases the overall temperature of the urban areas in comparison to the surrounding areas. This is called the Heat Island effect, wherein the urban regions are significantly warmer than the surrounding suburban and rural areas, especially at night. This in turn leads to various other environmental problems. Green roofs increase the green cover in the cities and due to evapotranspiration, help to mitigate the urban heat island effect. A regional simulation model using 50% green-roof coverage distributed evenly throughout Toronto showed temperature reductions as high as 2°C in some areas (Bass et al. 2002).

Table 1. A Comparison of Extensive and Intensive Green Roofs

Characteristics	Intensive Roof	Extensive Roof
Purpose	Functional; storm-water management, thermal insulation, fireproofing	Functional and aesthetic; increased living space.
Structural requirements	Typically within standard roof weight-bearing parameters; additional 70 to 170 kg per m^2 (Dunnett and Kingsbury 2004)	Planning required in design phase or structural improvements necessary; additional 290 to 970kg per m2
Substrate type	Lightweight; high porosity, low organic matter	Lightweight to heavy; high porosity, low organic Matter
Average substrate depth	2 to 20 cm	20 cm or more
Plant communities	Low-growing communities of plants and mosses selected for stress-tolerance qualities (e.g., *Sedum* spp., *Sempervivum*spp.)	No restrictions other than those imposed by substrate depth, climate, building height and exposure, and irrigation facilities
Irrigation	Most require little or no irrigation	Often require irrigation
Maintenance	Little or no maintenance required; some weeding or mowing as necessary	Same maintenance requirements as similar garden at ground level
Cost (above waterproofing membrane)	\$10 to \$30 per ft2 (\$100 to \$300 per m^2)	\$20 or more per ft^2 (\$200 per m2)
Accessibility	Generally functional rather than accessible; will need basic accessibility for maintenance	Typically accessible; bylaw considerations

Source: Dunnett and Kingsbury 2004

2. Reduction in Pollution level and enhancement of Air quality

Green roofs can help to reduce urban air pollution. The plants in a green roof can remove certain pollutants from the air. They remove gaseous pollutants including nitrogen oxides, sulphur dioxide, carbon monoxide and ground level ozone from the air. The increasing areas of plant cover helps to filter the air pollutants and help to lower respiratory diseases and breathing difficulties. In this way they help fight against respiratory disease e.g. asthma. According to a study conducted by Jun Yang et. Al. in Chicago (2008), a total of 1675 kg of air pollutants was removed by 19.8 ha of green roofs in one year with O_3 accounting for 52% of the total, NO_2(27%), PM10 (14%), and SO_2(7%). The highest level of air pollution removal occurred in May and the lowest in February. The annual removal of air pollutants per hectare of green roof was 85 kg ha/yr. This rooftop foliage also filters out fine airborne particles as the air passes over the plants, settling on to leaf surfaces. Green roofs are also a potential carbon sink and can remove carbon dioxide and produce oxygen thus making the air more clean, pure and healthy.

3. Reduction in storm water run-off

A large component of urban water resource management is moving the rainwater and snowmelt away from buildings and roads as fast as possible. The replacement of vegetation by hard surfaces in urban areas is causing hindrance in this storm water management. Since large parts of the city are now impermeable to water, it has to be diverted through artificial systems, taxing the capacity of the sewage system, or it runs off over the surface. Storm water runoff has contributed to problems in water quantity and quality and during extreme precipitation events, they overburden the existing storm-water management facilities and cause combined sewage overflow into lakes and rivers leading to flooding and erosion (figure 4).

Conventional storm-water management techniques include storage reservoirs and ponds, constructed wetlands, and sand filters. However, these surface-area intensive technologies may be difficult to implement in dense urban centers (Mentens et al., 2005). Two factors make Green roofs ideal for urban storm-water management. First, they make use of existing roof space and second, they prevent runoff even before it leaves the lot. Green roofs store water during rainfall events, delaying runoff until after peak rainfall and returning precipitation to the atmosphere through evapo-transpiration. Moran et al., in 2005, showed that rainfall retention from specific green roofs was 66% to 69% for roofs with more than 10 cm of substrate. Rainfall retention varied from 25% to 100% for shallower substrates in other studies (Beattie and Berghage, 2004). Green roofs can reduce annual total building runoff by as much as 60% to 79% (Köhler et al., 2002), and estimates based on 10% green-roof coverage suggest that they can reduce overall regional runoff by about 2.7% (Mentens et al., 2005).

4. Increase in Evapo-transpiration in urban centres

With green roof on the rooftops, the rain water can be stored by the substrate and then taken up by the plants which in turn release it into the atmosphere through evaporation and transpiration. Many experiments on green roofs suggest that most of the summer cooling benefits from green roofs are attributable to evapotranspiration (Gaffin et al., 2005, 2006)

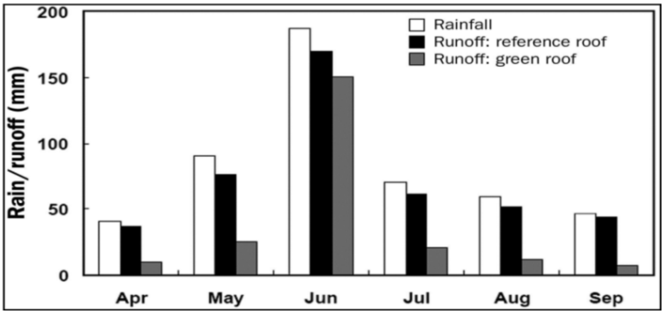

Fig. 4. Storm-water runoff retention in a green-roof test plot in Ottawa, Ontario, Canada, in 2002.

(Values are sums of total runoff retained. The green roof had 15 centimeters of growing medium and was planted with lawn grasses (Liu and Baskaran 2003); it was compared with an adjacent conventional roof of the same size.

5. Natural Habitat creation

The decrease of natural green cover in the cities has also resulted in the decline of faunal species due to their reducing habitats. Increase in greener space will provide habitats to birds, insects, butterflies etc., thus increasing the urban bio-diversity. Green-roof habitats show promise for contributing to local habitat conservation.

Studies have documented invertebrate and avian communities on a variety of living-roof types in several countries (Coffman and Davis 2005, Brenneisen 2006, Kadas 2006). Green roofs are commonly inhabited by various insects, including beetles, ants, bugs,flies, bees, spiders, and leafhoppers (Coffman and Davis, 2005). Rare and uncommon species of beetles and spiders have also been recorded on green roofs (Brenneisen, 2006; Grant, 2006). Species richness in spider and beetle populations on green roofs is positively correlated with plant species richness and topographic variability (Gedge and Kadas 2004). Green roofs have also been used by nesting birds and native avian communities (Baumann 2006). Thus, they can prove to be a blessing for our disappearing urban fauna.

6. Increase in agricultural space

Green roofs convert an earlier neglected space into an economically productive area. Many different kinds of vegetables, fruits, herbs etc. can be easily grown in roof gardens, which will obviously be much fresher than the market produce. Vegetable gardening on green roofs can thus, enhance nutrition and food-security in urban neighbourhood.

7. Reduction in power consumption

In summer, a typical insulated, gravel-covered rooftop temperature can vary between 60 °C and 80° C (Peck et al., 1999). This heat will always flow through the roof into the building and increase the power requirement for the cooling of the building. Therefore, reducing the rooftop temperatures would reduce the use of energy for space conditioning in both the summer and the winter. Evapotranspiration from rooftop vegetation could cool the roof, reducing the amount of heat flow into the building through the roof. The lower rooftop temperature would also reduce the temperature of the external air that is exchanged with the building's air. During the winter, the rooftop garden would provide additional insulation, which would reduce the flow of heat through the roof. Wong and his colleagues (2003) found that the heat transfer through a green roof in Singapore over a typical day was less than 10% of that of a reference roof. A study in Madrid showed that a green roof reduced the cooling load on an eight-story residential building by 6% during the summer (Saiz et al. 2006). In a peak demand simulation, the cooling load was reduced by 10% for the entire building and by 25%, 9%, 2%, and 1% for the four floors immediately below the green roof. For a typical residential house in Toronto, the cooling load for the month of July was reduced by 25% for the building and by 60% for the floor below the green roof (Saiz et al. 2006). Green roofs will have the greatest effect on energy consumption for buildings with relatively high roof-to-wall area ratios. In the summer, green roofs reduce heat flux through the roof by promoting evapotranspiration, physically shading the roof, and increasing the insulation and thermal mass.

8 Insulation from Sound

Green roofs have important acoustical benefits as well. Green roofs have a higher weight resulting in an increased sound insulation of the roof system. This could lead, depending of the geometry of the building, to strong reductions of indoor noise levels during plane fly-over (*Timothy Van Renterghem and Dick Botteldooren, 2008).* Green roofs can also be used to successfully reduce road traffic noise exposure, which is the main source of noise annoyance in urban areas (figure 5). The typical substrates used for green roofs are highly porous and thus allow sound waves to enter the growing mediums. Because of the large number of interactions between sound waves and substrate particles, attenuation (loss of intensity of sound waves) occurs. As a result, less noise will reach the back façade or the roof apartment compared to the situation with a non-vegetated roof that is most often made of a highly reflective material (e.g. concrete). Living roofs also provide aesthetic and psychological benefits for people in urban areas. Even when green roofs are only accessible as visual relief, the benefits may include relaxation and restoration (Hartiget al. 1991), which can improve human health. Other uses for green roofs include urban agriculture: food production can provide economic and educational benefits to urban dwellers.

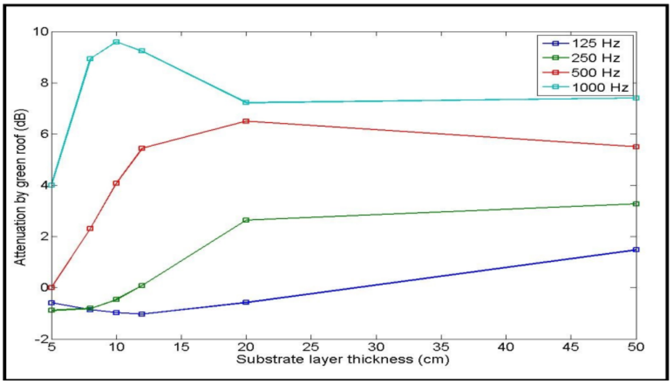

Fig. 5: Attenuation of Noise by green roof

Source - http://www.acoustics.org/press/155th/renterghem.html

Blue Roofs

The term “Blue Roof” has been coined to refer to systems that focus on rainwater collectionby using catchment pools, rain barrels and more discreet water-hungry plantings. Blue roofs are the specifically designed on-vegetated roofs that are constructed so as to be able to detain storm-water. Weirs are made at the roof drain inlets and along the roof to create temporary ponding and gradual release of storm-water. Blue roofs are less costly than green roofs. Coupled with light colored roofing material they can provide sustainability benefits through rooftop cooling.

The benefits of this are:-

i. Rainfall is intercepted at its first landfall and helps in reducing the occurrences of urban floods.
ii. Reduced reliance on sub surface drainage systems and hence cost reduction and a maximisation of land use potential.
iii. Opportunities for grey water re-use within the building or even water park play areas in schools and educational facilities.
iv. Irrigation for green/living roofs where required
v. Help in rooftop cooling in warm countries and bring down energy consumption.

Blue roofs can include areas purely for water storage and recreational opportunities. They can include a water maze for storm attenuation. They can even to assist with cooling the building and acting to reduce the burden on the HVAC system on warmer days. Blue roofs that are used for temporary rooftop storage can be classified as "active" or "passive" depending on the types of control devices used to regulate drainage of water from the roof.

A Case Study of Patna

The study area selected for the present research work is Patna Municipal Corporation which is a fast growing metropolitan city. It is the capital city of Bihar and is the second largest urban centre of eastern India. Patna urban agglomeration is one of the 53 million plus cities of India (2011). Patna Municipal Corporation forms the core city of larger Patna U.A. which comprises of several other constituent towns and outgrowths. So far as the size of population is concerned Patna U.A. is the largest city of Bihar. Its total population according to the 2011 census provisional data was 20.46 lakhs and ranks 18th among the million plus cities of India. The population of the Patna Municipal Corporation alone was 16.83 lakhs (Census of India, 2011) . The city has been witnessing rapid growth in population for the past few decades. Patna is rapidly expanding towards west and most of its outgrowth area has developed along the road towards west. Thus, the western Patna is newly growing area while the east Patna also called as ‘Patna city’ by the locals is the older part of the city. Limited area, high population, congestion in slums, rapidly increasing number of apartments etc. have led to high population density in the eastern Patna.

Methodology

The present study is based on primary level survey and empirical observation of the authors. The methodology of the present study follows three distinct phases: Pre-Field survey - The pre-field survey involves the review of the concerned literature, reconnaissance survey of the study area and collection of the base map. Field Survey – Preparation of the questionnaire, collection of the primary data by applying random sampling covering 160 samples (the buildings under survey). Post-Field Survey – Tabulation and analysis of primary data. Samples of the Survey: Since, the study is concerned with the utilization of the rooftops, the samples consists of buildings. A total of 160 buildings were randomly selected for the sample survey from different parts of Patna. Stratified Random Sampling technique was applied during the survey. The buildings under study were classified as following:

Table 2. Building types covered under the Sample Survey

S. No.	Building Category		Average Area in sq. ft.	Number of Samples
1	Residential	Private homes	3000	60
		Multi-storey Apartments	7200	30
2	Commercial Complex		15000	15
3	Commercial cum Residential complex			25
4	Institutional	Schools	25000	7
		Colleges		7
		Hospitals		6
		Government Buildings		10

Analysis of rooftop utilization according to Building type: Pattern and Problems

The utilization of the rooftops of different types of buildings mainly depends on the area of the rooftops and the awareness, consciousness and technological advancement of people living or using the building. Apart from them, the government regulations and incentives also play a major role in deciding the utilization of the rooftops. The following Table 3 presents the utilization of rooftops according to the type of buildings covered under the sample survey. The utilization of the rooftops on different types of buildings and the reasons for their lack of optimum utilization has been discussed below:

Private Houses

Out of total 160 buildings covered under the sample survey, a total of 60 private houses were selected. The average area of rooftops of these private individual houses is about 3000 sq. feet. Though the area of these houses is less, yet all of them are used for one or the other purposes, primarily domestic purpose. The most common domestic uses of rooftops are drying of clothes, food grains, spices etc. (on 90% of houses), recreation like sitting, playing etc. (on 78% houses); Morning walk (60%) and organizing family functions like birthday parties, puja celebrations, marriage celebrations etc. (53%). 68% of the houses have their water tanks installed on their rooftops. Thus it will be wrong to say that these rooftops are unutilized, because the maximum utilization of the rooftops takes place on these private houses only. Still, there is a great scope for their optimum utilization. Though 75% of people are aware about the benefits of rooftop rain water harvesting and rooftop gardening, yet due to their multiple domestic uses, the residents are not ready to spare or convert their rooftops for other purposes. An awareness program is needed to convince people that Rooftop Rainwater harvesting will not hamper any of the above mentioned activities being done there. Also 58% of these residents feel that this is a costly procedure and as such government incentive is also very necessary.

Table 3. Rooftop utilization according to Building type

(Figures in % to total buildings of that category under survey)

S. No.	Rooftop Utilization	Private Houses	Apartments	Commercial Complexes	Institutions
1	Water Tanks	68	70	65	72
2	Recreation	78	87	23	0
3	Morning walk	60	73	16	0
4	Drying clothes, spices, grains etc.	90	77	26	0
5	Organizing functions	53	77	8	0
6	Open dumping space	8	23	32	15
7	Rain Water Harvesting	0	0	0	0
8	Container gardening	18	30	0	0
9	Mobile tower installations	10	0	4	0
10	Guard rooms	0	10	0	0
11	Solar plate installation	0	0	0	0
12	Hoarding and Banners	5	0	0	0

Source: Based on Sample Survey 2013

Apartments

Like other metro cities, the culture of multi-storeyed apartments is rapidly spreading in Patna. Since Patna is expanding in its western part, this is the zone with maximum density of the apartments. A total of 30 apartments have been selected for the study out of which 23 lie in the fringe area of the western zone of Patna. Among the residential buildings, these apartments are significant from the point of view of study of rooftops. This is because the average size of rooftops of the apartments is more than double of that of the private residences. The average are of the rooftops of the apartments is about 7200 sq. feet, thus providing a greater scope for their utilization.

It can be observed from the Table 4 that compared to private houses, a greater percentage of apartment rooftops are being used for varied purposes. 70% of the apartments have their water tanks on their rooftops but due to their larger area, tanks occupy a very small area. The most common uses of apartment rooftops are recreation (87%); morning walk (73%); drying clothes and other items (77%) and organizing functions (77%). The large area of these rooftops also gives the freedom to some individuals to pursue container gardening in a part. Thus, partial gardening is also carried on 30% of these rooftops. Nearly one-fourth (23%) of these rooftops are also used as open dumping space. In some cases (10%), it has been also observed that the guard rooms are made on the rooftops.It has been observed that as in an apartment there are many families living together lack of common consciousness and participation is a major factor which prevents the optimum utilization of these rooftops, especially for rain water harvesting or green roofing.

Commercial Complexes

Commercial complexes covered under the study include both residential cum commercial complexes and purely commercial complexes. A total of 40 commercial complex/buildings including malls, hotels, offices, showrooms etc. have been selected for the study. Patna being the capital city of the state Bihar is replete with buildings which cover large areas and as such, have large rooftop areas. The average rooftop area of these commercial complexes is about 15000 sq. ft. However, in spite of being commercial buildings and having such large rooftops, it is surprising that there is practically no utilization of this valuable resource. Even economically profitable venture like solar-photovoltaic plates are not installed which could have saved a lot of money by bringing down electricity bills. Economically beneficial activities like rooftop restaurants, rooftop herbal gardening also can be taken up but due to lack of awareness this important resource lies unutilized.

Institutional Buildings

A total of 30 institutional buildings have been selected for this study which include 7 major schools; 7 major colleges; 6 major hospitals and Government buildings like Patna Secretariat, Patna High Court etc. It has been observed that though the average area of the rooftops of these institutional buildings is more than 25000 sq. ft., they are not being utilized for any purpose at all and thus they are lying waste. Even if we just take the total rooftop area of these 30 buildings, then this total unused roof area will amount to 750000 sq. ft. These buildings have a very great scope for many ecologically and economically productive uses of rooftops like Green roofing, rain water harvesting, rooftop herbal gardening etc. but due to lack of government incentives and policies no such step has been taken.

Conclusion

The study concludes that the ‘Green roof’ is a very significant solution to many urban environmental problems like urban heat island effect, urban flooding, air pollution, noise pollution, loss of urban biodiversity etc. The 'Blue roof' is also a good solution to the problem of urban flooding due to excessive storm water runoff. It also reduces reliance on sub-surface drainage systems and also helps in cooling of the buildings during summers. The author has observed that like other metro cities, the price of land is very high in almost all the parts of Patna too. As a result, it becomes difficult to spare the land for green spaces. But the large number of commercial and institutional buildings in these urban areas, with their large rooftop areas holds a great scope for both green roofs and blue roofs.

The promise of a healthier environment and greater resource security necessitates that we begin planning and implementing these sustainable rooftop systems now. Education, community awareness and proper legislations can bring about the kinds of benefits that so many cities have successfully demonstrated. The main disadvantages of green roofs are the higher initial cost of the building structure, waterproofing systems and root barriers. Presently, the biggest hurdle in field of green roof technology is the high cost involved in its installation. A properly designed and installed green-roof system can cost 15 to 20 dollars per square foot as a total cost (with the average cost decreasing with a larger area), not including the roof's waterproof layers. As such, the present need is to focus on research work towards development of cheap green roofing technology. Apart from this, government support is also an essential key to foster the implementation of these systems.

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SPATIO - TEMPORAL ANALYSIS OF MULTI DECADAL VARIABILITY OF TEMPERATURE OVER THE LAST CENTURY: A KEY TO UNDERSTAND THE REGIONAL DISPARITIES IN CLIMATIC VARIABILITY IN ANDHRA PRADESH, INDIA

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Abstract

Weather is a system, which controls the distribution and dynamics of living beings on the earth surface. Changes in climate were natural since weather elements are dynamic. In the past, also changes in climate occurred but the changes were gradual and unnoticeable. However, in the recent decade's weather changes that are occurring worldwide due to human activities such as urbanization and industrialization are conspicuous and raising the alarm. In the present paper an attempt has been made to study the trends in the temperature changes that have occurred in 13 districts of Andhra Pradesh State for the last 100 years. The decadal temperature analysis indicated that the maximum, minimum and mean temperatures are steadily on increase all over the State without any exception. Further, the analysis indicated that the State as a whole experienced an average increase of 1.1°C in mean temperatures and 1.3°C in maximum and minimum temperatures between 1901-1910 and 2001-2010 decades. The spatial analysis indicated that the mean decadal temperature increase is more around Visakhapatnam district and low in Chittoor district when compared to the other regions. An increase of 0.9°C of mean decadal temperature in the entire Visakhapatnam district and along the coastal parts of Nellore district and in the remaining parts of the State the increase is comparatively less especially in the north coastal Andhra Pradesh.

Keywords: Climate, Trends Analysis, Mean, Spatial analysis.

Introduction

Climate on the surface of the Earth is never static and varies on temporal and spatial scales all over the world. The variability of climate may be long and short durations of time (Houghton et al., 1994; Gardner et al 1996). In the past, climatic variability was a slow process and solely because of natural causes namely terrestrial, astronomical and extraterrestrial. The change in the climate that occurred in the past was mostly confirmed by observing lithogenetic, morphological and biological evidences (Ayoade, 1972).

The present day climate change in terms of warming may be a response to anthropogenic forcing, natural variability or a combination of two. However, in the recent times the climatic variations became rapid, glaring and abnormal due to anthropogenic processes namely industrialization and urbanization (Prakasa Rao, 1983; Charlson, 1993; Bhanu Kumar et al*.,* 2007).

Thus, assessment of climate of a region is essential as it renders direct or indirect influence on living beings. Among all the weather elements, temperature and rainfall are considered as significant parameters in weather analysis to study climatic variability because both are highly variable spatially and temporally at different local, regional and global scales (Murat Karabulut et al., 2008). Of these two, temperature is a major key indicator of global climate change, hence for the prediction of future climatic conditions it is essential to examine and understand, the level of variability of temperature from time to time ((IPCC, 2007 ; Hansen et al., 1999).

The twin processes namely urbanization and industrialization are solely responsible for temperature increase. Urbanization is a man-made process which triggers warming trends in hemispheric and global time series of land surface temperatures (Karl and Jones, 1989). The process of urbanization creates concrete jungles which trap heat by multiple reflections (Hema Malini, 2002). In addition, burning of fuel by vehicular traffic and domestic activities in urban areas trap the heat at the lower levels and raises the temperature near the ground (Rao et al., 2007; Katam et al., 2007). Studies of Fuiki (1970) and Kawamura (1977) indicated rapid rise in temperatures since 1950 in a number of cities of Japan as result of urbanization and industrialization. Jones and his associates (1990) in their study indicated that the effects of urbanization are insignificant on temperature increase which is estimated as 0.05 °C per century when compared with global trends in the range of 0.6 – 0.7 °C per century.

However, studies of Tadross and his associates showed that the wide spread urbanization may lead to night warming. Both urbanization and industrialization together responsible for deforestation, landuse/land cover changes, fossil fuel burning, draining of wet lands, adoption of modern technology in farming activities and livestock rearing which in turn induce escalation of green house gases (Landsberg, 1984). Green house gases (GHGs) namely water vapor, Carbon dioxide, methane, and nitrous oxide and Chloro Fluro Carbons (CFCs) in the atmosphere causing rising temperatures on both land and sea surface (Chaudhary, 2010). Nacicenovic et al (2000) reported that concentration of greenhouse gases was found maximum in the history of 19^{th} century. Mann and his associates (1998) based on their general circulation and energy –balance model experiments, as well as statistical comparisons of global temperature with potential forcing time series suggested that GHGs play a dominant role during 20^{th} century. Some predictive models suggested that there will be an increase of temperature of about 4 ˚C by 2100 (Dash and Hunt, 2007). As an evidence, it was found that the 20^{th} century was the warmest period in the last millennium with 1990s being the warmest decade of the millennium in the Northern hemisphere, and the 1998 the warmest year of the century (Dar, 2007; Manohar et al, 2009). Of all the green house gases, although CO_2 has the smallest global warming potential, it has contributed the most to global warming since 1750. The annual average concentration of CO_2 measured at Mauna Loa as 315 ppm in 1958 which has increased to 338 ppm in 1980 (Jager, 1983). By 2006 the CO_2 concentration raised to ~ 380 ppm (Sarma and Rama Krishna, 2007). Global Circulation Models suggest that based on the present rate of increase of Carbon dioxide the mean surface temperature is expected to increase between 1.4 °C and 5.8 °C by 2100 with respect to 1990 (IPCC, 2001). The studies indicated that the human induced temperature rise during last century is unequivocal and it increased the average global temperature to about 0.75 °C of which 0.6 °C was in the last three decades (Hansen et al. 2001).

According to IPCC (2007), the global average surface temperature has risen by 0.74 °C (0.56 °C to 0.92 °C) over the last 100 years from 1906-2005 and there would be a rise of 1.5 °C to 3.5 °C by 2100. Oliver and Hidore (2002) indicated that the global average surface temperatures increased by about 0.4^0C to 0.8^0C over the past century. Weather observations from land and ocean based stations reveals that the global mean surface temperatures increased by 0.6 ± 0.2 ˚C since 1850 and an expected an increase of 1.4 to 5.8 C by 2100 (Singh et al, 2008). According to the scientists of Goddard Institute for Space Studies (GISS) at NASA (2010), the average global temperatures of the Earth have increased by about 0.8 C since 1880. Two –thirds of warming has occurred since 1975, at the rate of 0.12 – 0.20 C per decade when these two processes are slowly establishing.

The cascading effects of increase in temperatures are biodiversity, water availability, ecosystem boundaries and global feed backs (Amin et al, 2004). Changes in the patterns of temperature affect the distribution of plant and animals and health of living beings (Onoz et al, 2012). Temperature rise causes a shift in animal and plant species from their original habitats (US Environment Protection Agency, 2012). Further, the rise in temperatures causes melting of snow fields in Arctic and Antarctica which in turn is responsible for sea level rise all over the world, threatening coastal ecosystems and human habitations (Chen et al. 2008; Stroeve et al. 2007). Cunningham and his associates (2005) have predicted sea level rise of 15 to 95 cm by the year 2100. The increase in sea level may cause coastal flooding and storm surges (Houghton et al., 1996). Vanishing of glaciers is a threat to snow fed rivers and it may lead to water scarcity conditions in those regions where the sources of rivers are from glaciers. The water scarcity hampers hydro power generation and agricultural activities. In arid and semi arid regions water scarcity conditions become worst. Apart from this, warming is responsible for frequent and intensified storms, droughts, floods, heat waves and periods of unusual warm weather and coastal flooding etc. (De et al, 2005). These extreme events cause high mortality and economic losses (Easterling et al, 2000). Epstein (2005) in his study mentioned that with warming of environments, mosquitoes which are sensitive to temperature changes, boosts their rates of reproduction, frequency in feeding, prolongs their breeding season and shortens the maturation period for the microbes. Thereby, there is scope for more incidences of vector borne diseases.

The impact of weather and climate on living beings and environment are well established. Through trend analyses it is possible to know the difference between past and existing and to an extent, future condition. Thus, there is need to prepare for the consequences of climate change with suitable and cost-effective adaptation responses (Tadross et al, 2005). The influence of weather and climate on human well being, and the inherent impact on the environment are well known. If we know the status of the climate today and the differences between this and recent past, we can begin to plan for the future. There is a need to prepare the people, to anticipate the consequences of climate change and evolve suitable and cost-effective adaptation responses (Tadross et al., 2005). The present day variations can be assessed directly from the instrumental measurements available for at least 100 to 200 years in many parts of the world. Hence changes in the weather elements of the recent times are more authentic.

For the present study, analyses of temperature variations have been taken in to consideration. The study of temperature variations and spatial distribution of temperature in any region are helpful to assess the climate change scenarios. The global temperature records represent average temperatures of the entire Earth. However, the average temperatures of the entire earth need not be same as average temperature of the earth but it varies locally. Thus, the increase in temperatures in a given year or decade might increase or decrease in a region (Carlowicz, 2010). Yue and Hashiono (2003) showed increasing trends in monthly temperature in Japan for 46 stations from 1900-1996. Srivastava and his associates (1992) in their study indicated the diurnal asymmetry of temperature trends over India. They found that major part of India experiencing rise in maximum temperatures rather than minimum temperatures. Rupa Kumar and his associates (1994) that the mean maximum temperature of many parts of India has increased by 0.6 °C and mean minimum temperature have decreased. Because of the spatial and temporal variations of temperature trends, it is essential to analyse station-wise data for a better understanding of trend patterns of regional and local scales (Schaefer and Domroes, 2009).

Keeping this in view, an attempt is made to understand the temperature variations if any in Andhra Pradesh State through the study of spatio-temporal variations by analysing time series of data of decadal annual average, decadal average maximum and decadal average minimum temperatures from 1901-2010. These types of studies are essential for future predictions.

Study Area

Andhra Pradesh, one of the 29 States of India lies on the eastern seaboard of the peninsular India and extends from 12º 45' to 19º 50' N latitudes and 76º 45' to 84º 45' E longitudes (figure1). The State is bordered by Telangana in the northwest, Chhattisgarh in the north, Odisha in the northeast, Karnataka in the west, Tamil Nadu in the south and Bay of Bengal in the east. The State is the eighth largest in terms of area and occupies 160,205 Km^2. The state has second longest coastline of 972 km. According to 2011 census, Andhra

Pradesh ranks ten with respect to population of 49,386,799. Administratively, the State is divided into 13 Districts, out of which 9 come under coastal Andhra region and 4 under Rayalaseema region.

Data collection and methodology

Data on three variables related to temperature namely mean annual maximum, mean annual minimum and mean annual temperatures of 13 representative stations of Andhra Pradesh were collected from the records of India Meteorological Department for the period between 1901 and 2010. The decadal analyses of temperature data were carried to understand the temporal variations. Maps were generated to assess the spatial variations of temperature in the State.

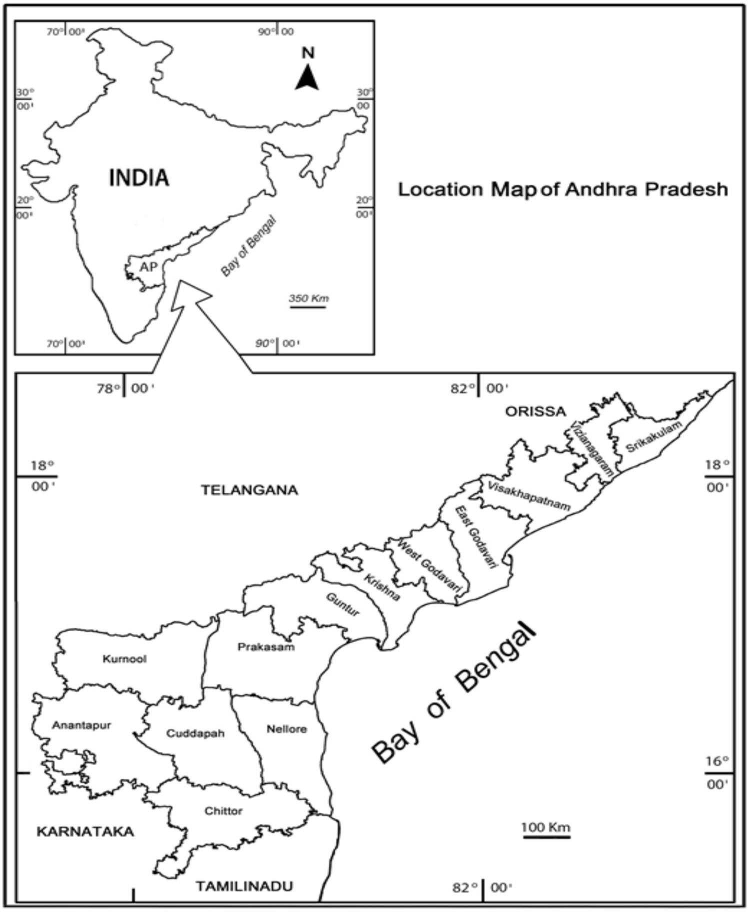

Fig. 1. Location of Andhra Pradesh State

Mean Decadal Average Annual Temperatures

The decadal average of temperatures for 1901-1910 and 2001-2010 for 13 weather stations representing 13 districts of Andhra Pradesh data were computed. Decadal average temperatures of 1901-1910 decade was taken as reference and compared. Positive deviation means that the temperature was warmer than the decade which has taken as reference and a negative deviation indicates that the temperature was cooler than the reference decade. Deviations of temperatures of 2001-2010 decadal temperatures from 1901-1910 were presented in the Table.1.

The analysis of decadal average annual temperatures of Andhra Pradesh indicates that all the has experienced rise in mean annual temperatures when compared to 2001-2010 decade with 1901-1910 decade (figure 2.A). Out of all the Districts Srikakulam and Anantapur Districts have experienced maximum increase in decadal annual temperatures by 2.3 °C followed by Nellore 1.8 °C, while, Kurnool and Chittoor Districts have indicated a minimum of 0.3 °C temperature rise only. The remaining stations have experienced the rise of decadal annual temperature between 0.7 °C and 1.4 °C.

Table 1. Trends of Decadal Average annual temperatures of Andhra Pradesh

Sl No.	Name of the station	Mean Decadal Temperature (°C)		Deviation of temperature
		1901-1910	2001-2010	
1	Srikakulam	24.6	26.9	**+2.3**
2	Vizianagaram	25.0	25.7	**+0.7**
3	Visakhapatnam	26.4	27.8	**+1.4**
4	East Godavari	27.1	27.9	**+0.8**
5	West Godavari	27.4	28.3	**+0.9**
6	Krishna	27.2	28.5	**+1.2**
7	Guntur	27.7	28.4	**+0.7**
8	Prakasam	27.9	29.5	**+1.4**
9	Nellore	27.6	29.4	**+1.8**
10	Cuddapah	26.0	27.1	**+0.8**
11	Kurnool	26.6	26.9	**+0.3**
12	Anantapur	25.3	27.6	**+2.3**
13	Chittoor	25.7	26.0	**+0.3**

Mean Decadal Maximum Temperatures

A maximum temperature represents day-time temperatures of any region. To investigate the trend in the day time temperatures, decadal analysis of maximum temperatures of Andhra Pradesh have been carried out and presented in the table.2. and graphically represented in the figure 2 B. Comparison of 2001-2010 maximum decadal temperatures with 1901-1910 revealed that among the 13 districts, Anantapur recorded the highest rise of maximum temperature with 2.8 °C followed by Visakhapatnam with 2.1 °C, Srikakulam with 1.9 °C Krishna with 1.8 °C and Vizianagaram with 1.7 °C. west Godavari and Guntur experienced minimum rise of 0.1 °C and 0.4 °C respectively. The remaining Districts have experienced moderate rise of maximum temperatures between 0.8 °C and 1.4 °C.

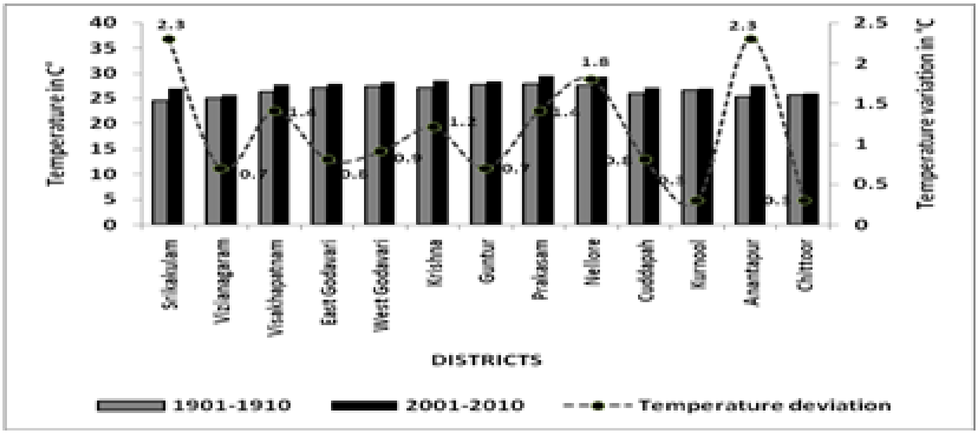

Fig. 2A. Mean decadal Temperatures of Andhra Pradesh

Mean Decadal Minimum Temperatures

Minimum temperature of any region represents the night-time temperatures. Decadal minimum temperatures of 2001-2010 decade with 1901-1910 decade were analysed and compared. The results are given in the table 3 and figure 2 C. Decadal analysis of minimum temperatures revealed that all the districts of Andhra Pradesh indicated rise in mean minimum decadal temperatures except Chittoor District. Visakhapatnam showed highest rise of nighttime temperatures by 2.7 °C followed by Nellore with 2.2 °C and Prakasam with 1.9 °C. The rise is 1.7 °C, 1.6 °C and 1.5 C at Anantapur , west Godavari and Kurnool and respectively. It was observed that Vizianagaram, east Godavari, Krishna and Guntur experienced minimum rise in temperatures between 0.6 °C and 0.9 °C. Chittoor is the only exceptional District, which showed fall in minimum temperatures by 0.2 °C during 2001-2010 decade when compared with 1901-1910 decade.

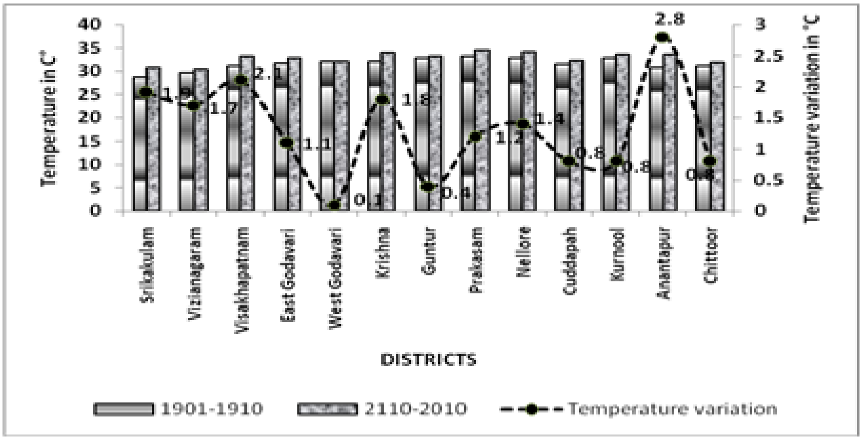

Fig. 2B. Mean decadal Maximum Temperatures of Andhra Pradesh

Table 2.Trends of mean maximum decennial temperatures of Andhra Pradesh

S.No	Name of the station	Temperature (°C)		Deviation
		1901-1910	2001-2010	
1	Srikakulam	28.8	30.7	**+1.9**
2	Vizianagaram	29.7	30.4	**+1.7**
3	Visakhapatnam	31.1	33.2	**+2.1**
4	East Godavari	31.7	32.8	**+1.1**
5	West Godavari	32.1	32.2	**+0.1**
6	Krishna	32.1	33.9	**+1.8**
7	Guntur	32.9	33.3	**+0.4**
8	Prakasam	33.3	34.5	**+1.2**
9	Nellore	32.8	34.2	**+1.4**
10	Cuddapah	31.5	32.3	**+0.8**
11	Kurnool	32.9	**33.7**	**+0.8**
12	Anantapur	30.8	33.6	**+2.8**
13	Chittoor	31.1	31.9	**+0.8**

Table 3. Trends of mean minimum decennial temperatures of Andhra Pradesh

S.No	Name of the station	Temperature(°C)		Deviation
		1901-1910	2001-2010	
1	Srikakulam	20.5	23.0	**+2.5**
2	Vizianagaram	20.2	21.0	**+0.8**
3	Visakhapatnam	21.6	24.3	**+2.7**
4	East Godavari	22.5	23.1	**+0.6**
5	West Godavari	22.7	24.3	**+1.6**
6	Krishna	22.4	23.2	**+0.8**
7	Guntur	22.5	23.4	**+0.9**
8	Prakasam	22.5	24.4	**+1.9**
9	Nellore	22.4	24.6	**+2.2**
10	Cuddapah	20.5	21.3	**+0.8**
11	Kurnool	21.4	22.9	**+1.5**
12	Anantapur	19.8	21.5	**+1.7**
13	Chittoor	20.3	20.1	**- 0.2**

Geospatial Analysis of Temperature trends

To find out the spatial perspective of temperature variations, which were analysed between the decades1901-1910 and 2001-2010, geospatial maps of annual, maximum and minimum temperatures were prepared in ArcGIS environment (Figure 3). The average decadal geospatial map representing annual temperatures of Andhra Pradesh State (Figure 3A) shows that the districts namely entire Srikakulam and Vizianagaram, north and north eastern and western parts of Visakhapatnam District, extreme northwestern parts of Krishna and Guntur Districts, extreme southern coastal parts of Prakasam, entire eastern coastal parts of Nellore in coastal Andhra region, western parts of Kurnool and almost entire Anantapur Districts in Rayalaseema region have experienced rise of annual decadal temperatures between 1.5 °C and 2.5 °C during 2001-2010 decade when compared with

1901-1910 decade. The remaining parts of the State have experienced a rise in temperature between 0.5 °C and 1.5 °C except the southern parts of Chittoor District which is the only region that indicated below 0.5 °C rise of temperature.

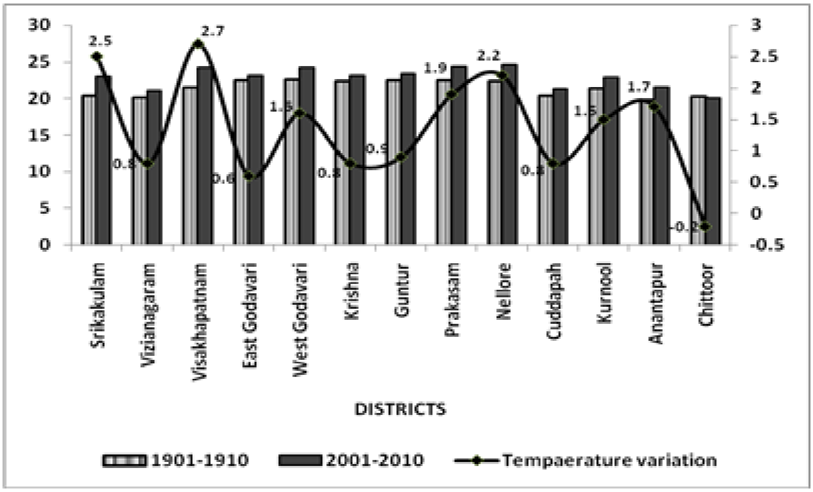

Fig. 2 C. Mean decadal Minimum Temperatures of Andhra Pradesh

The map (Figure 3B) shows the spatial variation of maximum temperature (day-time) between the decades 1901-1910 and 2001-2010. The map reveals the fact that maximum temperatures were increased all over the State without any exception. However, the increase is not uniform all over the State. The maximum rise of above 2.5 °C in day time temperatures have been observed in the western parts of Anantapur District and extreme western parts of Kurnool District of Rayalaseema region. A rise of 1.5 °C to 2.5 °C indicated by entire Srikakulam and Vizianagaram, north and northeastern parts of Visakhapatnam, coastal strips of east Godavari, west Godavari and Krishna Districts in coastal Andhra and central parts of Kurnool, eastern portions of Anantapur and a narrow western strips of Cuddapah and Chittoor Districts in Rayalaseema region. On the other hand, north western and central Parts of Visakhapatnam, south and south eastern portions of east Godavari, west Godavari, Krishna, Guntur, coastal strip of Prakasam, entire Nellore except extreme southern eastern coastal strip in coastal Andhra, entire Chittoor except extreme eastern part, entire Cuddapah except a small strip in the west and central parts of Kurnool Districts in Rayalaseema region have experienced a rise of temperatures between 0.5 °C and 1.5 °C. However, a rise of less than 0.5 °C occurred in the remaining parts of the State.

The spatial map has been prepared to study the variation of minimum temperature between the decades 1901-1910 and 2001-2010 (figure 3C) indicated a prominent rise of night-time temperature by 2.5 °C along the coastal belts of Vizianagaram and Visakhapatnam Districts. The remaining parts of these districts indicated a rise of 1.5 °C to 2.5 °C. Similarly, western portions of east and west Godavari, a narrow northwestern strip of Krishna, eastern parts of Prakasam and Nellore, western tracts of Kurnool and Anantapur Districts have indicated a rise of 1.5 °C to 2.5 °C.

The remaining parts of the districts were under the rise of 0.5 °C to 1.5 °C except coastal strip of east Godavari and almost entire Chittoor District have indicated a rise of less than 0.5 °C.

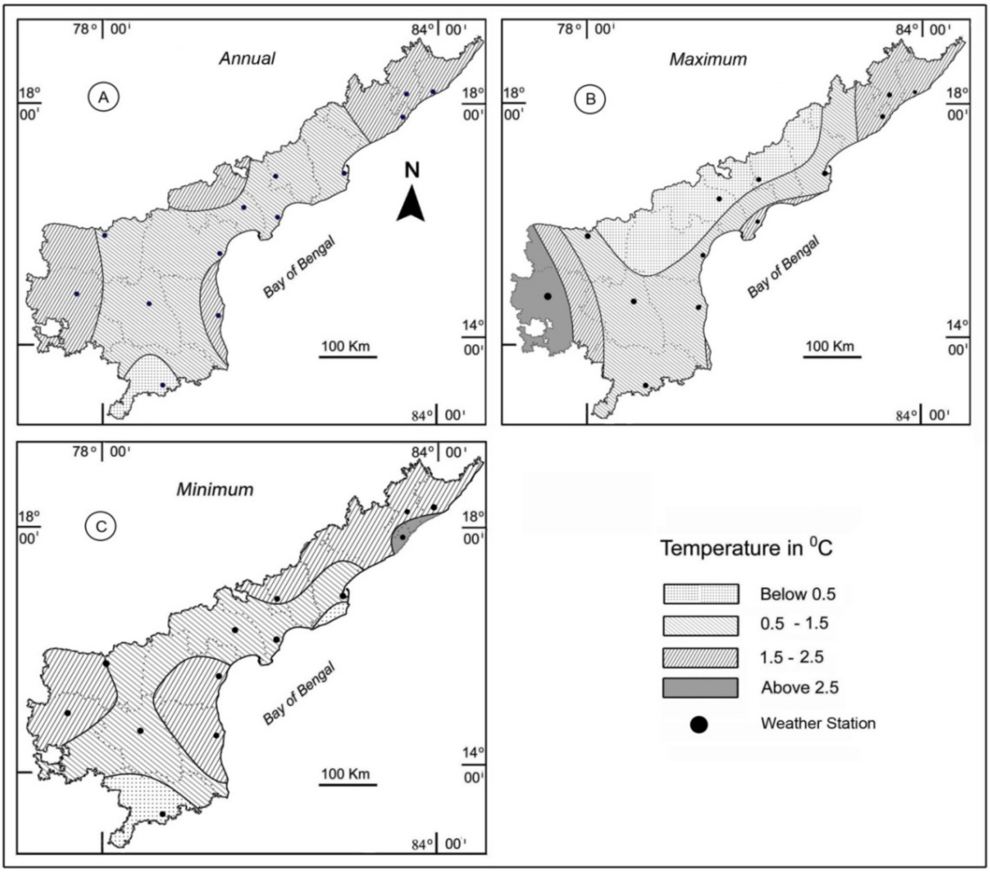

Fig. 3. Geo-spatial temperature distribution

Conclusion

The temporal as well as spatial analysis of decadal maximum, minimum and annual mean temperature in Andhra Pradesh indicated that there is a rise in maximum as well as minimum temperatures in the entire State between 1910-1910 and 2001-2010 decades. The increase of maximum as well as minimum temperature is prominent in the coastal districts namely Srikakulum, Vizianagaram, Visakhapatnam and Anantapur District in Rayalaseema region when compared to the other districts of the State. However, it was noticed that larger area of the State has experienced a rise of temperatures between 0.5 °C and 1.5 °C. Out of all the districts, Chittoor District is an exception which has experienced an increase in very low temperature increase with less than 0.5 °C. This alarming rate of increase can be attributed to the processes of urbanization, Industrialization, deforestation, landuse/ land cover changes, increase in the built up area, and increase in vehicles.

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DROUGHT VARIABILITY IN EASTERN BHUTAN, BHUTAN

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Abstract

This preliminary study on droughts in Eastern Bhutan for the period of 15 years (1996-2010) is based on aridity index derived from computation of water balance using Thornthwaite method. There are five districts in the eastern Bhutan. The monthly precipitation and temperature data of 5 meteorological stations each representing one district was used. It is found that all the districts have experienced droughts of different categories varying in their intensities and frequencies. The eastern region as whole is also found to be prone to mostly moderate drought (31.3%), followed by severe (31.4%), very severe (20%) and disastrous (14.3%).

Keywords: Drought, Water balance, Aridity index, Intensity, Frequency, Proneness.

Introduction

Many definitions of drought exist because the characteristics of drought differ between regions. Before we look into what drought is, it is important to make a reference to a concept of aridity which many a times is understood as drought. Aridity is a permanent feature of regional climate where as drought is a temporary aberration, relative to some long-term average condition of balance between precipitation and evapotranspiration in a particular area, a condition often perceived as "normal". While knowledge of aridity is essential from the point of view of large scale planning, study of droughts is very important for planning short term operations, especially in connection with agricultural development (Subrahmanyam, 1983). Drought is perceived as one of the most expensive and least understood natural disasters. Considerable research has been carried out in hydrology and water resources, but drought remains a serious concern in many regions of the world (Kim & Valdés, 2002). Droughts are acknowledged as one of the most severe of all natural hazards as they are the main cause of famines in many parts of the developing world (Subrahmanyam, 1983). Droughts are generally associated with a sustained period of significantly lower soil moisture levels and water supply relative to the normal levels that the local environment and society have stabilized. According to the water balance concepts, droughts are a physical condition of the environment in which the combined amount of water available from precipitation and from the soil contribution is not sufficient to meet the water demands of the atmosphere through evapotranspiration.

Dracup et al. (1980) have defined three types of droughts namely meteorological, hydrological and agricultural drought. A similar classification can be found in Wilhite & Glantz (1985), where four categories are identified:

1. Meteorological drought: Usually expressions of precipitation's departure from normal over some period of time. It reflects one of the primary causes of a drought.
2. Hydrological drought: Usually expressions of deficiencies in surface and subsurface water supplies. It reflects effects and impacts of droughts.
3. Agricultural drought: Usually expressed in terms of needed soil moisture of a particular crop at a particular time, and
4. Socio-economic drought: Definitions associating droughts with supply of and demand for an economic good.

Subrahmanyam (1983) opines that though droughts are defined differently depending upon the normal climatic conditions, available water resources, land use, agricultural practices and the various economic activities of a region or a locality, water shortage is at the root of all such definitions. Gupta et al (2011) says that drought may be recognized most unmistakably through its economic consequences but it requires a scientific approach on the quantitative index of water shortage.

Absence of a precise and universally accepted definition of drought can lead to some confusion as to whether a drought exists and its severity. Drought impacts also vary significantly between locations because of differences in economic, social, and environmental characteristics. In most of the cases, drought definitions are impact or application specific and region specific which take into account rainfall, temperature, evaporation, soil moisture, vegetation health, and stream flow as critical parameters that are used in the assessment of climatic change and spatial distribution of drought conditions on a global, regional, drainage basin and local level.

In Bhutan, drought remains as one of the least understood hazards. The intensity of drought and its spatial and temporal variations are not researched. In absence of such study, the comprehensive and integrated drought management incorporating climate, soil, water supply, ecosystem and human activities are bound to be a failure.

Objective

In the light of above discussion, he main aim of this paper is to establish the realty of occurrence of droughts in the country through the case study of water balance parameters of five districts that together form the Eastern Region of the country. The identification and categorization of drought based on its intensity, severity, and frequency are attempted here.

Study Area

Bhutan is a landlocked country in the eastern Himalayas. It is enclosed between 26° 42’ and 28° 15’ N latitude and 88° 45’and 92° 10’ E longitude. The total area of the country is 38,394 square kilometres. The country is entirely mountainous in nature with the land rising from about 80 meters above sea level in the south to the higher Himalayas in the north reaching over 7500 meters. The climate generally vary between Humid to Per humid. The central mountain valleys are temperate. It is extremely cold in the north and hot in the south. The temperature varies according to elevation of an area. The southeast monsoon is the main source of rainfall accounting for 80 to 90 percent of the annual rainfall in the country. The five districts namely Trashigang, Trashiyangtse, Pemagatshel and Samdrup Jongkhar form the Eastern Bhutan. As a whole, eastern Bhutan is a region of rugged topography interspersed with deep valleys.

Table 1: Basic facts of the Districts of eastern Bhutan

District	Population (2005)	Approx. area (sq. km)	Altitude (in metres)	Climate	Average Temp. (0^C)	Annual Rainfall (mm)
Mongar	37,069	1,939	240 - 4,000	Moist sub humid	17.9	883
Trashigang	51,134	2,198	520 - 4500	Humid	15.6	1,208
Trashiyangtse	17,740	1,446	760 - 5,900	Humid	15.3	1,189
Pemagatshel	13,864	1,019	80 - 2,640	Per humid	17.2	1,869
Sambdrup Jongkhar	39,961	1,871	80 - 2,640	Per humid	21.1	3,931

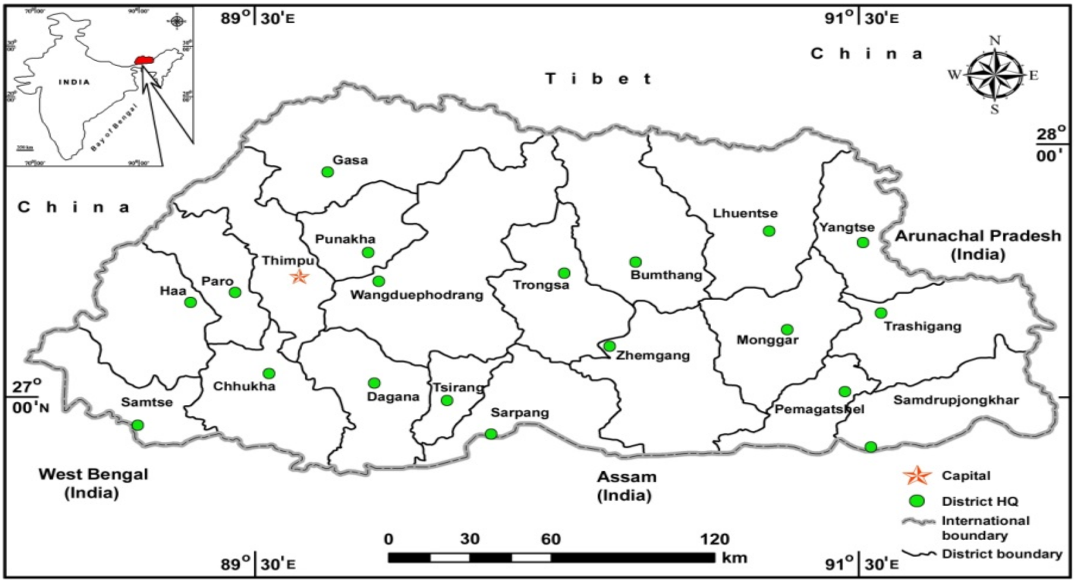

Fig. 1. Study Area

Data Collection and Methodology

The monthly precipitation and temperature data were obtained from the National Center for Weather, Climate and Water Resources, Department of Hydro-Met Services, Ministry of Economic Affairs, Thimphu. It is the premier institute in the country for providing weather and climate data for sustainable planning and development.

Subrahmanyam and Sastri (1969) reported that aridity index (Ia) as originally developed for the purpose of climatic classification can be employed as a rational parameter for the quantitative analysis of drought. They investigated droughts in India and particularly in Andhra Pradesh using the aridity index and results were found to be valid. Based on their methods, yearly aridity indices of 15 years (1996 - 2010) of districts of Eastern Bhutan were calculated according to the book-keeping procedure for water balance originally proposed by Thornthwaite (1948) and Thornthwaite and Mather (1955). The departures of the yearly values of Ia from the median values for each station was worked out and graphically represented. Using the standard deviation, individual years were then categorized into moderate, large, severe or disastrous drought years accordingly as the yearly departures of the aridity index ranged from 0 to ½ σ, ½ to σ, σ to 2 and over 2 σ. The five year frequency of droughts was worked out by dividing the study period into three periods and adding the drought years. Drought proneness which is the percentage ratio of the total number of drought years of all the categories to the total numbers of the years examined of the study area for moderate, severe, very severe and disastrous droughts was calculated.

Results and Discussions

Drought Categorization and Intensity

The intensity of droughts indicates its strength or magnitude. This aspect of the drought study is important because strong drought will have greater impacts to the vegetation or agriculture than the weak drought. During the study period, all the five districts of the region experienced a total of 7 drought years each of varying categories of intensities (Table 2). Mongar and Trashigang experienced 3 moderate, 2 severe and 2 very severe drought years each. Trashiyangtse experienced 3 moderate, 2 severe and 2 disastrous drought years, Pemagatshel experienced 2 moderate, 3 severe, 1 very severe and 1 disastrous drought years and Sambdrup Jongkhar experienced 1 moderate, 2 severe, 2 very severe and 2 disastrous drought years (Fig.2). Over all, moderate and severe type of droughts is more common compared to very severe and disastrous droughts. The prevalence of drought in the study region is perplexing as the climates of the region is moist sub humid, humid and per humid types with little or no water deficiency. Thornthwaite while classifying drought based on the failure of the water supply to satisfy needs (as cited in Mather, 1974) states that sub humid and humid areas are characterized by contingent and invisible type of droughts as a result of significant periods of no rainfall or irregular and variable rainfall. Therefore, droughts occur in humid areas and can lead to failure of crops.

Table 2: Drought years and their intensities

District/Station	Moderate	Severe	Very Severe	Disastrous	Total
Mongar	1996, 1999 & 2009 **(3)**	1998 & 2002 **(2)**	2001 & 2004 **(2)**	-	**07**
Trashigang	1996, 1998 & 2002 **(3)**	2000 & 2001 **(2)**	1999 & 2006 **(2)**	-	**07**
Trashiyangtse	1998,2004 & 2008 **(3)**	2000 & 2002 **(2)**	-	1999 & 2009 **(2)**	**07**
Pemagatshel	2001 & 2009 **(2)**	1996, 2000 & 2010 **(3)**	2002 **(1)**	1999 **(1)**	**07**
Sambdrup Jongkhar	1997 **(1)**	2009 & 2010 **(2)**	2001 & 2005 **(2)**	1999 & 2006 **(2)**	**07**
Easter Bhutan	**12**	**11**	**07**	**05**	**35**

Figures in ( ) represent total no. of years

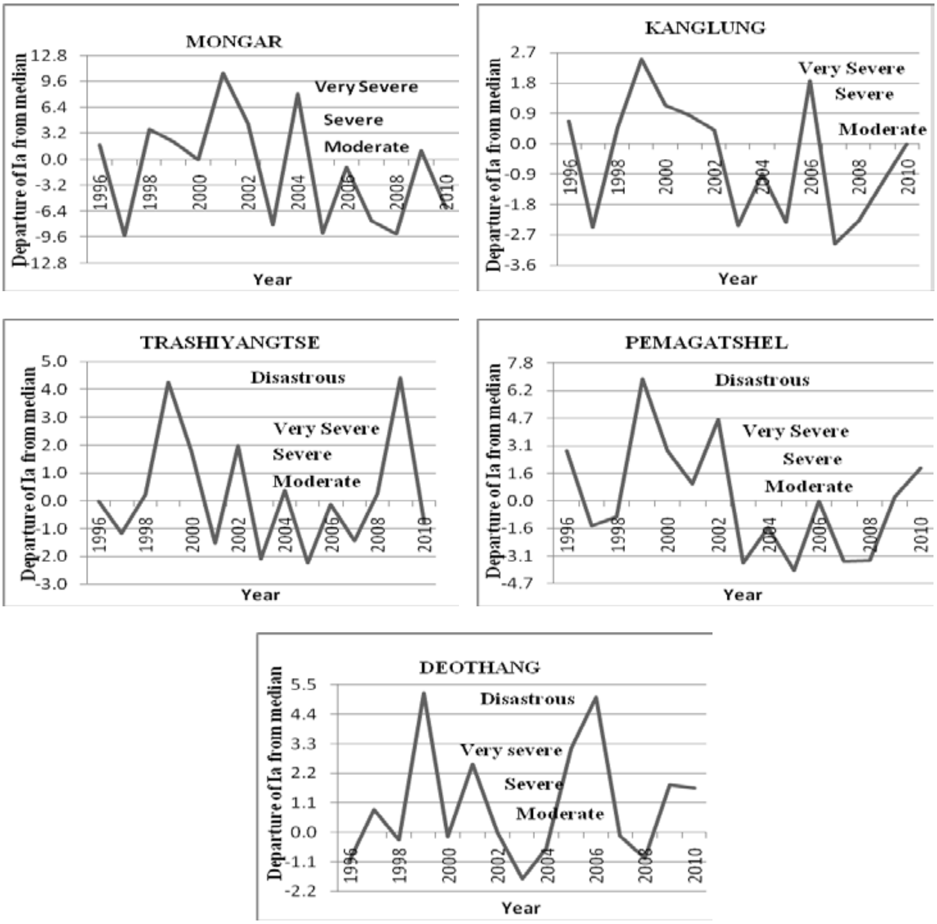

Fig. 2. Drought categorisation

(Table 3). Mongar experienced 4 drought years (2 moderate, 1 severe and 1 very severe), Trashigang experienced 3 drought years (2moderate and 1 severe), Trashiyangtse experienced 3 drought years (1 moderate, 1 severe and 1 disastrous) and Pemagatshel experienced 3 drought years (2 severe and 1 disastrous). On the other hand, Sambdrup Jongkhar experienced maximum number of drought years during 2006-2010 with 3 drought years (2 severe and 1 disastrous) (Fig. 3).

Table 3: Five year frequency of drought years

Station	1996-2000					2001-05					2006-10				
	M	S	VS	D	Tot	M	S	VS	D	Tot	M	S	VS	D	Tot
Mongar	2	1	0	0	**3**	0	1	2	0	**3**	1	0	0	0	**1**
Kanglung	2	1	1	0	**4**	1	1	0	0	**2**	0	0	1	0	**1**
Trashiyangtse	0	2	0	1	**3**	0	2	0	0	**2**	0	1	0	1	**2**
Pemagatshel	0	2	0	1	**3**	1	1	0	0	**2**	1	1	0	0	**2**
Deothang	1	0	0	1	**2**	0	0	2	0	**2**	0	2	0	1	**3**
Eastern Bhutan	5	6	1	3	**15**	2	5	4	0	**11**	2	4	1	2	**9**

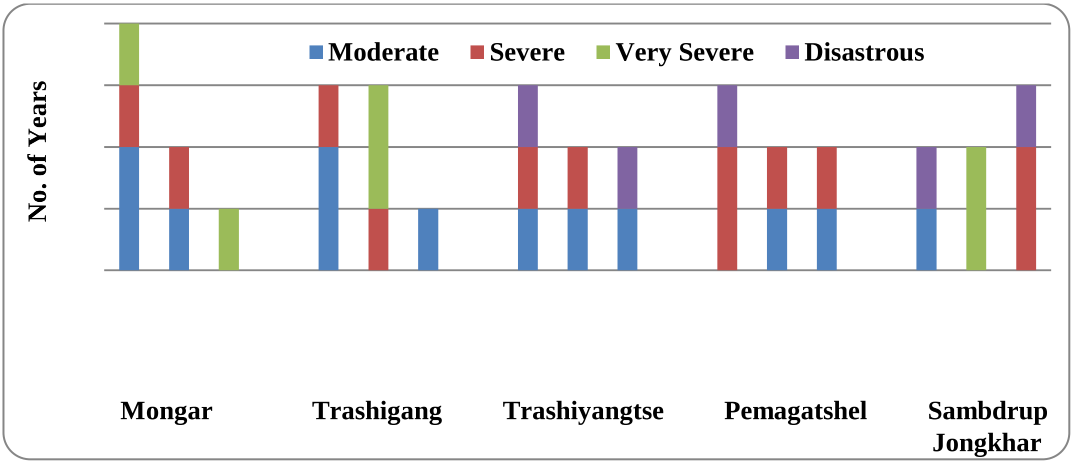

Fig. 3: Five year frequency of drought years

Table 4: Drought proneness (%)

Station	Moderate	Severe	Very severe	Disastrous
Mongar	42.9	28.6	28.6	0
Trashigang	42.9	28.6	28.6	0
Trashiyangtse	0	71.4	0	28.6
Pemagatshel	28.6	42.9	14.3	14.3
Sambdrup Jongkhar	14.3	28.6	28.6	28.6
Eastern Bhutan	34.3	31.4	20	14.3

Drought Proneness

Drought proneness means areas which are more prone or inclined to droughts. The analysis of drought proneness is equally important as the study of drought frequency and intensity since the knowledge of drought prone areas is helpful in planning the land use and in adopting the remedial measures to minimize the impact. As a whole, the region is more prone to moderate drought with 34.3 per cent followed by severe 31.4 per cent, large 20 per cent and disastrous 14.3 per cent. This trend is in consistent with the general assumption that the humid regions are less prone to the droughts of larger intensity. District wise analysis indicates that all the districts of the region have experienced 7 years each of droughts out of 15 years. The drought proneness of each district is, therefore, 46.7 percent. The proneness of each district to a specific type of drought is shown below (Table 4).

Conclusion

It is observed through this preliminary study of the droughts in eastern Bhutan that though the climates of the area are ranging from moist humid, humid to per humid yet it experiences varying categories of droughts, mostly moderate and severe. It is a case of contingent and invisible droughts as per Thornthwaite's classification of droughts which has the potential to lead to crop failures without supplemental irrigation. The frequency of drought occurrence indicated that drought was more frequent during the period 1996-2000 than in remaining two periods of 2001-2005 and 2006-2010. The drought proneness of the region showed that the entire region is more prone to moderate and severe droughts than very severe and disastrous droughts. This corroborates the assumption that larger intensity droughts are less frequent in humid areas than in arid and semi-arid areas. It is also observed that all the districts of the region, as whole, are equally prone to the drought. Such study in general is useful in the planning and design of comprehensive and integrated drought management incorporating climate, soil, water supply, ecosystem and human activities in the study area.

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CLIMATE CHANGE AND CHRONIC KIDNEY DISEASE

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Abstract

The adverse effects of climate change are detrimental to health, wealth and economy of mostly the poor and low-income communities around the world. These climate changes have bearing on human health evidenced by increase in heat-related illnesses and deaths. It is well documented that acute renal failure is one of the complication in heat stress. All these factors eventually develop repeated subclinical renal dysfunction, which may further develop into chronic kidney disease (CKD). In India CKD is an increasing public health concern with poor outcome. In our study, most of the CKD (48.4%) cases are registered relatively high between the months of March and May. In our study the average age of CKD patients was found to be 46.64 years ±11.63 and the distribution of male and female is 63% and 37% respectively. In the present study, creatinine clearance values using CG, MDRD and MCQE in CKD patients are significantly lowered when compared with control (p<0.001). In our study, most of the people registered are agricultural workers (24%), construction workers or labourers (23%) and industrial labour workers (19%) who belong to low income group. In the present investigation, it was observed that there was a progressive decline in GFR as the age advanced; these are more at risk of developing renal disease when exposed to heat stress. CKD finally ends in end stage renal failure and requires dialysis for survival, further exposure to heat leads to adverse effects. Efforts to support adaptation and mitigation of climate change to create healthier, more sustainable communities are the need of the day.

Keywords: Climate change, Chronic kidney disease, Glomerular Filtration rate

Introduction

Increasing frequency and intensity of heat waves is one of the consequences of global warming. As there is progressive global warming, the adverse effect of heat wave on human health is increasing day by day. Exposure to hot weather causes heat related illnesses [1, 2]. Heat related illness depends not only on weather condition at any given time, but also on previously existing health conditions and also socioeconomic status [3]. Most of the people affected by this type of stress are elder people and urban dwellers [4].

The temperature is on rise for the past few years and continues in to the future pertaining to the present scenario. In India majority of the population depends on agriculture and industries. Thus continuous exposure to constant hot and humid weather is inevitable. Also, the low income groups survive in poor living conditions with meagre facilities. Heat stroke is a life threatening illness characterized by elevated core temperature that rises above 40^0C leading to abnormal organ function and death if not treated. The incidence of such deaths may increase with global warming [5, 6].

Heat stress causes volume depletion, if severe, it may cause acute kidney injury even in healthy individuals. It is a known factor that acute kidney injury leads to chronic kidney disease in general, in the absence of functional recovery from the initial injury and recent studies have shown that sub-clinical damage also increases the risk of CKD. Hyperthermia induced volume depletion leads to repeated sub-clinical damage to the kidney, and further progresses to CKD [7, 8].

Chronic kidney disease manifests as a result of either structural damage or decreased kidney glomerular filtration rate (GFR) of less than 60 ml/min/1.73m^2 for 3 or more months[9]. Classification is a major step in CKD which is done by quantifying the glomerular filtration. GFR will assess the filtering capacity of nephrons in the kidney[10]. GFR is helpful for not only for early detection of renal impairment but also a good indicator for the need of dialysis. CKD patients are classified based on GFR under five stages. These are stage 1 (GFR ≥ 90 ml/min/1.73 m^2), stage 2 (GFR 60 to 89 ml/min/1.73 m^2), stage 3(GFR 30 to 59 ml/min/1.73 m^2), stage 4 (GFR 15 to 29 ml/min/1.73 m^2) and stage 5 (GFR less than 15 ml/min/1.73 m^2) [11].

Diabetes mellitus, hypertension, glomerulonephritis, renal vascular disease and many other nephrotoxic factors cause progressive damage to kidney function and the effect of heat stress speeds up the progression to overt disease. Prevalence of CKD with characteristics similar to the Indian epidemic have been reported in specific regions in Sri Lanka, Egypt and Central America.[12,13] Many epidemiological studies have been carried out on hot weather condition and various heat related illnesses. But very few studies were carried out on heat stress and related renal dysfunction. Besides, most of the studies are carried out in well developed countries of west, where the living conditions and facilities are relatively better than those of India, still a developing country. Thus the present study is chosen to study the effect of heat on the development of CKD where poor living conditions and enormous exposure to heat prevail in most of the parts of India.

Materials and Methods

Control group comprised of 123 age and sex matched healthy individuals who were free of features of kidney disease and were having a normal blood urea and serum creatinine level. The upper limit for serum creatinine levels was 1.2 mg/dl and the corresponding value for blood urea was 45 mg/dl. Individuals suffering from diseases that are likely to alter these parameters were excluded from the study. Likewise, persons with history of drug intake which cause changes in these parameters were also excluded. Renal insufficiency patients who are admitted during January2011 to December 2012 are selected, in this 198 patients with evidence of CKD were taken as cases. These CKD patients were admitted into Nephrology unit of MIMS hospital, Nellimarla. The CKD cases included both non dialysis group and hemodialysis group. They were included in the study on the basis of clinical signs and symptoms of kidney disease along with elevated blood urea and serum creatinine levels. The hemodialysis patients were undergoing hemodialysis in Nephrology department, but non dialysis patients were under conservative medical therapy.

Informed consent was taken from the patients and controls who participated in the present study. Ethical committee approval has also been obtained. In all these groups blood urea and serum creatinine were measured. The blood urea was estimated by GLDH – Urease method[14]. Serum creatinine was estimated by Jaffes method[16]. The eGFR was computed by the following methods:-

1. Cockcroft-Gault Creatinine Clearance (ml/min)[15] = (140 - age) x (weight in kg) / Serum Creatinine (mg/dl) x 72 (Multiply with0.85 if female)CG formula is adjusted to body surface area (BSA) by using DuBois, DuBois method[16,17]

$$BSA = (W^{0.425} \times H^{0.725}) \times 0.007184$$

2. MDRD Creatinine Clearance (ml/min/1.73m^2)[18] = 186 x (Serum Creatinine (mg/dl))$^{-1.154}$ x (age in years)$^{-0.203}$ x 0.742 (Multiply with 0.742 if female)
3. The MCQE estimated GFR (ml/min /1.73 m2)[19] = exp [1.911 + 5.249 / SCr – 2.114 / SCr^2 – (0.00686 x age (years)] (– 0.205 if female)

Where SCr is Serum Creatinine in mg/dl. Values <0.8 mg/dl set to 0.8 mg/dl, as per the reported method.

Statistical Analysis: All the data is expressed in Mean and Standard deviation. For the statistical significance, Z test was performed.

Results and Discussion

Climatic parameters such as temperature, humidity, wind, evaporation and sunshine influence the human health [20, 21]. Alteration of theses parameters, particularly raised temperature will causes health complications. Body gains heat from two sources that is the environment and the metabolic sources. This gained heat will be regulated to 37^{0}C by hypothalamic thermoregulatory center, and regulates even the rise of less than 1^{0}c. The main regulatary process is cutaneous vasodilation which increases the flow of warm blood in the skin thus initiating thermal sweating. The sweat evaporates and cools the body surface, but humid climate restricts the evaporation process leading to discomfort. In heat dissipation, there is more cutaneous circulation and lesser visceral circulation, particularly in the intestine and kidneys and causes organic dysfunction. Continuous sweating without adequate water intake causes dehydration and further leads to hypovolemia and salt depletion which impair thermoregulation [22, 23].

The environmental conditions of India are different from western regions and the rest of the world as well. Considering these aspect, Indian meteorological department (IMD) has categorized heat waves differently in to two. The first category includes places where the normal maximum temperature is greater than 40^0c. In such regions, if the day temperature exceeds by 3-4^0c above the normal, it is said to be affected by a heat wave. If greater than 5^0c or more than the normal, it is severe heat wave. The second category considers the regions where the normal maximum is 40^0c or less. In these areas, if day temperature is 5-6^0c above the normal, then the place is said to be affected by moderate heat waves. A severe heat wave condition exists when the day temperature exceeds the normal maximum temperature by 6^0c.

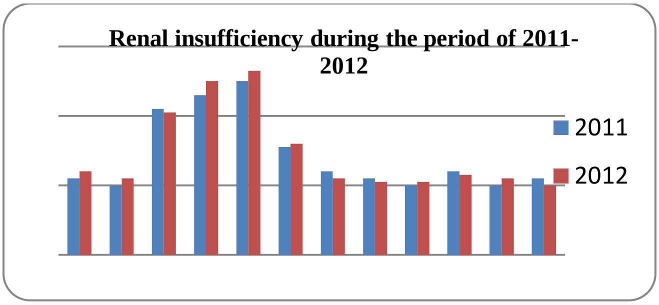
In our study, most of the CKD (48.4%) cases are registered between the months of March and May. The renal insufficiency cases are also registered more between months of March and May (table 1). In these months there is a rise in temperature. At same time there is also increased humidity in these areas which can lead to hyperthermia. Alana et al. (2008) reported that there is a renal function marker i.e. serum creatinine that rises, in about 67% of patients who are affected by heat stress. And they also reported that during summer season there is an increased hospital admission for renal disease during heat waves when compared to non-heat wave period[24]. Knochel et al.(1996) reported that incidence of acute renal failure is 30% due to extreme heat, which may cause a pre renal disease of volume depletion[25], Dematte et al.(1998) reported in their study 53% of patients affected with classical heat stroke developed moderate to severe renal in sufficiency[26].

In the present study, Blood urea and serum creatinine register an increase in their levels in patients with CKD when compared to those of controls ($p<0.001$, table 2). The reason attributed to raised blood urea and serum creatinine in patients with CKD is the declining of glomerular filtration. Evaluation of renal function by estimating GFR is one of the most important aspects in the management of CKD. In the present study, creatinine clearance values using CG, MDRD and MCQE in CKD patients are significantly lowered when compared with control ($p<0.001$) (table 3). This is evident by raised serum creatinine in CKD group. We chose three formulas because each formula as their on limitation so that we compared with three formulae for evaluates CKD.

There is evidence that consequence of heat exposure is renal dysfunction resulting from dehydration and hyperthermia.[2].In hyperthermia, the thermoregulatory physiological and circulatory mechanisms are necessary to overcome extreme heat conditions. These may cause mild to moderate renal hypoperfusion following hypohydration and peripheral vasodialation and lead to stress on the kidneys. Acute renal failure is one of the complications of heat stress [27, 28]. Direct thermal injury may cause kidney tissue damage and leads to renal impairment. All these factors eventually develop repeated subclinical renal dysfunction, which may further develop in to chronic kidney disease (CKD). It is also registered that people living in lower altitudes are more likely to develop CKD than those living at higher altitude because of higher temperature at lower altitudes [29, 30, 31]. CKD finally ends in end stage renal failure and requires dialysis for survival, further exposure to heat leads to adverse effects.

In the present study, most of the people registered are agriculture workers (24%), construction workers or labourers (23%) and industrial labour workers (19%) (figure 2) and belong to low income group. Such workers are engaged in strenuous physical activity in extreme hot environmental condition during summer. It causes hyperthermia, leading to volume depletion based on the type of hydration practices outside the work. Also, the nature of work caused muscle damage consequently leading to subclinical kidney damage and further more CKD. Besides this if these are any other causative factors for CKD, the heat stress makes the disease status overt. The other major issue is most of these workers engaged in hot weather and lesser water intake suffer from volume depletion which further causes changes in the blood perfusion affecting kidney, a sensitive organ and leads to ischemic injury of the kidney.[32] Some of the studies show that workers in the agriculture, mining, fishing and shipping industries have higher prevalence rate of CKD [33]. Chaudary et al. and Reid et al. noted that loss of human lives was more in regions of poor socioeconomic condition than the regions of better conditions [34, 35]. When the creatinine clearance was compared age wise in control group, it was noticed that there was marked difference in the values of GFR as age advanced.

In our study of control subjects, it was observed that there was a progressive decline in GFR as the age advances and it is true by all the three methods of estimation of GFR. (figure 1a and b). In elderly healthy individuals also both anatomical and functional changes occur in kidney. Renal mass is lost, mainly due to progressive atrophy of renal cortex and decreased of renal blood flow[36, 37]. The glomerular filtration rate (GFR) reduced at an average of 8ml/min/1.73m2/ decade in normal healthy individuals without renal impairment starting at the age of 40 years[38, 39]. Increasing age results in a decline in lean body mass and water content in the body this can cause greater strain in elderly people exposed to hot weather due to loss water in the form of sweat. Besides this, the elderly are more at risk of developing heat related renal disease due to lowered thermotolerance, impaired thirst sensation and diminished conservation of sodium and water during dehydration[40]. Elderly people with poor left ventricular function face difficulty to overcome this physiological phenomenon, resulting in hypoperfusion of the kidney [27, 28]. In one of the studies they found that elderly age group people admitted more during heat waves with renal disease[24]. The number of cases registered as Renal insufficiency and CKD are much higher in the month of march to may then compare to other months.



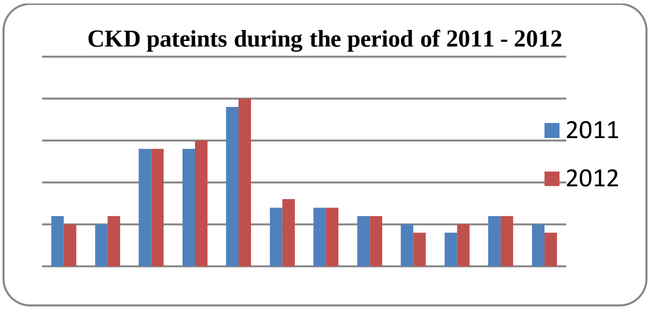


Fig. 1a and b: Showing cases registered in Renal Insufficiency and CKD during the period of January 2011 and December 2012.

Table 1. Demographic features and diagnostic parameters in controls and CKD Patients.

		Control (n=123)		CKD Patients (n=198)
Age (mean±SD) years		44.02±13.76		46.64±11.63
Sex (Males %) (Females %)		69% 31%		63% 37%
Body weight(kgs)		66.72±6.64		62.24±6.95
Height (cm)		172.67±5.17		171.96±5.87
Blood urea (mg/dl)		28.55±8.16		98.77±36.77**
Serum Creatinine (mg/dl)		0.90±0.13		4.60±2.54**

*p<0.001

The diagnostic criteria for CKD consisting of blood urea and serum creatinine were significantly higher (p<0.001) in CKD patients when compared to control.

Table 2. Creatinine clearance in controls and CKD Patients.

	Control (n=123) (mean±SD)	CKD Patients (n=198) (mean±SD)	P value comparison between control vs. CKD
CG (ml/min/1.73m^2)	92.12±20.41	23.06±14.51	<0.001
MDRD (ml/min/1.73m^2)	92.61±20.52	20.82±15.08	<0.001
MCQE (ml/min/1.73m^2)	114.94±19.11	22.47±17.18	<0.001

When the creatinine clearance values between control and CKD cases were compared on the basis of CG, MDRD and MCQE equation it was observed that the values were significantly decreased ($p<0.001$) in the CKD cases as per all the three equations.

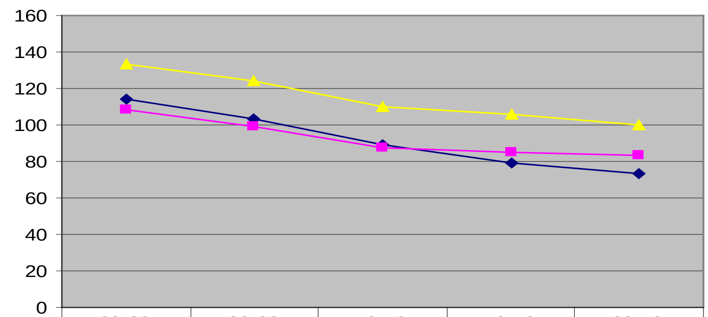
Table 3. Distribution of CKD patients based on Occupation

Occupation		CKD patients (198)
Agriculture workers		47 (24%)
Construction workers/ Labor		45 (23%)
Industrial workers		38 (19%)
Official job holders		24 (12%)
House holders		22 (11%)
Others		22 (11%)

Most of the people registered in agriculture workers and labour, who are continuously exposed to heat weather.

Besides this, obese people contain more adipose tissue, which acts as a less effective surface area and can cause insufficient heat loss and also there is less water content due to more adipose tissue. All these factors result in ineffective heat loss and promote to heat stress [41]. Some of the studies reported that people suffering from diabetes mellitus have an increased susceptibility to extreme heat and heat related renal dysfunction [42, 43] possibly due to pre-existing renal conditions resulting in unfavourable kidney damage in heat stress [44, 45]. Many therapeutic drugs like psycotropic drugs, antihypertensive drugs and anti-histamines can inhibit thermoregulation in various ways. Patients using the above drugs and also exposed to heat undergo more heat stress [46].

Accordingly, we hypothesize that repeated exposure to hot weather causes hyperthermia further leading to volume depletion, which may cause impaired renal function. Heat stress precipitates overt renal dysfunction if there is already a pre existing renal compromise due other factors. There is evidence that acute kidney injury follows heat stress. But such repeated sub clinical renal insults eventually progress to CKD. However, repeated acute kidney injury, though silent, produces self-perpetuating cycle of inflammation and repair, resulting in kidney fibrosis that has more adverse effect and finally presents clinically as CKD [47]. Our study has certain limitation that the sample size is small and influence of regional factors where the patients are mostly from northeast part of Andhra Pradesh. In our study, the factors accentuating CKD are poor socioeconomic and physical labour of agricultural and industrial workers where there is continuous intense exposure heat. However, this requires further more detailed study that might also throw light on the present havoc of global warming.



	20-29	30-39	40-49	50-59	60-70
CG (ml/min)	113.89	103.44	89.36	79.08	72.93
MDRD (ml/min)	108.46	99.5	87.25	84.75	83.28
MCQE(ml/min)	133.56	124.27	110.23	105.58	99.77

Fig. 2. Difference in the values of GFR

Conclusion

In accordance with global warming trends reported worldwide, temperatures are gradually increasing. Along with raised both heat and humidity adversely affects people living in the poor facilities and working in hot climatic conditions. Our data suggest that burden of renal diseases may increase as period of hot weather becomes more frequent. This is further aggravated if age advanced and people with chronic diseases like diabetes and hypertension. Long term treatment of end stage renal disease is costly and increases mortality. Health education programs need to awareness the climate changes and heat related illness.

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SPATIO – TEMPORAL ANALYSIS OF RAINFALL DISTRIBUTION IN VAIPPAR RIVER BASIN, TAMILNADU – A GIS APPROACH

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Abstract

Water is the vital natural resource essential for the survival of mankind. Rainfall, the source of water which is unevenly distributed spatially and temporally. Unprecedented increase in population, urbanization, agricultural expansion and industrialization leads to higher levels of human activities. As water demand increases, issues on water availability and demand become critical. This makes the management of water resources (assessing, managing and planning of water resources for sustainable use) a complex task. It has become more critical in places where rainfall is very low and erratic. Rainfall is the one of the fundamental physical parameter among the climate as for the development of society is concern and it determines the drought as well as the environmental factors for the particular region. Among the climatic elements the rainfall is the first index, ever thought of by farmers and climatic analyzers as it is the most important single factor which determines the cropping pattern of an area in general and the type of crop to be cultivated and its success or failure in particular. Rainfall is a highly significant piece of hydrologic data. Rainfall is the important element of Indian economy. Although the monsoons effect most part of India, the amount of rainfall varies from heavy to scanty on different parts. There is great regional and temporal variation in the distribution of rainfall. Rainfall is a key factor determining the sustainability and conservation of living species on the earth. Rainfall is the crucial agro climatic parameter to the agricultural activities, and one of the designs for groundwater recharge for potential groundwater. The rainfall is primary source for water and it is characterized by its amount, intensity and distribution in time. Vaippar river basin is an important water source in Virudhunagar and adjacent, districts. The paper describes an attempt to analyze the rainfall variation of the study area. In order to understand the spatio temporal pattern of annual and seasonal rainfall, their variability of rainfall have been analysed through Arc GIS environment.

***Keywords*:** Rainfall, Water, Monsoon, Season and GIS

Introduction

Changing pattern of global climate and its impacts may be unnoticeable over a short period of time. However, over a generation of humankind, the impacts of climate change could be clearer, particularly on the water, which has direct impact on the livelihood of the people, but by the time a lot of damage could have happened. Due to the ever-increasing demand for water resources, the pressure on their judicious utilization is also increasing. The levels of water resources is decreasing over years due to all the above activities and decreasing of annual rainfall year by year due to climatic changes and increasing runoff due to urbanization and deforestation. Hence, it is necessary to increase water resources and maintain the quality of water resources to meet for future demands.

Water is a prime natural resource and essential for life on earth. Rainfall is one of primary source for water. The rainfall distribution of India is uneven and varies considerably from region to region, season to season and year to year. Rainfall as widely measured by a well distributed and organized network of raingauge stations. The surface water resources of any region can be evaluated by studying systematically the distribution of rainfall based on the data from raingauge stations over a period of time.

Study Area

The present study area, Vaippar river basin covers an area about 5255 sq km. The basin located between 77° 15' to 78° 20' East longitude and 8° 58' to 9° 43' North latitude. The Vaippar river originates on the eastern slope of the Western Ghats at an altitude about 1,500 mts above msl. The river basin further divided 9 sub watersheds namely, Arjunanadi, Mannarkottai, Kayalkudiar, Deviar - Nagariar, Kalingalar -Nikshebanadi, Middle Vaippar, Melakarnadi Odai, Uppar and Lower Vaippar. It lies between Gundar river basin in north and eastern part, south by Tamiraparani and Kallar river basins, western by Kerala state and part of Vaigai basin (Fig.1).

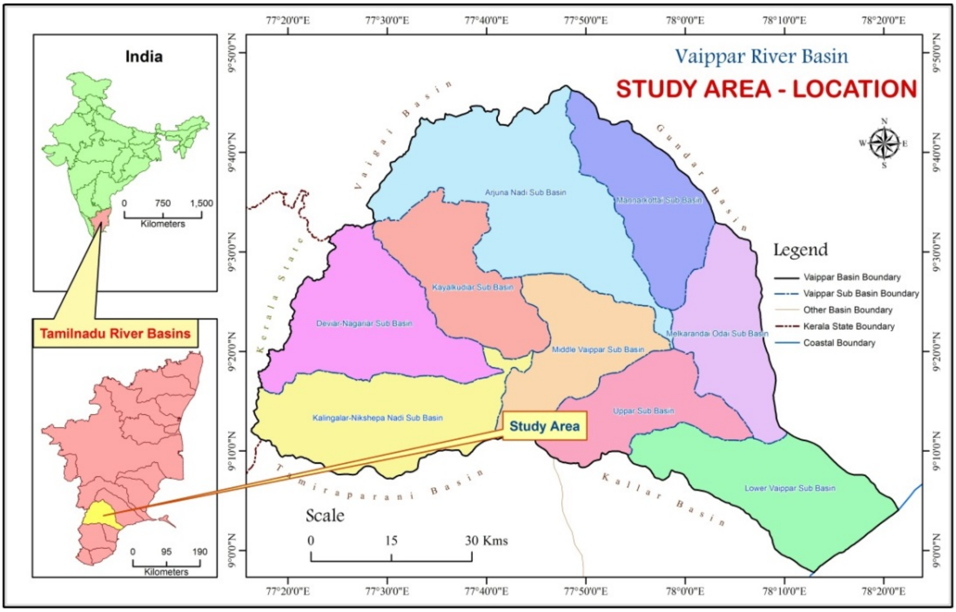

Fig. 1. Location of the Vaipar basin

In the present investigation, the ultimate aim is to study about the spatio temporal pattern and seasonal variation of rainfall in Vaippar river basin. The, objectives are to identify the spatial and temporal pattern of rainfall in 1981 and 2010; to analyse the seasonal variation of rainfall distribution; and also to identify the amount of rainfall changes, if any.

Database and Methodology

The base map of Vaippar basin has been prepared from Survey of India toposheet on 1:50,000 scale. The monthly rainfall data for 30 years (1981 – 2010) have been collected for 11 stations which are located in the Vaippar river basin. The seasonal and annual rainfall has been calculated. The calculated data has been processed and analysed by preparing various maps and diagrams using GIS software.

Results and Discussion

Rainfall is one of the most important climatic variables because of its two sided effects - as a deficient resource, such as droughts and as a catastrophic agent, such as floods. The changing rainfall pattern, and its impact on surface water resources, is an important climatic problem facing society today. Studies on rainfall behaviour have attracted a lot of attention from scientists throughout the world. Previous studies have been carried out to investigate the changes in rainfall pattern temporally and spatially.

Mean Annual Rainfall

The long term mean annual rainfall of the watershed is about 799.3 mm of which the winter, summer, southwest and northeast monsoon contribute 6.1, 20.2, 20.1and 53.6% of the annual rainfall respectively. The mean annual rainfall various between 949.8 mm records at Watrap whereas the minimum of 581 mm rainfall records at Vilathikulam, where the stations are located in the northern part and southern part of the study area (Table 1). The annual rainfall gradually increases from southeast to northwest. Fig..2 shows Vilathikulam station gets very low rainfall, Watrap and Srivilliputtur stations get very high rainfall. Sivagiri, Virudhunagar and Aruppukottai stations get moderate rainfall and other stations get low rainfall in the basin. The annual rainfall variability varies from 8.2% to 36.5% in the basin. The long term precipitation ratio is 139.4%. It varies from low in Sattur (81.2%) and High in Sivagiri (180.3%).

Seasonal Rainfall

One of the important climatic parameter of rainfall is divided into four well-marked seasons. They are winter (January - February), summer (March - May), southwest monsoon (June - September) and northeast monsoon (October - December).

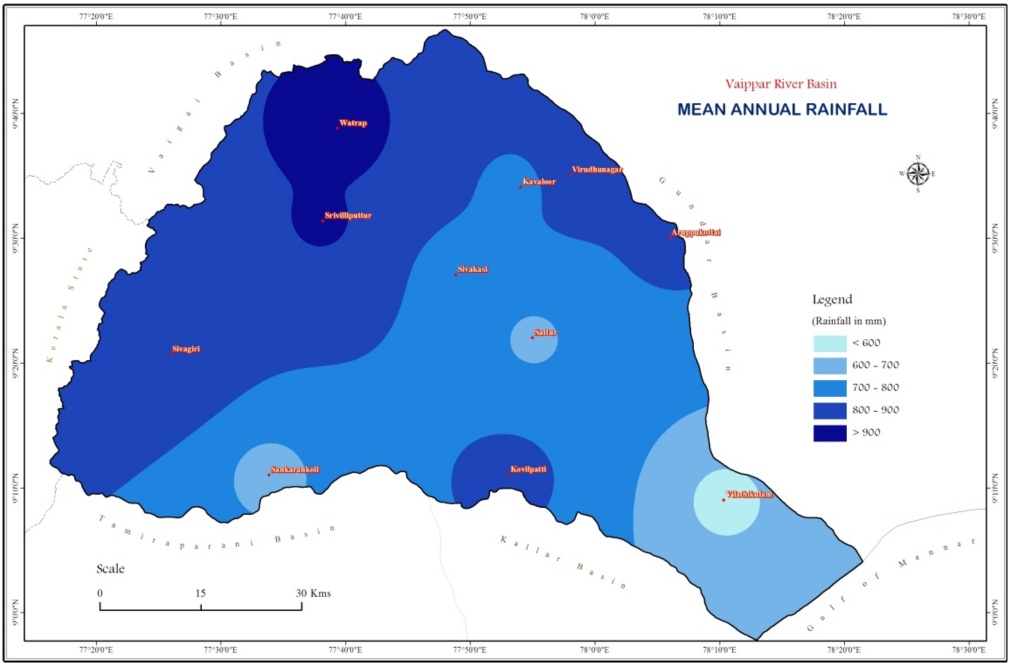

Fig 2. Mean Annual Rainfall of the study area

Table 1: Seasonal and Annual Rainfall – 1981 to 2010

S.No	Rain Gauge Station	(Rainfall in mm)				
		Winter	Summer	SW Monsoon	NE Monsoon	Annual
1	Aruppukottai	36.2	142.4	210.6	430.0	819.2
2	Kavaloor	37.8	154.7	199.7	392	784.2
3	Kovilpatti	47.4	196.2	190.3	438.9	872.8
4	Sankarankoil	50	135.5	81.2	410.6	677.3
5	Sattur	36.9	149	151.9	343.6	681.4
6	Sivagiri	92.7	180.7	104.2	516.9	894.5
7	Sivakasi	36.6	172	162	409.3	779.9
8	Srivilliputtur	55.8	209.7	168.2	476.7	910.4
9	Vilathikulam	37.5	81.2	89.1	373.2	581
10	Virudhunagar	43.4	162.8	229.2	406.7	842.1
11	Watrap	65.9	191.3	179.9	512.7	949.8
Average		**49.1**	**161.4**	**160.6**	**428.2**	**799.3**
Percentage		**6.1**	**20.2**	**20.1**	**53.6**	**100**

Source: Compiled by Author

Winter Season Rainfall

During winter season Sivagiri station gets the maximum rainfall (92.7 mm) in the southern part if the basin. It decreases from west to east the following order of high, moderate, low and very low rainfall regimes (Fig. 3).

The lowest rainfall (36.2 mm) is recorded at Aruppukottai station which is located in the western part Madurai district. Its rainfall average 72.7 mm, this season contributes 6.1 % to average annual rainfall.

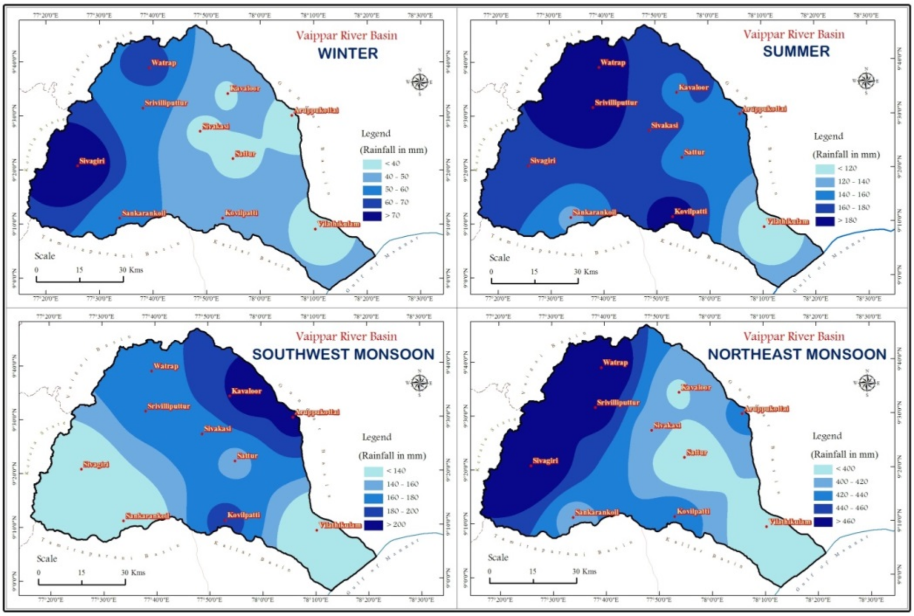

Fig. 3. Seasonal Rainfall map of the study area

Summer Season Rainfall

Hottest weather season and the amount of rainfall gradually increase. However, the amount of rainfall occurrence in this season is largely due to convection effect. This season contributes 20.2% of mean annual rainfall in the basin. The maximum rainfall 209.7 mm at Srivilliputtur and minimum (81.2 mm) rainfall gets at Vilathikulam. Northwestern part of upper basin gets high rainfall and lower part of plain region gets very low rainfall in nature.

Southwest Monsoon Season Rainfall

In India the southwest monsoon, rainfall is the most important phenomenon. The southwest monsoon cause heavy rainfall along the west coast and gradually extends its influence to the east and north in Tamilnadu during first week of June, but Tamilnadu state lies on lee side of the Western Ghats does not receive much rain. The study area receives 20.1% of rainfall during this season. During this season the rainfall of different stations within the basin recorded at the lowest (81.2 mm) in Sankarankoil, Vilathikulam (89.1 mm) and Sivagiri (104.2 mm). The highest rainfall recorded in Virudhunagar (229.2 mm), Aruppukottai (210.6 mm) and Kavaloor (199.7 mm). Other stations get moderate rainfall in the southwest monsoon season.

Northeast Monsoon Season Rainfall

The northeast monsoon of October to December is major rainy season in Tamil Nadu, and the state receives bulk of its rainfall during this season. The northeast monsoon gives maximum rainfall for the entire Vaippar basin. This season average rainfall 428.2 mm and it contributes 53.6% of annual average rainfall (Fig.3). Upper part of Watrap, Srivilliputtur and Sivagiri stations get very high rainfall of more than 460 mm. On the other hand Kavaloor, Vilathikulam, Sattur stations get less than 400 mm of rainfall during the season. Other stations get moderate amount of rainfall.

Spatio temporal variation of rainfall in 1981 – 2010

Rainfall characteristics always pose peculiar problem in the tropical and sub-tropical areas, much so in the monsoon region particularly India. The analysis of temporal variation is very useful to identify the nature of rainfall rhythm in a particular region. Vaippar basin is one of the important water sources of southern part of Tamilnadu state, particularly Virudhunagar District.

In the year 1981 (Table 2) the total annual average rainfall of the entire basin is about 974.9 mm. the annual average rainfall is increased in 1,126.6 mm in the year 2010. Aruppukottai, Kavaloor, Kovilpatti, Sattur, Sankarankoil, Sivagiri, Sivakasi, Vilathikulam and Watrap stations get low rainfall in the year 1981 and high rainfall in 2010. On the other hand only two stations get low rainfall in the year 2010 namely, Srivilliputur and Virudhunagar. From the figure.4 indicates the temporal change of rainfall in the year 1981 – 2010. The change between these two time points very little. Srivilliputur area gets very low rainfall this is the indication of deforestation activities increased in the region.

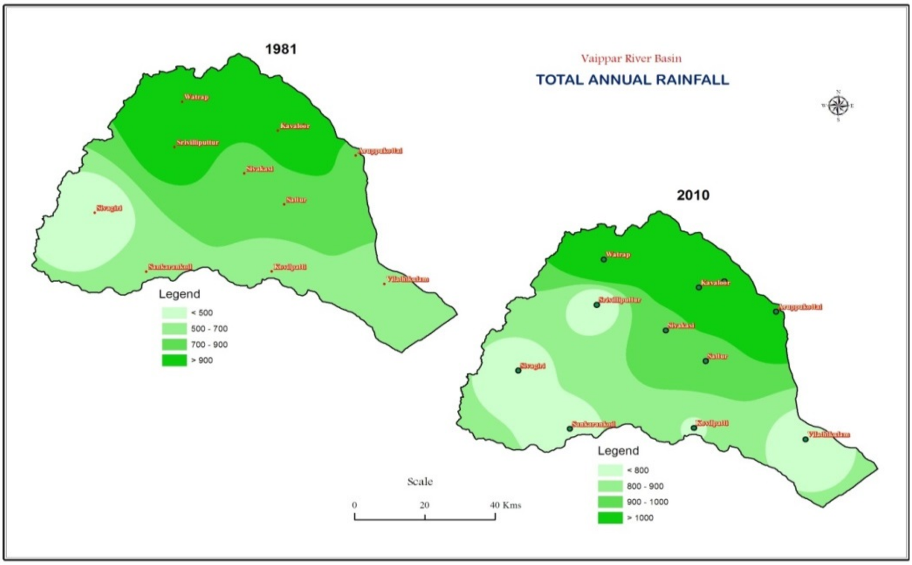

Fig 4. Spatio-Temporal variation of Rainfall in the study area

Table 2: Spatio - Temporal Variation of Rainfall

S.No	Station Name	1981	2010
1	Aruppukottai	845.7	1160
2	Kavaloor	883.7	1189.3
3	Kovilpatti	498.2	786
4	Sankarankoil	538.1	748
5	Sattur	806	935.7
6	Sivagiri	152	745.4
7	Sivakasi	768	933
8	Srivilliputtur	1139.8	630.5
9	Vilathikulam	570.2	700.5
10	Virudhunagar	1384.3	1229.3
11	Watrap	1156.7	1325
	Total	**10723.7**	**12392.7**
	Average	**974.9**	**1126.6**

Conclusion

The study on spatio-temporal analysis of rainfall distribution in Vaippar River Basin using GIS techniques concludes that, the northern parts of the basin gets high rainfall and middle part gets moderate rainfall and low rainfall noticed in south, southwest and southeast region between two time points. The following are the key points of the study: (a) the study area has different topography such as hilly region in north, northwest and west and plain region is identified in lower part of the basin; (b) Long term annual average rainfall increase from southeast to northwest direction of the basin; (c) Vilathikulam station gets low rainfall in all seasons. Watrap station gets more rainfall in all seasons except southwest monsoon; (d) Winter, summer and northeast monsoon increasing direction is similar except southwest monsoon; (e) Central and western parts get low rainfall, whereas the north and southern parts get high rainfall and eastern parts gets moderate rainfall; (f) The rainfall is very high in hilly areas such as Srivilliputtur forest and Watrap forest of Vaippar basin.

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Archives - 1

HINDU COLONISATION IN THE EAST

from The Madras (Indian) Geographical Journal

(Volume X, 1935 -1936, pp.43-48)

Under the auspices of the Madras Geographical Association, Prof. K. A. Nilakanta Sastri. Professor of History and Archaeology in the University of Madras, delivered on the 20th February 1935 a lecture on “Hindu Colonisation in the East," in the University Geography Department, Wesley College, Royapettah. Prof. V. Rangachariar, Professor of History, and Presidency College was in the chair.

Mr. Nilakanta Sastri said that the study of the subject of Hindu colonisation in the east was making very rapid progress; the part of South India in this great movement was important and it should be of very especial interest to South Indians. The first knowledge of these things in modern times might be said to have started from beginning of the 19th century; Col. Mackenzie, who held high offices in India and who did so much for the collection and preservation of antiquities of South India found himself in Java for some times and as in South India he brought together a large number of interesting records bearing on the history and monument s of Java. The first systematic work in modern times on the eastern lands is no doubt the great history of Java by Sir Stamford Raffles. Not much advance was made on these early beginnings till towards the commencement of the present century, when the Dutch govern of the East Indies and the French Government of Indo-China took up very earnestly the study of the ancient remains of Hindu civilisation in these lands. In fact it was one of the curiosities of history of archaeology that while in 1905 the Indian Archaeology department was the envy of the French and Dutch government, to-day the tables might be said to have been turned. To some extent that was inevitable because India is a vast country systematic work in this great sub-continent on archaeological Research and publication must have always been difficult and expensive; and it has been rather slow and not sufficiently systematic because neither the people nor the Government have sufficiently realised the importance of the part that archaeology plays in the reconstruction of the past in this country. Archaeology has suffered from government attempts at retrenchment. "With the advantage of more compact areas and I should venture to say backed by Governments which have on the whole evinced a better appreciation archaeological studies, the Dutch and French scholars who have been working in the Eastern colonies have produced splendid results in the last 20 or 30 years. It is absolutely impossible for anyone who does not read these reports and journals as they are issued from time to time in the original to form a proper estimate of the great advance that has been made.

"Recent research has pointed out the existence of many-pre-historic contacts between India and those lands. The spread of the Monkhmer races which extend in one stretch from the eastern part of Central India to the eastern coasts of Indo-China is one of the evidences. Then Mr.Hornell who was for sometime the head of the fisheries department in Madras undertook a very interesting study of the designs of boats in the Indian ocean, and he reached very important conclusions from that study which go to show that racial and cultural contacts must have existed from very ancient times between the eastern coast of South India and the Eastern Archipelago on the one side and Madagascar on the other. It is very difficult for me to set out here the evidence in detail but it seems to me a very sound line of argument. Another scholar, Col. Gerini, has pointed out in a remarkable book how the Malaya peninsula is a sort of greater or outer India in a very literal sense of the term because many place names repeat themselves in the peninsula in almost exactly the same relation as we find them in India. He calls this ‘toponymic mimicry’. The historical beginnings of these colonies are difficult to trace. Ptolemy in the second century calls these lands 'India across the Ganges', and he had considerable knowledge of them. And Gerini's book is one of the most systematic attempts to correct Ptolemy and interpret him in the light of modern geographical knowledge.

"We have also another line of evidence which helps us in fixing the beginnings of this colonisation and that comes from Chinese sources. The historians of China speak of two Hindu kingdoms which they call Pandering, and Fu-nan which must correspond to modern Cambodia. If in the second century A.D. these states were found fully established, then it is evident that the colonisation must have begun in the first few centuries before the Christian era began. More than that regarding the commencement of the movement we are not able to say. A little later, we have the evidence of a beautiful bronze Buddha statue from Celebes. The find is very recent, only about four years or so old. A very learned argument by the Head of the Dutch Archaeological Department in Java, Dr. Bosch, leads him to the conclusion that the statue must have been cast by a sculptor belonging to the school of Amaravati, that is about the 3rd century A.D. I think that the argument is fairly conclusive because the technique of the bronze is almost decisive on this question.

"A little later about the third, fourth and fifth centuries, we have more definite and tangible evidence from inscriptions. It is difficult to decide the sequence of these inscriptions, and a date of out 350 to 450 A.D. would be satisfactory for all of them. They come from such different places as Champa, the East of Borneo and the west of Java.The script of these inscriptions leaves absolutely no doubt either with regard to their age or with regard to their origin. In fact in the period of those inscriptions we are in the full flood of Hindu colonisation; the Hindus have settled themselves in these lands for good and begun to unfold their national life in all the various departments of civilised existence, in sculpture, art, religion, architecture, etc. Fa-hien who accidentally touched on the Sumatran coast has left us a valuable record of what he saw, which again tells us that the land was completely hinduised. It also tells us Buddhism had not attained that importance which it was soon to attain in those lands.

"It is not possible here to give in detail the political history of these lands. The history of Java is in some ways most interesting. After the early inscriptions of Purnavarman, we have evidence from Chinese sources of the existence of Hindu kingdoms both in the east and west of Java. But the great splendour of Javanese history does not begin until we come to the age of Sailendras, a very famous line of kings whose origin and connections have been debated for a long time and is by no means settled yet. They were Buddhist line of rulers and it was under them that that the most celebrated of Javanese monuments, Barabudur came into existence.

“Little was known of Barabudur thirty years ago. Now we have sumptuous descriptions and illustrations of it from the archaeological and architectural points of view. All this work has been done only after the beginning of this century. The sculptors Barabudur must unmistakably have been Hindu sculptors. The Sailendras quickly declined in Java, but the why or the wherefore not known. But soon they are found again ruling in very great power in Sumatra.The recovery of the history of Srivijaya is one the most splendid romances of Indology. Srivijaya seems to have had trade contacts with China, Persia and Eastern African coast. One of the Sailendra monarchs built a monastery at Nalanda the days of Deva Pala Deva. Another built a monastery at Nagapatnam. And the Chola monarchs who were then powerful in the 10^{th} century favoured the foundation of the Buddhist monastery at Negapatnam for the benefit of the people of Sumatra and Java.

"After the fall of the Sailendras, the next great period of Javanese history is the period of the kingdom of Mataram. In this age, at Prambanan, another group of monuments came into existence and these may be called the Barabudur of Javanese Saivism. The next great periods were those of Kadri (1100-1222), Singasari (1222-1292), and lastly Majapahit (1292-1450), which closes the Hindu Javanese history. In the last period at Panataran, another group of monuments came into existence. The Prambanan and the Panataran groups contain sculptures of celebrated Hindu legends in Javanese versions, the Ramayana, the story of Krishna and the Garudeya or the adventures of Garuda.

"If we turn to Indo-China, Kamboja and Champa are the two chief kingdoms. These lands were thoroughly Indian, I won't say that they were Hindu, because Hinduism and Buddhism were inter- mingled in those lands in a way in which they had not mixed in India. In fact in religion, art and in their whole cultural life they were thoroughly Indian. Even their music and their dancing as may be judged from their sculptures are typically Indian in character, and the great poem of Valmiki runs as a connecting strand through the whole."

Proceeding the speaker said that the style of the temples of Java recalls the rathas of Mahabalipuram. Students of South Indian history knew that there is current a story of a Nagi princess in the netherworld being visited by a gifted prince from the earth and their union giving rise to a powerful royal line of rulers. This story also was current in the eastern colonies. "Then we have a good Tamil inscription discovered in the neighbourhood of a Vishnu temple at Takuapa. The fact that that inscription is in Tamil clearly shows that the people from the Tamil land went to those colonies, settled there and built a Vishnu temple. This inscriptio1 shows that the effects of colonisation were real, live and persistent throughout the centuries. In the 11^{th} century, we have an inscription found in Sumatra dated in the Sakaera 1010 corresponding to 1088 A.D. Both these Tamil inscriptions mention the names of well-known merchant guilds of South India. In Siam there said to be in existence court Brahmins who are said to take ceremonial occasions reciting the Akom, and the Akom resembles the Thevaram of South India. In all ways we see the South Indian influences that were at work in those colonies the centuries.

"Trade was one of the chief objects which brought these together and maintained communications among them. China took a prominent part in this trade. The Chinese trade was largest in 11th and 12th centuries, and the articles that were taken to China fell into two classes. First, there were manufactured textiles, cotton, spices and drugs. But more valuable and more embarrassing to the Chinese Government was the trade in articles of luxury, in jewels and precious stones as ebony, ivory, amber, coral, perfumes and rhinoceros horn. The government-monopolised trade sometimes and always tried to regulate it. The trouble was that it led to currency difficulties arising from drain of silver and gold from China. From China porcelain ware, light silk and other articles were imported. One of the most important branches of international l trade was the trade in camphor and the best camphor came from the north of Sumatra."

Concluding the speaker quoted various passages from Ma-huan and Chau Ju-kua depicting the social life of those colonies and those passages clearly indicated that child marriage and sati prevailed among those colonists as much as in India.

In winding up the proceedings of the evening the Chairman, Prof. V. Rangachariar said that the Greater India Society of the North claimed there was some North Indian influences on the customs and manners of life of those colonists and instanced the case of Nalanda and its influences on the monument s at Barabudur. Nalanda was a great centre of the Mahayana Buddhism and this the chairman said played a great part in Barabudur. Great scholars, he said, were not agreed on the exact date of the Indian emigration to those colonies and there was also considerable difference of opinion as to the Indian stock, whether northern or southern, which went and settled in Indo-China. The generality of scholars are agreed on the fact that the emigration should have taken place during the 1^{st}, 2^{nd} or 3^{rd} centuries A.D. and the evidence of one of most interesting discoveries of recent years shows that the Telugu people went to Indo-China. The Chairman referred to the Hindu colonisation in Burma. Evidences in favour of the view that emigration must have taken place during the 2nd or 3rd centuries have been summarised in English publications issued under auspices of the Punjab Historical Society. These monographs gave all the Sanskrit inscriptions. Continuing the Chairman said those colonisations were not due to religious persecutions, militaristic enterprises but were the direct result of business enterprise. The word Champa may give us a clue to the fact that the early emigration should have been from the Chola countries. The Chairman disagreed with the view of Prof. Elliot that the colonists should have come from the western dominions. Concluding the Chairman hoped that the speaker of the evening (Prof. Nilakanta Sastri) would come out with a source book which would give valuable materials on the different aspects of cultural development in the Colonies. Prof. N. Subrahmanyam then proposed a vote of thanks to the Lecturer and the Chairman and the function then came to a close.

PROCEEDINGS OF THE SIXTH CONFERENCE OF THE MADRAS GEOGRAPHICAL ASSOCIATION, SALEM SESSION - MAY, 1936

from The Madras (Indian) Geographical Journal

(Volume XI, July 1936, No.2, pp.69-71)

The Sixth Conference of the Madras Geographical Association was held in the Salem College on the 7th, 8th and 9th May 1936 under the presidency of Mr. B. Rama Rao, M.A., D.I.C., F.G.S.. Director of Geology in Mysore.

The opening session of the Conference commenced at 4 P.M. on Thursday the 7th May 1936 at the spacious assembly hall, before a large gathering of members and visitors. Mr. C. R. Viraraghavacharya, Chairman of the Reception Committee welcomed the delegates and visitors to the Conference with an address. Mr. B. Rama Rao the President-Elect was then formally proposed as President by Prof. V. Rang Acharya (Madras) and the proposition was seconded by Mr.Rao Saheb C. M. Ramachandra Chettiar (Coimbatore) and supported by Mr.T. S. Chandra Chettiar (Ambasamudram). After he was installed in the chair, the President delivered his address. After the Presidential Address was over, Mr. N. Subrahmaanyam, the Secretary of the Association made a statement regarding its working during the past ten years of its existence, referring to the Summer Schools and Refresher Courses held, excursions conducted, original studies and researches made, the Journal published as its organ, etc. He then appealed for the co-operation of all concerned for the success of the Conference and of the Association. Prof. V.Rangacharya then read a paper on'' Salem as the Home of Early Man," after which the Conference rose for the day.

The Second Session began at 4 P.M., on Friday the 8th May, then the following papers were read and discussed :-

(i) The Salem Magnesite Industry by Mr. H. R. Robinson;
(ii) Public Health of Salem District in relation to Environment by Mr. A. J. George; and
(iii) Place-Names of Salem District by Mr. Rao Saheb C. Ramachandra Chettiar.

The Third Session of the Conference met at 8 A.M., on Saturday, the 9th May, when the following papers were read and discussed:-

(i) Forests of Salem District by Mr. S. Raghunadha Rao, and
(ii) Population of Salem District by Mr. K. Srinivruraghavan.

The Concluding Session of the Conference commenced at 2 P.M. on the same day, when Mr. N. Subrahmanyam read a paper the Communication-lines and Town-sites of

Salem District. After it was discussed, the following papers were taken as read for want of time :-

(i) The Physiography of Salem District by Mr. K. S. Chandrasekharan ;
(ii) The Geology of Salem District by Mr. P. Sridhara Rao
(iii) The Meteorology of Salem District by Mr. C. K. Anantasubrahmanyam;
(iv) The Agricultural Geography of Salem District by Mr. N. R. SundaramAyyar ;
(v) The Cattle of Salem District by Mr. R. W. Littlewood
(vi) The Urban Geography of Salem by Mr. R. Dann ;
(vii) Salem and Other Towns of the Tamil Region by Mr. M. Thirunarayanan ; and
(viii) The Shevaroys Region by Mr. V. Natarajan.

The President then delivered his concluding address, in course of which he said :- "Several interesting papers of varied interest have been read at this Conference during the last three days ; and many experts have dealt with several important aspect of the Geography of the Salem District. I was personally much interested in the paper on the Magnetite Industry as well as some others; and all the papers were very interesting even to me, an outsider. I thank the authors of them all for having contributed in no small measure to the success of this Geographical Conference. I am also thankful to the Reception Committee and the S.I.T U, for enabling this session to be held here."

Mr. C. R. Viraraghavacharya, the Chairman of the Reception Committee, in proposing vote of thanks, spoke as follows :-"We are under a deep debt of gratitude to Mr. B. Rama Rao for having graced this occasion by readily consenting to preside over this conference in such a successful manner . It is really very kind of him to have chosen to exchange the pleasant weather of Bangalore for the last three days for the scorching heat of Salem. It is his great academic interest and goodness of heart that have made him so. I have great pleasure in proposing a hearty vote of thanks Mr. Rama Rao for so ably conducting the Sixth Geographical conference to success.

“In this connection let me also couple the name of Mr. N. Subrahmanyam, the very heart and soul of the Madras Geographical Association, to whose dynamic energy the success of this Conference’s in no small measure due. In spite of his selfless work for the last ten years, Geography has not yet been given the place that deserves in the educational systems of South India. I fear that people in this country have not yet realised the importance of the subject. Still, even the present position of it in the S.S.L.C. Scheme and the University is the result of his persistent activities. The thanks of all lovers of Geography are due to him for all this work as well as for the successful organisation of this Conference."

In proposing a vote of thanks on behalf of the Association, Mr. N. Subrahmanyam, the Secretary spoke at some length on the nature and scope of Modern Geography and its position abroad; and then appealed to all the teachers of Geography to join the Association in large numbers and help to strengthen it, so that they might themselves reap the fruit thereof. He then said:-" Let me thank the ever-vigilant Chairman of the Reception

Committee, Mr. C. R. Viraraghavacharya, and its energetic Secretary Mr. D. J. E. Collins as well as the whole Committee for making excellent arrangements for the comfort and convenience of the President and delegates during the past three days. We are also thankful to the General Secretary of the S.I.T.U. Conference Mr. A. V.Sundaresan, who co-operated with the Reception Committee in the general arrangements of the Conference.

On behalf of the delegates, Mr. K. N. PasupathiIyer (Kurnool) , thanked the Reception Committee for all the arrangements made by them for the convenience of the delegates, and suggested that in organising future Conferences steps may be taken to avoid overlapping of meetings so that it may be possible for delegates to attend all the important functions and meetings connected with the several Conferences, that were conducted side by side.

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News and Notes

THE INDIAN GEOGRAPHICAL SOCIETY

Department of Geography, University of Madras, Chennai – 600 005

UG & PG Results of 6th Talent Test - 2016

THE IGS FOUNDER PROF. N. SUBRAHMANYAM AWARD

With the Cash Prize of Rs. 10,000/-

(First Prize: Rs. 5,000/-, Second Prize: Rs. 3,000/-& Third Prize: Rs.2,000)

UG Results of 6th Talent Test - 2016			
Register Number	**Name**	**Institute**	**Rank**
1322Q0004	Jeevitha K.	Department of Geography, Bharathiar University Arts & Science College, Gudalur - 643 212.	**1**
131GE035	Sivaranjani M.	Department of Geography, Nirmala College for Women (Autonomous), Coimbatore – 641 018.	**2**
U13GE034	Seethalakshmi M.	Department of Geography, Government Arts College for Women (Autonomous), Kumbakonam - 612 002.	**3**

PROF. A. RAMESH AWARD

With the Cash Prize of Rs. 15,000/-

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PG Results of 6th Talent Test - 2016			
Register Number	**Name**	**Institute**	**Rank**
B405003	Gowtham V.	Department of Geography, Madurai Kamaraj University, Madurai - 625 021.	**1**
33214404	Vanlalhlupuii C.	Department of Geography, University of Madras, Chepauk, Chennai – 600 005.	**2**
20146803	Sakthivel S.	Department of Geography, Presidency College (Autonomous), Chennai – 600 005.	**3**

Please Note:

1) The Winners are requested to send their passport size photograph, postal address & contact phone number by email (kkumargeo@gmail.com / geobalas@gmail.com)
2) The Winners are requested to make arrangements to attend the award ceremony function being arranged in the *International Conference* on Future Earth Perspectives in South Asia being organised between 05th and 07th February, 2016 at Department of Geography Bharathidasan University, Tiruchirappalli at 3:00 p.m.
3) For any queries kindly contact the Coordinator Dr. K. Kumaraswamy (9442157347) / Co-coordinators Dr. G. Bhaskaran (9444414688) or Mr. K. Balasubramani (9944060319)

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WATER BALANCE AND MICRO-CLIMATIC VARIATIONS OF HINDUPUR MUNICIPALITY, ANANTHAPURAMU DISTRICT, ANDHRA PRADESH, INDIA

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Abstract

The water balance elements of Hindupur Municipality has been studied with the mean monthly rainfall and temperature over a period of 50 years using Thornthwaite and Mathur(1955) book keeping procedure. The studies revealed the average annual rainfall is about 583mm, average annual potential evapotranspiration is about 1571mm and average annual actual evapotranspiration is about 771mm. The annual water deficit is 800mm. Climatologically the Hindupur Municipality enjoys dry sub humid type of climate. The total surface water resource is about 22,247,280 m^3. Out of this about 10% is stored in surface tanks, 12.8% is recharged to ground water, 25% is lost in the form of surface run-off, and 52.13% is lost in the form of evaporation and evapotranspiration. The micro climatic studies revealed that there is slight change in the decadal rainfall from 1901 to 2009. There is increase in the temperature by 1^0 to 2^0 in the Hindupur Municipality. Slight changes are found in relative humidity and wind speed in the Hindupur Municipality. The study reveals that micro climatic changes are found only in temperature increase by 1^0 to 2^0 in Hindupur Municipality.

Keywords: Water balance, potential evapotranspiration, actual evapotranspiration, water deficit, water surplus

Introduction

Water balance is the study of water input in the form of precipitation and water loss in the form of evaporation and evapotranspiration. It is an applied climatology to identify the water surplus and water deficit zones on monthly, seasonal and annual basis. Urban climatic studies are important to understand the microclimatic changes taking place due to change in the land uses, increased metallic roads and depletion of vegetation cover. The studies on water balance at regional, basin and state level are carried out by Hemamalini (1979), Subrahmanyam (1982), Madhuramma (1992), Suresh Babu (1993), Sambasiva Rao (1984, 1986, 2002, 2005 & 2012), Samuel Raju (1996), Ravindra (2013) and Somanna (2013).

Study Area

Hindupur Municipality covers an area of about 3816 hectares. As per 2011 census Hindupur Municipality had a population of 1,51,677. Males constitute of 51% of population and Female constitute 49% of population. The average literacy rate is 62%, which is higher than the national average of 59.5%. The male literacy rate is 69% and female literacy rate is 55%. Hindupur is constituted as Grade – III Municipality in 1920. It has been upgraded as Grade –II Municipality in 1952, and Grade – I Municipality in 1970, Hindupur has been upgraded to special grade municipality by merger of six panchayats in 1989. There are about 30 wards in the Hindupur Municipality.

The municipality is located at 13°50' N latitude and 77°30' longitude at an altitude of 624 meters above mean sea level. The broad gauge section of Southwestern Railway connecting the Bangalore and Hyderabad. The municipality receives an average rainfall of about 577 millimeters. The mean maximum temperature of about 42°C is recorded in the month of May and the mean minimum temperature of about 15°C is recorded in the month of December & January. The Hindupur Municipality experiences dry sub humid type of climate.

The main objectives of the study are to describe the water balance at monthly, seasonal and annual basis; to assess the water balance andto bring out the microclimatic variations if any, in the Hindupur Municipality.

Methodology

The data pertaining to mean monthly rainfall, temperature, humidity and wind speed are collected for the Hindupur Municipality from the Indian Meteorological Department (IMD), Pune over a period of 50 years. Basing on the mean monthly rainfall and temperature the water balance elements like potential evapotranspiration, actual evapotranspiration are worked out using Thornthwaite and Mathur (1995) water balance formula and book keeping procedure. The relative increase or decrease in rainfall, temperature, humidity and wind speed is worked out for the last 50 years taking maximum, minimum and average values of rainfall, temperature, humidity and wind speed. Basing on the values of relative increase or decrease the changes in micro climate of the Hindupur Municipality are discussed.

Results

Water Balance of the Hindupur Municipality

The water balance elements like potential evapotranspiration (PE), actual evapotranspiration (AE), water deficit (WD), water surplus (WS), moisture adequacy (Ima), aridity index (Ia), and climatic classification are worked out using Thornthwaite and Mather (1955) method taking mean monthly rainfall and mean monthly temperature of Hindupur Municipality over a period of fifty years. The average annual rainfall of Hindupur Municipality is 583 mm. During winter period the municipality receives average rainfall of 7 mm, in summer period of receives 80 mm and during south west monsoon period the average rainfall is 336 mm. In north east monsoon period the average rainfall of Hindupur Municipality is 160 mm. The municipality receives more than 100 mm in September and October months. The rainfall varies from 50 to 100 mm in May, June, July and August months. In January, February, March, April, November and December months the average rainfall is less than 50 mm (Table 1).

The average potential evapotranspiration (PE) varies from 83 mm in January to a maximum of 168 mm in May month. The PE is less than 100 mm in January, November and December months. It varies from 100 to 150 mm in February, March, July, August, September and October months. It exceeds 150 mm in April, May and June months. During winter period the PE is 213 mm. In summer period it is 483 mm. During south west monsoon period the average PE is 565 mm and in north east monsoon period it is 310 mm. The average annual PE of Hindupur Municipality is 1571 mm. The average monthly actual evapotranspiration (AE) varies from 50 mm in March month to 135 mm in September month. The AE is less than 50 mm in January, February, March and April months. It varies from 50 to 100 mm in May, June, July, August, November and December months. It exceeds 100 mm in September and October months. During winter period the AE is 53 mm and in summer period it is 96 mm. During south west monsoon period the AE is 338 mm and in north east monsoon period it is 284 mm. The annual average AE is 771 mm.

The mean monthly water deficit (WD) varies from o mm in September and October months to a maximum of 138 mm in April month. The average WD is less than 50 mm in September, October, November and December months. It varies from 50 to 100 mm in January, June, July and August months. It exceeds 100 mm in February, March, April and May months. During winter period the average WD is 160 mm and in summer period it is 387 mm. During southwest monsoon period the average WD is 227 mm and in northeast monsoon period it is 26 mm. The average annual WD of Hindupur Municipality is 800 mm.

There is no water surplus (WS) in Hindupur Municipality in January, February, March, April, May, June, July, August, October, November and December months. The water surplus of 5 mm is found in September month. The water surplus is nil in winter, summer, southwest monsoon and northeast monsoon period. The annual water surplus is zero. The monthly moisture adequacy (Ima) values vary from 10% in March month to a maximum of 100% in September and October months. The Ima is less than 50% in January, February, March, April, May, June and July months. It vary from 50% to 100% in August, September, October and November months. During winter period the Ima is less than 25% and in summer period it is 20%. During southwest monsoon period the Ima is 60% and in northeast monsoon period the Ima is 92%. The annual Ima is 49%.

The mean monthly Aridity Index (Ia) varies from 0% in September and October months to a maximum of 90% in March month. The Ia value is less than 50% in August, September, November and December months. It excess 50% in January, February, March, April, May, June and July months. During winter period the Ia value is 75% and it is 80% in summer period. During south west monsoon period the Ia value is 40% and it is 8% in northeast monsoon period. The average annual Ia value of Hindupur Municipality is 51%. Climatologically Hindupur Municipality experiences semi-arid type of climate in January, February, March, April, May, June and July months. The municipality enjoys dry sub-humid climate in August, November and December months and wet sub-humid climate in

September and October months. During winter and summer periods the Hindupur Municipality experiences semi-arid type of climate. In south west monsoon period it enjoys dry sub-humid climate and in northeast monsoon period the Hindupur Municipality experiences wet sub-humid type of climate. The annual climatic classification of Hindupur Municipality shows dry sub-humid type of climate.

From the analysis of water balance elements it is found that the Hindupur Municipality receives good rainfall in July, August, September and October months. The water deficit is low in September, October and November and December months. There is water surplus in September month. The monthly moisture adequacy values reveal that July, August, September, October, November and December months are good months for crop culture under natural climatic conditions. The water requirement is high in January, February, March, April, May, June and July months. The analysis of water balance graph reveals (Fig.1) that the Hindupur Municipality experiences water deficit in January, February, March, April, May, June, July, August, November and December months. During September month there is water surplus of 5 mm. The water deficit is very low in November and December months. The soil moisture use is found from January to August months and the soil moisture recharge is found in October, November and December months.

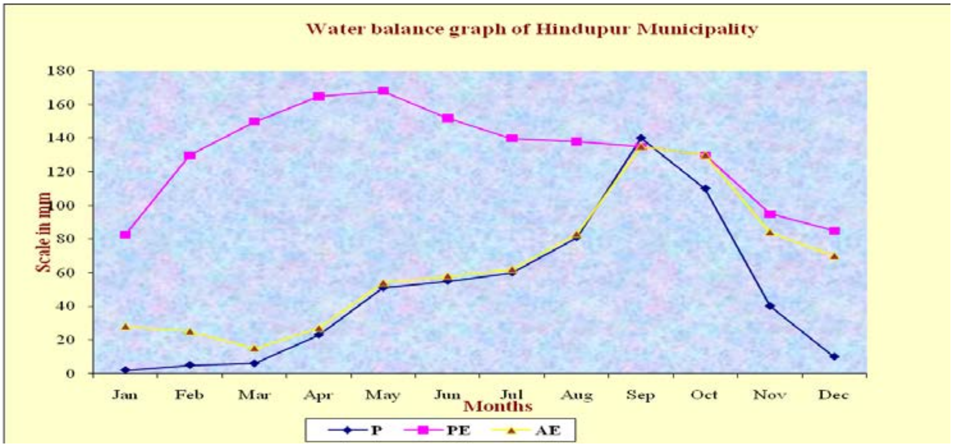

Fig.1 Water Balance

Water Balance of Hindupur Municipality

1. Total surface water resources

   = Average annual rainfall x Geographical area of the Hindupur municipality.

   = 583 mm x 38.16 sq.km

   = 22,247,280 cubic meters

2. Total ground water resources (12.87% of the ground surface water resources)

   = 2,863,225 cubic meters

3. Total water loss due to surface run-off (25% in TSWR)

= 5,561,820 cubic meters

4. Water loss in the form of evaporation and evapotranspiration

   = 13,822,235 cubic meters

In other words out of 22,247,280 cubic meters about 12.7% is recharged to ground water, 25% of the water is lost due to surface run-off and 62.13% is the water loss in the form of evaporation and evapotranspiration. Due to low recharge and high ground water extraction in the Hindupur Municipality the ground water levels have steeply fallen and the people of Hindupur Municipality are going to a depth from 100 to 150 meters for extraction of deep ground water resources through power bore wells. The fallen in shallow water levels varied from 5 to 10 meters during the last 20 years. On the western side of the Hindupur Municipality the fall in shallow ground water levels varies from 5 to 10 meters. On the eastern and southeastern side the fall in ground water level is about 5 meters during the last twenty years. The reason for fall in shallow ground water levels are due to low recharge, high urban sprawl, high population growth of Hindupur Municipality, over extraction of water resources and high water demand. In view of high water shortage the people of Hindupur Municipality collect the water during rainy days from the reinforced concrete roofs to water percolation sumps located in few houses.

Micro – Climatic Variations of Hindupur Municipality

The analysis of mean monthly rainfall (Table 2) indicates that the lowest mean monthly rainfall of 2.3 mm is found in January and the highest mean monthly rainfall of 144.5 mm is found in September month. The rainfall is less the 10 mm in January, February, March and December months. The rainfall varies from 10 mm to 50 mm in April and November months. The mean monthly rainfall ranges from 50 mm to 100 mm in May, June, July and August months. The rainfall exceeds 100 mm in September and October months. The decadal wise rainfall from 1901 to 2009 shows (Table 3) that the mean decadal rainfall varies from a minimum of 426 mm in 1981-90 to a maximum of 650 mm in 1911-20. The average annual decadal rainfall is less than 600 mm in 1921-30, 1931-40, 1941-50, 1961-70, 1971-80 and 1991-2000. The rainfall has exceeded 600 mm in 1901-10, 1911-20 and 2001-2009. The average annual rainfall of hundred years is 583 mm. During 1921-30, 1961-70, 1971-80 and 1981-90 the decadal wise mean rainfall is less than normal rainfall of 583 mm. The analysis of mean decadal rainfall does not show any local micro-climatic variations as the growth of the Hindupur Municipality has taken place. The fall of rainfall in Hindupur Municipality depended upon the monsoons.

The mean monthly temperature in Hindupur Municipality varied from a minimum of 21^0 C in December to a maximum of 30^0 C in April and May months in 1960. During January, February, November and December months the mean temperature is less than 25^0 C (Table 4). In March, July, August, September and October months the temperature varies from 25^0 C to 27^0 C. The mean monthly temperature during 2009 varies from 22^0 C in December month to a maximum of 32^0 C in May month. The mean monthly temperature is less than 25^0 C in January, November and December months. The mean monthly temperature varies from

25^0 C to 28^0 C in February, March, June, July, August, September and October months. The mean monthly temperature has exceeded 30^0 C in April and May months. The increase in temperature from 1960 to 2009 is 1^0 C in January, February, March, April, June, July, August, September, October, November and December months. In month of May the increase in temperature is 2^0 C. In Hindupur Municipality as the urban area has expanded linearly in north-south direction, south-east and western side. The temperature values show an increase of 1^0 C to 2^0 C from 1960 to 2009 due to increase in residential area with reinforced concrete roofs, increase in number of two wheelers, three wheelers, four wheelers and heavy vehicles, increase in vehicular movements, reduction in green cover area and release of more automobile exhaust along the major roads. Thus a micro-climatic variation in Hindupur Municipality is noticed in the increase of temperature from 1^0 C to 2^0 C.

Table 1. Water Balance elements of Hindupur Municipality

Water Balance Elements	J	F	M	A	M	J	J	A	S	O	N	D	Winter	Summer	SW monsoon	NE monsoon	Annual
P	2	5	6	23	51	55	60	81	140	110	40	10	7	80	336	160	583
PE	83	130	150	165	168	152	140	138	135	130	95	85	213	483	565	310	1571
AE	28	25	15	27	54	58	62	83	135	130	84	70	53	96	338	284	771
WD	55	105	135	138	114	94	78	55	0	0	11	15	160	387	227	26	800
WS	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Ima	34	19	10	16	32	38	44	60	100	100	88	82	25	20	60	92	49
Ia	66	81	90	84	68	62	56	40	0	0	12	18	75	80	40	8	51
Climatic Classification	D	D	D	D	D	D	D	C1	C2	C2	C1	C1	D	D	C1	C2	C1

P = Precipitation, PE = Potential evapotranspiration, AE = Actual evapotranspiration, WD = Water deficit, WS = Water Surplus, Ima = Moisture adequacy and IA = Aridity Index, C1 = Dry sub-humid, C2 = Wet sub-humid, D = Semi-arid

Table 2. The mean monthly rainfall of Hindupur Municipality

Sl. No.	Month	Mean monthly rainfall (mm)
1	January	2.3
2	February	5.2
3	March	6.5
4	April	22.6
5	May	60.6
6	June	61.4
7	July	58.8
8	August	92
9	September	144.5
10	October	121.3
11	November	41.8
12	December	9.5

The mean monthly relative Humidity of Hindupur Municipality varies from a minimum of 33% in March month to a maximum of 64% in October month (Table 5). In February, March, April and May months, the relative humidity is less than 50%. The relative humidity varies from 50 to 60% in January, June, November and December months. The relative humidity is more than 60% in July, August, September and October months.

Table 3. Decadal wise mean annual rainfall of Hindupur Municipality

Sl. No.	Decade	Rainfall (in mm)
1	1901-10	609
2	1911-20	650
3	1921-30	579
4	1931-40	590
5	1941-50	588
6	1951-60	611
7	1961-70	566
8	1971-80	577
9	1981-90	426
10	1991-2000	589
11	2001-2009	630

Table 4. The mean monthly temperature in centigrade of Hindupur Municipality

Sl.No	Month	Mean temperature (°C)		Increase in temperature from 1960 to 2009 (°C)
		1960	2009	
1	January	22	23	1
2	February	24	25	1
3	March	27	28	1
4	April	30	31	1
5	May	30	32	2
6	June	27	28	1
7	July	26	27	1
8	August	26	27	1
9	September	26	27	1
10	October	25	26	1
11	November	22	23	1
12	December	21	22	1

The mean monthly wind speed of Hindupur Municipality varies from a minimum of seven kilometers for hour in November and December months to a maximum of 17.5 kilometers per hour (km/hour) in June month. The mean wind speed is less than 10 km/hour in January, February, March, April, October, November and December months. In May and September months the wind speed varies from 10 km/hour to 15 km/hour. The wind speed exceeds 15 km/hour in June, July and August months (Table 6). The high wind speed during June, July and August months is due to dry and cool winds with low moisture flowing from southwest to northeast during southwest monsoon period.

Table 5. The mean monthly Relative Humidity of Hindupur Municipality

Sl. No.	Month	Mean (%)
1	January	52
2	February	40
3	March	33
4	April	36
5	May	45
6	June	57
7	July	62
8	August	62
9	September	63
10	October	64
11	November	58
12	December	55

Table 6. The mean monthly wind speed of Hindupur Municipality

Sl.No.	Month	Mean wind Speed for day (km/hour)
1	January	9
2	February	8.5
3	March	9.5
4	April	9.8
5	May	11.8
6	June	17.5
7	July	17
8	August	17
9	September	12.5
10	October	7.5
11	November	7
12	December	7

Conclusion

From the analysis of water balance elements it is found that the Hindupur Municipality receives good rainfall in July, August, September and October months. The water deficit is low in September, October and November and December months. There is water surplus in September month. The monthly moisture adequacy values reveal that July, August, September, October, November and December months are good months for crop culture under natural climatic conditions. The water requirement is high in January, February, March, April, May, June and July months. The analysis of mean decadal rainfall does not show any local micro-climatic variations as the growth of the Hindupur Municipality has taken place. The fall of rainfall in Hindupur Municipality depended upon the monsoons. The temperature values show an increase between 1^0 C and 2^0 C from 1960 to 2009 due to increase in residential area with reinforced concrete roofs, increase in number of two wheelers, three wheelers, four wheelers and heavy vehicles, increase in vehicular movements, reduction in green cover area and release of more automobile exhaust along the major roads. The mean monthly wind speed of Hindupur Municipality varies from a minimum of seven kilometers for hour in November and December months to a maximum of 17.5 km/hour in June month.

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VULNERABILITY OF FLOOD PRONE COMMUNITIES IN THE LOWER REACHES OF SHILAI RIVER- GHATAL BLOCK, PASCHIM MEDINIPUR, WEST BENGAL

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Abstract

Climate change, an alteration in the state of the climate can be identified by changes in the mean state and/or the variability of its properties and it persists for an extended period of time. Climate change may be due to natural internal processes or external forces. Specifically, local outcomes of climate change are uncertain in the form of frequency, intensity, spatial extent or duration of weather. Climate extremes like heavy precipitation events increase vulnerability and will ultimately lead to increased stress on human and natural systems and a propensity for serious adverse effects in many places around the world. The main topic of concern in this research paper is the changes in extremes of atmospheric weather and climate variables (e.g., temperature and precipitation), large-scale phenomena that are related to these extremes (viz. change in monsoon character) and collateral effects on the physical environment (e.g. floods etc) and human susceptibility. The study area is the Ghatal block located at the lower reaches of Shilai River catchment and administratively is located within Ghatal sub-division of Paschim, Medinipur District of the State of West Bengal. As Ghatal block falls within the Micro-watershed of Shilai River, therefore from the hydrologic point of view, the effect of overland flow rather than the effect of the channel flow is a dominating factor as the channel storage capacity of small watersheds is limited. Moreover a small watershed is very sensitive to high intensity rainfalls of short durations and to land use-changes. The area is very much prone to flood and sediment damage also. The river banks are high and the river itself is narrow here. In winter, water falls very low and is further reduced towards its end by being taken –off for irrigating the spring crops. But in Monsoon the river becomes extremely vulnerable and therefore flooding a huge areal extent. This flooding, through the passage of time is subjected to get affected by climatic variations and they inundate all the low lying areas within the block for a longer period of time during monsoon, which affects the agricultural practices and even to human livelihood pattern. The study will focus on the socio-economic conditions of the local people and ways and methods adopted by them to cope with this vulnerability and their adaptability. It will also focus on the developmental plans taken up by the government and proposal of preparing a framework on flood risk-management plans to combat such increasingly adverse environmental conditions.

***Keywords*:** Vulnerability, Micro-Watershed, Adaptability, Risk-Management

Introduction

Climate-related disaster risk is most adequately depicted, measured, and monitored at the local or micro level (families, communities, individual buildings or production units, etc.) where the actual interaction of hazard and vulnerability are worked out in situ. At the same time, it is accepted that disaster risk construction processes are not limited to specifically local or micro processes but, rather, to diverse environmental, economic, social, and ideological influences whose sources are to be found at scales from the international through to the national, sub-national and local, each potentially in constant flux.

Disaster entails social, economic, or environmental impacts that severely disrupt the normal functioning of affected communities. Extreme weather and climate events will lead to disaster if:

1) Communities are exposed to those events; and
2) Exposure to potentially damaging extreme events is accompanied by a high level of vulnerability (a predisposition for loss and damage).

On the other hand, disasters are also triggered by events that are not extreme in a statistical sense. High exposure and vulnerability levels will transform even some small-scale events into disasters for some affected communities. Recurrent small- or medium-scale events affecting the same communities may lead to serious erosion of its development base and livelihood options, thus increasing vulnerability. The timing (when they occur during the day, month, or year) and sequence (similar events in succession or different events contemporaneously) of such events is often critical to their human impact. The relative importance of the underlying physical and social determinants of disaster risk varies with the scale of the event and the levels of exposure and vulnerability. The potential negative consequences of extreme events can be moderated in important ways (but rarely eliminated completely) by implementing corrective disaster risk management strategies that are reactive, adaptive, and anticipatory, and by sustainable development.

The Intergovernmental Panel on Climate Change (IPCC) 2007, has defined, "Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity." Therefore, vulnerability assessment is the process of identifying, quantifying, and prioritizing (or ranking) the vulnerabilities in a system. Vulnerability from the perspective of disaster management means assessing the threats from potential hazards to the population and to infrastructure. It may be conducted in the political, social, economic or environmental fields.

Study Area

The study area is the Ghatal block located in the lower reaches of Shilai River catchment and administratively is located within Ghatal sub-division of Paschim, Medinipur District of the State of West Bengal. Ghatal block is the severely flood affected area which lies between 22° 35' 5'' and 22° 47' 37''North latitude and 87 °36 ' 22'' to 87° 49'' 8'' East longitude. The study area is situated in lower catchment of the Shilai river, which is originated from Chhtonagpur plateau. The study area has tropical monsoon climate, mean annual rainfall ranges between 250 and 300 mm. Which is concentrated in the months of June – September and the mean annual temperature is 26° C. The soil properties and hydrologic condition are quite suitable for agricultural cultivation. The geographical area of Ghatal block is 229.91 sq km and have 12 panchayat, 156 moujas and 47,758 household (2001). The main objective of the study is to do the socio-economic vulnerability assessment due to climate change in some selected villages. The adaptability measurements and coping strategies of the local people to the regular flood hazards. In-depth analysis of the developmental and risk-management plans to combat such increasingly adverse climatic and environmental conditions and if require, proposal of newer plans.

Source of Information

Multiple databases, including both primary and secondary are required for this research work. The primary data has been obtained based on questionnaire survey, which is concentrated on frequency and duration of flooding, climatic experience of people in last 100-150 years, problems faced by local people during flooding, effect on their livelihood pattern during floods, availability of government aid, healthcare and transport facilities during flooding etc. The secondary data along with their sources are the toposheets from Survey of India, available Satellite images in soft copy format from Geography Department, University of Burdwan; Climatic data (temperature, rainfall) from District Statistical Handbook of Paschim and Medinipur. Other data is from District collectorate office etc. Beside these, numerous books, journals and reports are followed for basic understanding.

Methodology

Various methods are adopted for proper analysis and interpretation of the study area. Based on available multi-seasonal satellite images and ground observation, the changing river course, flood affected areas, landuse-land cover patterns are identified and the landuse-land cover map, drainage map, flood affected mouza maps are prepared for Ghatal block. From the climate data, the rainfall and temperature graphs are prepared from 2005 to 2012 and the years of most variable climate are identified. The river height map during monsoon has also been prepared for last year (2012) to identify the average depth of river compared to the danger level in recent years. Beside these, the problems of flood hazards are identified, socio-economic impacts of flood hazard on local people are analysed along with their coping strategies.

The study area has a tropical monsoon climate, hot summer and well distributed normal rainfall. The year divided into four seasons, the winter season starts about middle of December and continuous till the end of February and summer which extend up to May. The South West monsoon season continuous up to the end of September, October and the first half of November is the post monsoon. The study area have highly effected in monsoon season by flood.

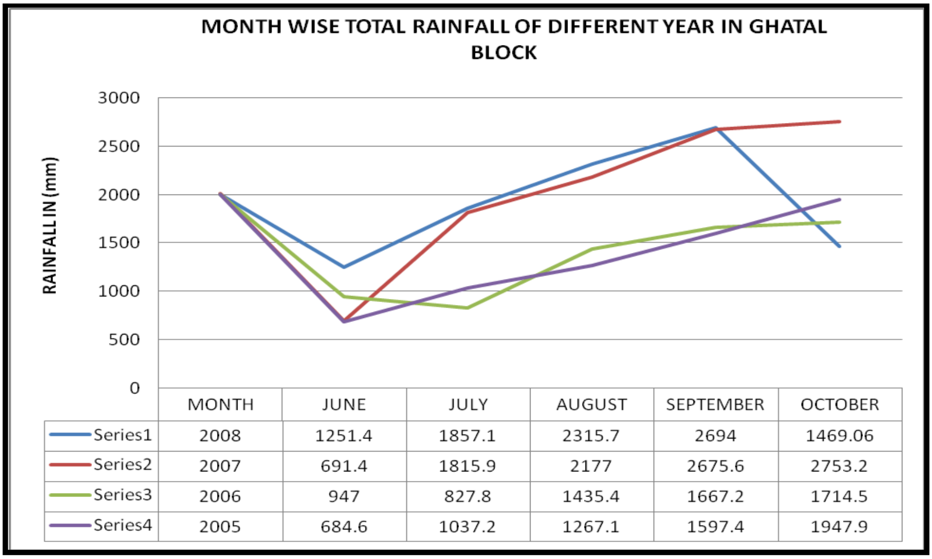

Fig. 1 Month wise total rainfall

Temperature

Temperature rapidly rises about from early March. May is the hottest month with a mean daily temperature 31.7° C. The mean annual temperature is about 28. 92° C. The temperature rapidly decreases appreciably in January when the mean temperature is about 19.7° C, January is the coldest month of the year.

Rainfall

The average annual rainfall is from 250 to 300 mm. Rainfall decreases in the cold weather months of November and December. Considerable amount of monsoon rainfall occurs in association with the movement of Cyclonic depression from the Bay of Bengal. It rains heavily from June to September.

Winds

From about the middle of March a strong breeze begins to blow from the south and continues through the hot weather. After southerly winds have commenced, thunderstorms are considered as frequent features. From the beginning of June these local sea-breezes are replaced by the steadier sea winds of the south west monsoon, which blows till the month of October. This is followed by the short calm lasting till about the middle of the November. The northerly trade wind sets in and lasts generally till about the end of February.

On the basis of rainfall occurrence and consequent gauge height data at river gauge station, the occurrence of floods in Ghatal block is listed up from 2005.

Table 1: Occurrence the Flood Events

Year	Month of Monsoon Time	Cumulative Rainfall of Month In (mm)	Water Level of Silabati River (M.) Gadghat Guage Station	Remarks	Charctertics Of Flood On The Basis Of River Gauge Height
2012	June	409.5	**4.13**	Moderate Flood Occurrence	1.1m-3m= **Low Flood Occurrence**
	July	868.9			3.1m -6 m= **Moderate Flood Occurrence**
	August	1126.9			6.1m-9m= **High Flood occurrence**
	September	1346			9.1m-12m **= Very High Flood Occurrence**
	October	1428.7			
2008	June	1251.40	**8.50**	High Flood Occurrence	
	July	1857.10			
	August	2315.70			
	September	2694.00			
	October	1469.06			
2007	June	691.40	**10.21**	Very High Flood Occurrence	
	July	1815.90			
	August	2177.00			
	September	2675.60			
	October	2753.20			
2006	June	947.00	**8.00**	High Flood Occurrence	
	July	827.80			
	August	1435.40			
	September	1667.20			
	October	1714.50			
2005	June	684.60	**8.17**	High Flood Occurrence	

Ghatal block is a severely flood affected area. In this study area have 12 panchayat, 156 moujas and two municipalities. The historical flood events shows that 10 panchayat and 63 moujas highly flood affected. The flood affected mouzas are shown in the figure 2.

Table 2: Characteristics of River Water Level

Characteristics Of Water Level At Gadghat River Gauge Station	
Preliminary Danger Level	8.88 (m)
Danger level	8.99(m)
Extreme Danger Level	9.60 (m)

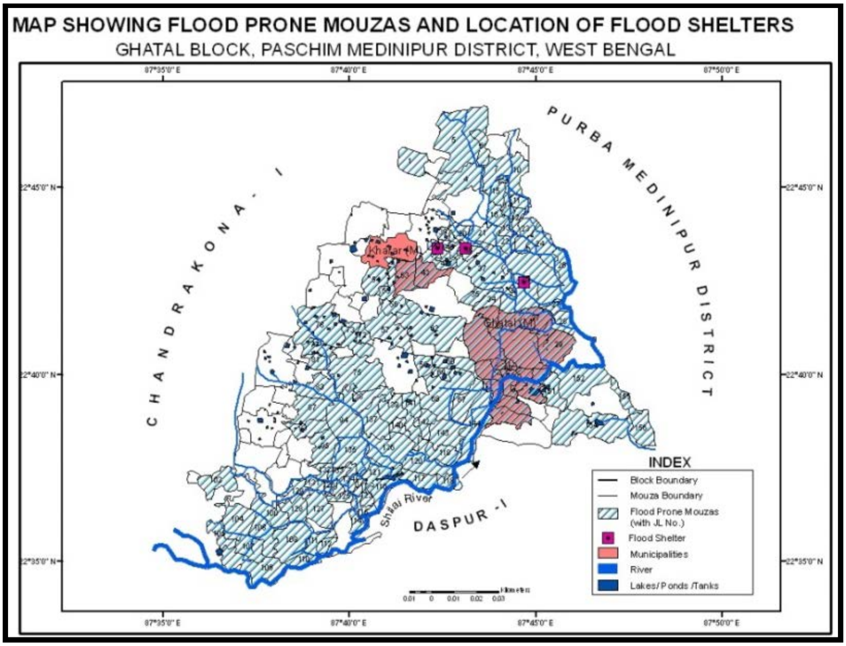

Fig. 2. Flood Prone Zones in the study area

Livelihood pattern of the local people in the study area

Ghatal block is a severe flood prone area. Past records depicts that in every year, flood affects the major portion of the area in monsoon time (June to September). Due to flooding in the lower catchment of Shilai river, water over spilling in the study area and the other causes of flooding are narrow river channel, over sedimentation of channel, higher intensity of runoff, heavy rainfall and very low elevation of flood inundated area. To identify the extent of flood exposure to local people, 100 households are surveyed in Ghatal Block, along both sides of Shilai river, ranging about 100mt from the river bank to beyond 2km reach. Among them 54% people are living within 500m from the Shilai river, 23 % are found within 500m to 2km from the river channel and the rest of 23% respondents are found beyond 2km from the river reach. A more or less similar hazardous scenario is being found all over, only with differential intensity.

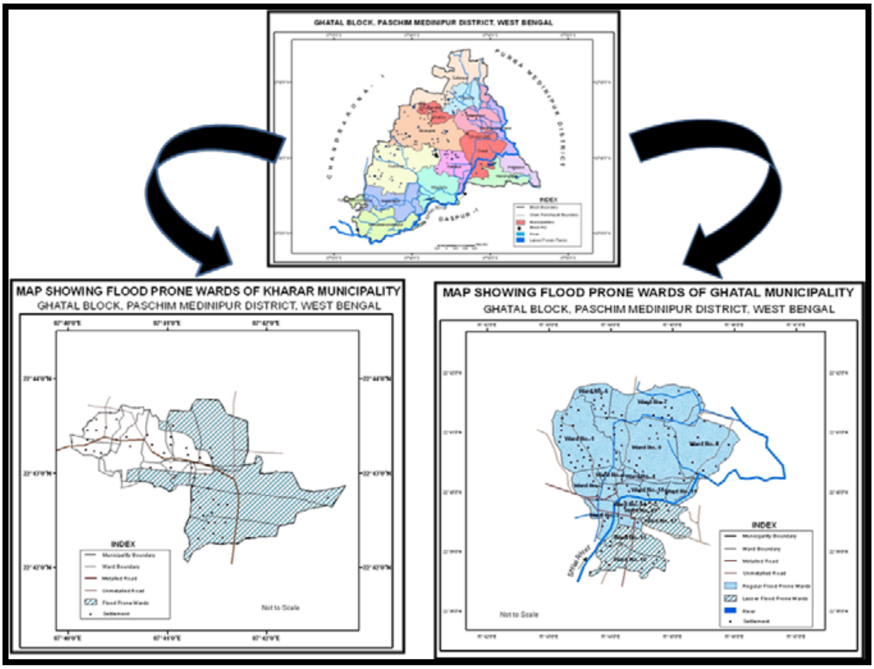

Fig. 3. Flood prone municipalities

Table 3. Location and Distance of Surveyed Households from Shilai River Bank

Total Households surveyed	Left bank respondants (Flood prone area)	Right bank respondants (Less Flood prone area)	≤ 500m from river bank	501 m to 2 km from river bank	> 2 km from river bank
100	81	19	54	23	23

Table 4. Frequency of Monsoon flooding

Total Households surveyed	Not Regularly	Once in a year	Twice in a Year	More than twice	Total Households surveyed
100	9	65	14	12	100

Table 5. Duration of Monsoon Flooding

Total Households surveyed	Not Regularly	Once in a year	Twice in a Year	More than twice	Total Households surveyed
100	9	65	14	12	100

Frequency and Duration of Flooding

Among all the respondents, according to the 65% peoples' consent, they face flood once in every year. They are mostly beyond 500m reach from river channel and about 80ft above of river bed. To them flood is a regular event during monsoon, therefore they have to dodge kharif cropping during monsoon rather are more dependent on rabi crops. It is only 14%, who faces flood twice in a year and 12% experience floods more than twice in a year. These people are actually within 500m of range of the river even sometimes within 100 to 200 m ranges are also found. Only 9% people do not face flood regularly as they are farthest from the river channel. However, whether the flood is frequent or rare, the flooding period also varies widely. According to the local resident, 32% people faces flood for 1 month or slightly less, 35% people experience 8-15 days flood inundation, 28% has the suffering of less than 7 days. But conspicuously the people nearest to the river faces more than 1 month of flooding which accounts for only 5% people. There is a great variability of rainfall pattern in recent years which has its influence on the extremity of flooding in Ghatal block.

Agricultural Activities

Occupancy of Land: The case study has been thoroughly prepared by household survey throughout Ghatal blocks. People have varying amount of availability of farmland. While 30% people are not at all dependent on the cultivation the rest 70% are directly or indirectly involved with this agricultural practice. Among them 30% having near about 1 acres (more than 2.5 bighas) of land each, 19% having 1 bigha to 2.5 bigha of farmland and 21% having less than 1 bigha of farmland.

Type of Farmland: Moreover, a conspicuous feature of these farmlands are that all these lands are double cropland but due to regular flooding, only 73% people can afford this double cropping while only 27% people has to depend on single season cropping, mostly on vegetables in winter months. Some people also cultivate boro paddy in their fields.

Table 6: Characteristics of Farmland in Ghatal Block

Households depend on Single Cropping	Households depend on Double Cropping	Area of Single cropping (in %)	Area of double cropping (in %)
19	51	27%	73%

Table 7: Source of seeds

Households depend on Single Cropping	Households depend on Double Cropping	Area of Single cropping (in %)	Area of double cropping (in %)
19	51	27%	73%

Source of Seeds: As the region is very much vulnerable to flood hazard, therefore the landowners and cultivators have to take special caution regarding storage of seeds. It is found that majority of them about 56% people generally buy the seeds from open market and store it, while 27% has their own storage from the farmland . Only 17% people have to depend on both the open market and their own storage.

Availability of Irrigation Water: Due to the flooding in monsoon people has to depend majority on rabi and zayed cultivation, they have to arrange for irrigation water. There are number of irrigation practices like 47% cultivators are dependent on River Lift irrigation, 24% from Mini shallow tubewell and 3% from pumping from pond and rest of them uses a combination of deep, shallow tubewell or canal and river lift irrigation etc. It is found that the agriculture in Ghatal block during non-monsoon period is totally dependent on irrigational practice and which is a success even under the threat of flood as a regular event.

Table 8: Source of Irrigation Water

Total Households Having Irrigational Facilities	River Lift Irrigation	Mini shallow Tubewell	Pumping from Pond	Canal & Mini Shallow tubewell	Deep and Mini shallow Tubewell	River lift irrigation and mini shallow tubewell	Pond and mini shallow tubewell	River lift irrigation, Canal and mini shallow tubewell
70	33 (47%)	17 (24%)	2 (3%)	2 (3%)	10 (14%)	2 (3%)	2 (3%)	2 (3%)

Table 9: Types of Domestic Animal and Their Usage

People having Domestic Animals	People have Cow	**People have Cow and Goat**	**People have Cow and Duck**	People have domestic usage	People has selling purpose
51	45 (90%)	3 (5%)	3 (5%)	46 (90%)	5 (10%)

Domestic Animals and Their Usage

Out of total surveyed people 51% of them have their own domestic animals. All of them have cows, 5% have both cows and goats while another 5% have cows and ducks. It is being found that 90% people domestically use their animal while 10% has a motive to sell those as per requirement. However it is found that during flood, animals are shifted to higher lands and if they are felt ill, the owners avail doctors for their treatment. The case of death of animals during floods have also taken place but to a very little extent.

Source of Drinking Water

As the region is vulnerable to flood, therefore people have to assure the access of safe drinking water during flooding also. Most of the population is served by municipal tap water in Ghatal town; about 30% town people are dependent on this. In other parts of the block, 18% people have the access of tubewell, 12% have sub-mersible pump etc. The rest of the people use ponds, river water, combination of tubewell-tapwater etc for domestic purposes. During monsoon, people dependent on ponds, rivers has to cross a long path even to other villages also to get access of tubewell water.

Table 10: Source of Drinking water During Flood

Tapwater	Tubewell	River and Tapwater	Tubewell and Tapwater	Tubewell and pond	Sub mersible pump
30%	18%	7%	21%	12%	12%

Table 11: How long Surveyed families are residing

<20 years	20-50years	50-100 years	>100 years
2%	14%	19%	65%

Demographic Pattern

The people are found in both left and right bank of the Shilai River, however the left bank people are more flood prone compared to the right bank residents. The area has a very high density of population about 883 persons/ sqkm area. Majority of people are residing from a very early period in this region. About 65% people are the permanent residents who are living with their family for last 100 years or more, about 19% people residing here for about 50-100years, about 14% people are staying there only for 20-50 years and only 2% people are the local resident for less than 20 years. Therefore a huge section of the population has experienced the climate change and the resultant recurring floods over a longer passage of time.

Moreover the age structure has a proportional shape with high working age population and low child and old age population. But in case of gender profile the region shows backwardness, as the sex ratio is only 852, which is much less than the national standard, even to district standard. With such a demographic profile the local community faces the regular flood occurrence from very early stages and has tried to cope up with their vulnerable conditions.

Table 12: The Age and Sex Structure of the people among the Surveyed Household

<25 years	25-50 years	>50 years	Male	Female	Children below 12 years of age (male +Female)
6%	40%	54%	54%	46%	20%

Vulnerability Assessment of Flooding in Ghatal Block

According to the local people, the vulnerability of the flood in local areas has aggravated the situation especially due to slow but continuous change-over of the climatic variables for past a few years. In addition, various other dimensions have identified by the local people as well as district planners as the causes of local flood. These are:

- Heavy precipitation and release of reservoir water increases the intensity of floods.
- The continuous sedimentation on the river bed reduces the depth of the channel flow.
- Shifting of the river –course increases the vulnerability of flood hazard.
- Bank erosion causes is another important factor of flooding.
- Moreover flows above risk level create the possibility of devastating flood as a whole.

Effects of Flooding on Farmland

Due to the flooding, farmers generally avoid monsoon season (kharif crop) cultivation as the farmlands are inundated for long. But they have found out a good resultant effect of this flood on their farmland. About 30% of them agreed that such flood causes sedimentation increase in their land which in next cropping season helps them to increase the productivity of their land. About 47% people are in the consent of about crop loss as well as sedimentation increase. Only 13% depicts that there is a regular yearly productivity reduction and only 10% agrees to have their fields being damaged by this flood occurrence. Therefore the farmlands, though they are multi-cropping lands, are generally being used for single cropping or sometimes double cropping except monsoon.

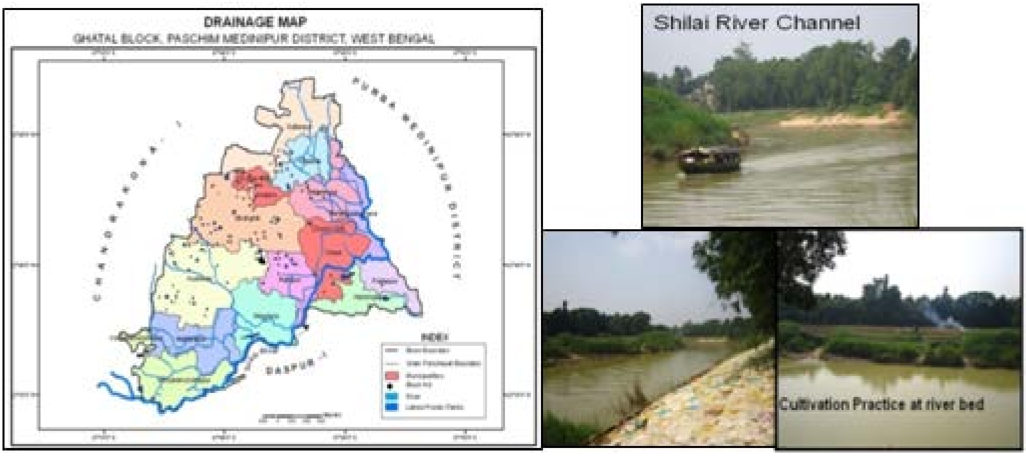

Fig.4 Study Area

Table 13: Peoples' Perception Regarding The Effects of Flood on Farmland

Sedimentation Increase	Croploss and sedimentation Increase	Field damage and Croploss	Reduction of Yearly production
30%	47%	10%	13%

Table 14: Peoples' Perception Regarding The Effects on Fish Cultivation

People Having Ponds	Compelled to catch fishes before monsoon	Loss of fishes & fish death	Cleanliness of water and inflow of fishes from over-spilling of pond
56%	50%	8%	42%

Effect on fish-cultivation

Among the surveyed people, only 56% having the ponds for fish cultivation. Due to flooding they are bound to adopt a number of measures to protect their fishes. About 50% people are compelled to catch the fishes before monsoon as there is the possibility of loss of fishes as well as loss on productivity. Even 8% has the say that sometimes they are unable to save their fishes and has to face the fish death in this period. Only 42% people accept the idea of cleanliness of water during flooding and rapid inflow of fishes from others pond or even from canals etc.

Effect on Houses

During the flooding period the local residents face a lot of problems in terms of housing condition. As most of the houses in rural sides are kutchha, therefore these houses are most intensely affected by the flood. Beside this, the Pakka houses are also get damaged due to long inundation period. Therefore the people have to bear the burden of reconstruction and renovation almost regularly. If the flood situation reaches to the extreme vulnerable then only people shifts from their home to some other areas. However only 16% people generally shifts to some other places due to extreme flooding.

Effects on drinking water availability:

The people residing in the very proximity of Shilai river, generally face more problems in accessing drinking water during flooding. 23% people in the Ghatal municipality depends on municipal tap water all round the year, but about 54% people depends on local tubewell, which during flooding get inundated. Therefore the people have to move to distant areas to access other tubewells even in unhygienic means. Only 23% people, mostly in the town areas confirm that they do not face any problem in accessing drinking water even through flood days.

Table 15: Peoples' Perception Regarding Drinking Water Availability During Flood

Municipal Tap water Availability	Nearly /Distant Tube well (Sometimes Unhygienic)	No Problems Faced because of having own tap or tube well
23%	54%	23%

Table 16: Peoples' Perception Regarding Effects on Sanitation During Flood

Use of home Latrine	Move to Community Latrine at distance	Open Latrine
53%	42%	5%

Effects on Sanitation

Although 95% people has the access of home latrines considering rural and town areas, it is only 53% people who can access those during flood times, the rest 42% has to move to far distant places as all latrines outside their house are inundated during floods. Moreover the pakka drainage facilities are only visible in the town areas, though the houses near the river channel faces the prolong inundation due to flooding.

Effects on Health

The prolonged occurrence of flood causes severe health problems to local residents. The most common form of illness due to flooding is Diarrhoea. Beside this, Cholera, food poison, other water borne disease and even snake bite is very common in the flood affected localities. About 42% people are prone to diarrhea and cholera during flooding, moreover in earlier days due to unavailability of doctors people even died.

Table 17: People Face Health Problems During Flood

Diarrhoea and Cholera	Diarrhoea, Cholera and Snake Bite	Diarrhoea, Cholera and Food Poison	Diarrhoea, Cholera and Other Water Bourne Disease
40%	42%	9%	9%

Availability of Healthcare Facilities During Flooding

As the transport facilities are totally hampered during flooding therefore it is very difficult to get access of medical treatment in times of flood hazard. More or less 58% people access municipal hospital, whereas 19% people whose economic condition is a little better access nursing home. It is only 21% people who do not consult with any doctors rather prefer to have medicines consulting with shop-owner or quack doctors. It is only a few about 2% who relies completely on local quacks for remedial of disease at that period.

Table 18: Availability of Healthcare Facilities to People During Flood

Municipal Hospital	Nursing Home	Medicine Shop & treatment from experienced seller	Local Quacks
58%	19%	21%	2%

Effects on Accessing Electricity

About 87% people including rural and urban areas of Ghatal block access electricity. But the intensity of power cut during floods is more or less same. About 55% people face the continuous power cut even for 7-8 days during inundation and use lanterns, only 27% people use chargeable electronic lanterns when flood intensity is less. Only 5% people do not face any sort of power cut problems as they reside in much farthest and higher lands from the river bed.

Table 19: People Face Electricity Problems During Flood

No Power Cut During Regular Flood	Power Cut During Regular Water logging and Usage of lantern	Power Cut During Regular Water logging and Usage of Emergency	No Electricity Line
5%	55%	27%	13%

Effects on Transport and Communication

When the flood condition is very dire in nature, then nothing is available whether public or private transport. Every house in Ghatal block owns Dingi or Donga (Small boats) to communicate to some other places during flood situation. Therefore, the use of those boats, forcible changes of route, use of vans, rickshaws, damage to roads are very common during flood time. Actually bus transport totally stops during flood times. As the region comes out from inundation, it takes some time to get back to normal condition.

Table 20: Distance to Be Covered Regularly By Local People for Education/Occupation

<500m From house	500-2km From house	>2km From House
21%	51%	28%

Table 21: People Access Transport Facilities During Flood

Use of Own Boats	Use of Local Government Boats	Use of neighbour's Boat half the way and Access of Bus/Van For The rest Path
74%	16%	10%

Methods for Combating Flood Hazard

Adaptation to Climate Change

Adaptation in human systems is defined here as the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, it is defined as the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate. In Ghatal block, there is the possibility of flood protection, some ***suggestions*** can be provided for future development. This are summed up below.

- ***Flood Routing***: It is the technique in hydrology to compute the effect of storage on the shape and movement of the flood wave. It is used in establishing height of a flood peak in downstream location in short term flood forecasting, estimating the protection that would result from construction of a reservoir, determining required levee height for flood protection, determining the adequacy of the spillways, predicting the behaviour of the river after a change in channel conditions. It may be divided of two basic types: ***Reservoir Routing & Channel Routing***, The former analyses the effect of reservoir storage on the flood hydrograph while the latter analyses the effect of storage of a specified channel reach on the flood hydrograph.
- ***Flood Design****:* Reservoir, levees, Channel improvements etc are some of the flood control measures. For an economic and efficient design of these measures floods are to be estimated with reasonable accuracy. Design of Culverts, road, rail bridges, drainage works and irrigation diversion works also need a reliable estimate of the flood at the site concerned. A design flood is the flood discharge adopted for the design of a structure after careful consideration of economic and hydrologic factors. As the magnitude of the design flood increases, the capital cost of the structure also increases, but probability of annual damages will decrease. In general, the methods used in the estimation of the design flood can be grouped as : *Envelop curves, empirical flood formula, rational method, unit hydrograph application, frequency analysis* etc.
- ***Channel Improvement****:* Channel improvement is done by deepening, widening straightening lining and cleaning out of vegetation and debris from the river channel these change in the river channel increase the flood conveyance capacity of the river.

Channel improvement is supplemented by bank stabilization by constructing ripraps, dykes or super and planting deep root trees on embankment.

- ***Dredging of Sediment From River Bed:*** The Shilai river has a long history of its development, but since its development to its flow, huge accumulation of sediments are found in the channel bed, specially in the lower reaches. To increase the water carrying capacity of the river, even in the monsoon, the river should be dredged in regular basis.
- ***Construction of Permanent Embankment:*** As the agricultural fields of Ghatal block are very fertile, therefore local people are willing to protect the land from regular flood. Various embankments are found in both left and right bank of the river, but they are of little value as those are temporary in nature. Therefore, permanent embankments, embankment cum road (preferably metalled) are required to control the over-spilling of flood water and consequent damages in roads and in farmland.
- ***River Course Modulation:*** In a meandering river, meander loops impede drainage and retard disposal of flood water. Whenever, the river meanders becomes extremely sharp, they can be straightened by artificially cutting individual or a series of bends. As there are some sharp bends in Shilai River within Ghatal block, therefore for reducing the intensity of flood such measures should be adapted.
- ***Canal Development from River To Field For Irrigation:*** This is another important measure for flood water diversion. Through the construction of canals the flood water can be diverted to the field in the form of irrigation water. This would reduce the intensity of flood and also may reduce the occurrence of unavailability of irrigation water.
- ***Housing Act for Riverbank Dwellers:*** This is another structural measure to be followed by local people. According to the housing act, people should construct their houses at a distance from river bank. This reduces the possibility of house damage, loss of houses, reconstruction, and rehabilitation problem during and after flood occurrence.

Conclusion

Flood in Shilai river is a regular and recurrent phenomenon. It has occurred in the past and will continue to occur in future as well. It is neither possible to totally stop floods nor to completely eliminate flood damages. However, it is possible to minimize the severity of the impact and damage potential. River friendly and multi-pronged measures that are based on scientific understanding of the causes and effects of floods and that recognize the geomorphic importance and environmental value of floods are likely to be more effective, than the existing ‘hard’ engineering measures of flood control.

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SEASONAL VARIATION OF RAINFALL PATTERN IN THENI DISTRICT, TAMILNADU – A GEOSPATIAL ANALYSIS

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Abstract

Rainfall is primary source for water and it is characterized by its amount, intensity and distribution in time. Rainfall is a key factor determining the sustainability and conservation of living species on the earth. The rainfall is an important governing factor in planning the agricultural program for any area. Rainfall has been observed to exhibit large spatial as well as temporal variation and it determines the drought, flood estimation as well as the environmental factors for the particular region. Knowledge of distribution of the precipitation in time and space will enable to design better rainfall-runoff models and to forecast floods to improve flood response and mitigation measures. The rainfall distribution of India is uneven and varies considerably from region to region, season to season and year to year. India is a tropical country. In its agricultural planning and utilization water depends on monsoon rainfall. More than 75% of rainfall occurs during monsoon and the reliability of monsoon is also doubtful. In such a situation knowledge about spatial and seasonal pattern of normal rainfall helps are to be prepared for time of scanty or bounty rain. Theni District lies in eastern slope of Western Ghats. The district was bifurcated from Madurai District in the year 1996. The district had five Taluks, eight Blocks and 28 urban centres as per 2001 census. The GIS technologies nowadays occupy a prominent place among the modern computer tools and constitute an invaluable support in the solving of problems with a spatial dimension. Keeping this in mind the paper aims to identify and analyse the seasonal variation of rainfall pattern in Theni District with using Arc GIS environment.

Key words: Season, Rainfall Variation, Theni District, GIS

Introduction

The World Water Council gives this description of the importance of water for life: "Water is life. All living organisms are predominantly made of water: human beings about 60%, fish about 80%, plants between 80% and 90%. Water is necessary for all chemical reactions that occur in living cells (it) is essential for food production and all living ecosystems. Water is very important to life; without water our life cannot move. Availability of quality freshwater is one of the most critical environmental issues of the twenty first century. Rainfall is most important source for fresh water. The characteristics of rainfall vary from place to place, day to day, month to month and also year to year over a wide range. This raises the question: is there an identifiable pattern in these variations, or is the variability purely random. Variability may be defined as a tendency of rainfall to fluctuate around a long-term average (normal) value. It follows that one can consider this variability on several time scales, such as, days, weeks and months, and also on diverse spatial domains, that is, stations, districts or States. As the monsoon is known to be organized spatially on a large scale and is persistent in time for several months, it could be useful to study the data on a few optimal scales. However, the optimal time and space scales for rainfall are unknown and thus one has to accept the data as they are and estimate empirically the existence of patterns. In the present investigation, this is undertaken for the monthly as well as seasonal rainfall data of Theni District.

Study Area

Theni is one of the southern districts of Tamil Nadu State and it is bounded on the north by Dindigul District, on the east by Madurai District, on the south by portions of Virudhunagar District and Idukki District of Kerala State and on the west by Idukki (Kerala). The district administrative headquarters of Theni District is situated at Theni - Allinagaram town. The District lies between 9^o 30’ North to 10^o 15’ North latitude and 77^o 10’ East to 77^o 45’ East longitude. The topography of the district is mostly hilly. Vaigai, Suruli, Varahanadi and Manjalar rivers are flowing in Theni District. The district comprises of two Revenue Divisions viz., Periyakulam and Uthamapalayam, and Five Revenue Taluks, viz., 1.Theni, 2.Periyakulam, 3.Andipatti, 4.Uthamapalayam and 5.Bodinaickanur. There are eight community development (CD) blocks viz., Andipatti, K.Myiladumparai, Periyakulam, Theni, Bodinaickanur, Chinnamanur, Uthamapalayam and Kambam for Rural development and Local administration.

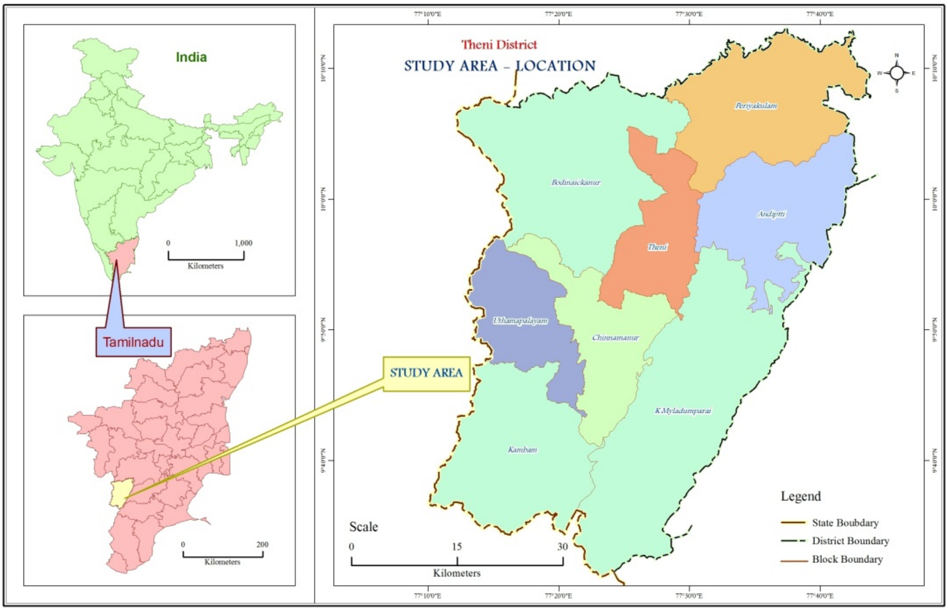

Fig. 1. Location of the study area

Database and Methodology

The objectives of the present study are to study the rainfall pattern, variability of Rainfall and identify the rainfall zones of Theni District of Tamil Nadu. The monthly rainfall data for 30 years (1976 – 2005) have been collected for 9 rain gauge stations which are located in Theni District. The seasonal and annual rainfall has been calculated. The calculated data has been processed and analyzed by preparing various charts, maps and diagrams using GIS software.

Results and Discussion

The study has used the long term (30 years) mean monthly rainfall data for nine raingauge stations, located in Theni District to analyse its various facts. The changing rainfall pattern, and its impact on surface water resources, is an important climatic problem facing society today.

Spatial Pattern of Mean Annual Rainfall

Theni District's 30 year long term mean annual average rainfall is about 743.8 mm. The mean annual rainfall varies from 589 mm to 967.1 mm. It is interesting to note that among 9 raingauge stations the maximum of 967.1 mm rainfall is recorded at Periyakulam followed by Manjalar Dam (857.5 mm). Gudalur receives 831.9 mm rainfall and Andipatti station gets 779.7 mm, whereas the minimum of 589 mm of rainfall is at Veerapandi in central part of the district (Table. 1).

However the western part of Bodinaickanur and southwestern part of Uthamapalayam and Kambam areas receives low rainfall than the average. The southern parts and the northern parts of the district get high rainfall while the central part the district gets moderate amount of rainfall.

Table: 1 Seasonal and Annual Rainfall – 1976 to 2005

S.No	Rain Gauge Station	(Rainfall in mm)				
		Winter	Summer	SW Monsoon	NE Monsoon	Annual
1	Periyakulam	54.8	230.9	199.3	482.1	967.1
2	Vaigai Dam	34.9	126.4	149.2	379.2	689.6
3	Gudalur	27.7	186.9	266.9	350.4	831.9
4	Uthamapalayam	27.6	136.0	144.1	342.7	650.4
5	Bodinaickanur	38.3	148.7	110.3	347.6	644.8
6	Veerapandi	34.1	130.4	98.7	325.9	589.0
7	Andipatti	25.3	150.1	229.5	374.8	779.7
8	Kambam	20.2	151.6	210.2	302.5	684.4
9	Manjalar Dam	48.8	177.2	207.6	423.9	857.5
Mean		**34.6**	**159.8**	**179.5**	**369.9**	**743.8**
Percentage		**4.7**	**21.5**	**24.1**	**49.7**	**100**

Source: Compiled by Author

Rainfall Zones

Based on the average annual Rainfall the district may be divided in to four zones.

1. The very high rainfall zone south of the district
2. High rainfall zone in Kambam valley and Preiyakulam area
3. Moderate rainfall in the eastern part of the district
4. Low rainfall zone in the western and northwestern parts.

Distribution of Seasonal Rainfall

Rainfall is one of the important climatic parameter. It is divided into four well - marked seasons. They are winter (January - February), summer (March - May), southwest monsoon (June - September) and northeast monsoon (October - December).

Winter Season Rainfall

The winter season contributes small amount of rainfall to the annual share. It is the driest among all seasons. In this season rainfall varies from 20.2 mm to 54.8 mm. The winter season gets an average of 34.6 mm rainfall and this season contributes 4.7% to mean annual rainfall (figure 2).

During winter the rainfall is very low in south and east central parts in Andipatti, Uthamapalam, Kambam and Gudalur. It is interesting to note that all these lowest winter rainfall areas record less than 30 mm of rainfall. In general the rainfall increases from south to north direction. Periyakulam and Manjalar Dam areas record very high rainfall during the season. Moderate rainfall is recorded in Vaigai Dam, Veerapandi and Bodinaickanur, while other raingauge stations get moderate rainfall.

Summer Season Rainfall

This is hottest weather season and the amount of rainfall gradually increases. However the amount of rainfall occurrence in this season is largely due to convection effect. This season contributes 21.5% of mean annual rainfall and amounts to 159.8 mm. In this season the highest amount of rainfall is recorded at Periyakulam (230.9 mm) whereas the lowest rainfall is recorded in Vaigai Dam (126.4 mm). The very high rainfall zone occurs to the north of Periyakulam and Manjalar Dam and to the south of Gudalur. Low rainfall occurs in the central part of the district. Figure. 2 clearly indicate the direction of rainfall pattern in summer season.

Southwest Monsoon Season Rainfall

In India the southwest monsoon is very important phenomenon for water resources. In the first week of June, the southwest monsoon cause heavy rainfall along the west coast and gradually extends east and north of entire state but Tamil Nadu located in lee side of Western Ghats does not receive much rain.

During this season the Theni District receives 24% of rainfall. The rainfall of different stations varies between the lowest of 98.7 mm at Veerapandi and the highest in Gudalur. Fig.2 indicates that the distribution of rainfall decreases from south to north in nature. Southern part of the district get more than 250 mm rainfall, Bodinaickanur and Veerapandi areas gets less than 150 mm rainfall during this season. Other parts of the district get moderate rain.

Northeast Monsoon Season Rainfall

The Northeast Monsoon (NEM) is the main rainy season in Tamil Nadu, accounting for 40 - 50% of the annual rainfall in the interior parts and so is much more important in Tamil Nadu than the southwest monsoon. This season extends from October to December and in this season the agricultural activities are more.

In Theni District the northeast monsoon season gets an average of 369.9 mm and it contributes to 49.7% of annual rainfall. The highest rainfall is seen in the northern part and southern part of the district (Fig. 2). The rainfall gradually increases from central to south and north part of the district. The highest rainfall is recorded in Periyakulam (482.1 mm), whereas the lowest rainfall is recorded in Kambam (302.5 mm).

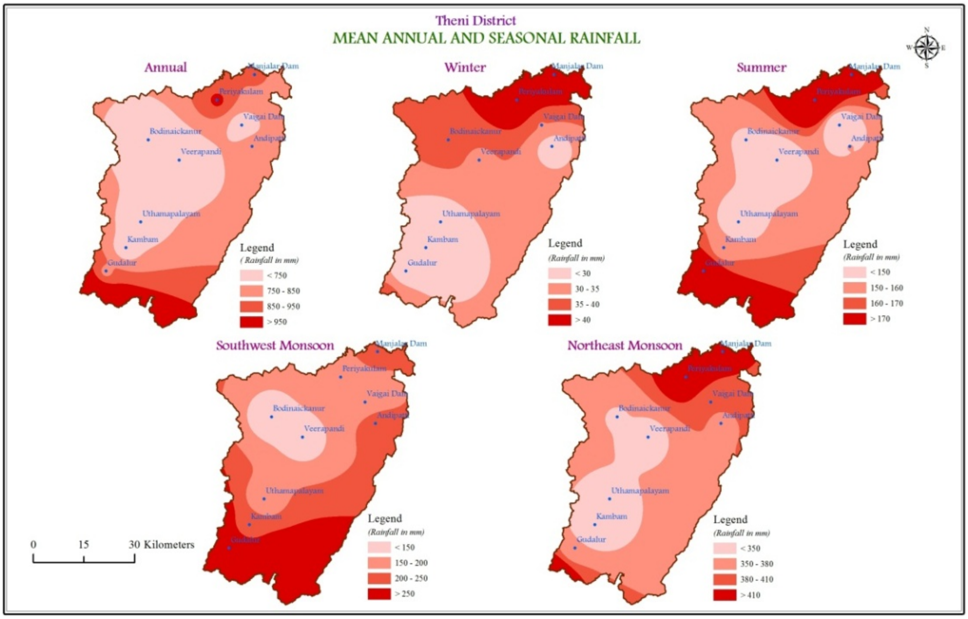

Fig. 2. Mean Annual and Seasonal Rainfall in Theni District

Rainfall Variability

According to Trewartha, the variability of rainfall may be defined as the deviation from the mean or "ratio of the standard deviation to the mean rainfall" and in other words variability of coefficient of variation. It shows the variability of rainfall in percentage. The higher the variability percentage, the lower is the dependability and vice versa. The variability gives the stability of rainfall in the district.

Coefficient of Variability = SD/Mean x 100

Where, SD = Standard Deviation = $\sqrt{\Sigma d2/n}$

The coefficient of variability of rainfall is the standard deviation from the mean expressed as percent of the mean annual rainfall. The isolines have been drawn on the basis of values compiled for 9 stations in order to bring out the spatial pattern (Table. 2).

Table: 2 Seasonal and Annual Rainfall Variability– 1976 to 2005

Sl.No	Station Name	Winter	Summer	SWM	NEM	Total
1	Periyakulam	128.1	46.1	60.8	48.2	27.7
2	Vaigai Dam	132.8	51.4	54.2	63.9	35.5
3	Gudalur	150.5	59.6	63.3	55.8	43.2
4	Uthamapalayam	153.9	65.4	50.9	43.9	31.0
5	Bodinaickanur	125.7	45.3	66.6	49.4	33.8
6	Veerapandi	126.3	59.2	66.1	53.0	38.0
7	Andipatti	186.0	41.9	41.3	54.6	27.9
8	Kambam	155.3	57.1	44.5	41.6	18.8
9	Manjalar Dam	161.2	56.1	56.0	47.8	35.2
	Mean Average	**146.6**	**53.6**	**56.0**	**50.9**	**32.3**

Source: Compiled by Author

Mean Annual Variability

The mean annual variability of the study area is calculated for the nine raingauge stations located in the study area. Coefficient of variability is calculated from the long term mean annual rainfall and standard deviation of the each raingauge station. The annual variability is 32.3% and it varies from 18.8% to 43.2% in the study area.

The low variability (below 30%) is found in the south of Kambam and northern part of Andipatti and Periyakulam in the study area. The variability range of 30 - 33 percentage is found in the central and eastern parts of the district. More than 36 percentage of variability is found in the Veerapandi and Gudalur areas. The mean annual variability is shown in figure. 3.

Summer Rainfall Variability

The summer rainfall variability of the study area is 53.6%. The maximum rainfall variability is recorded at Uthamapalayam (65.4%) and (Table: 3.3) the minimum is recorded at Andipatti (41.9%) (Fig. 3). Below 50 percentage of variability is found in the western part of Periyakulam, Andipatti, and Bodinaickanur region of the study area. The variability is between 50 and 58 percentage occur in the central and southern parts of around Gudalur. The low variability of less than 58% is found in the Uthamapalayam, Kambam and Veerapandi.

Southwest Monsoon Variability

This season will have some variations in rainfall variability due to the influences of southwest monsoon rainfall of India. The rainfall variability of the southwest monsoon is about 56%. The variability of southwest monsoon season varies between 41.3% at Andipatti and 66.6 % at Bodinaickanur. The zone of 50 – 54 percentage of variability is found in south and some areas in the central zone, of the study area.

Northeast Monsoon Variability

The rainfall variability of northeast monsoon resembles almost the characteristics and the general pattern of mean annual rainfall variability. Owing to this nature, the annual rainfall variability reflects characteristics of NW monsoon season rainfall variability. The total variability of the northeast monsoon season is 50.9% and it varies from 41.6 % at Kambam and 63.9 % at Vaigai Dam. Andipatti and Vaigai Dam area have high variability in nature. Low variability occurs in Uthamapalayam and Kambam High Variability occurs in southern part of Theni District, while low variability occurs in northern part of the study area.

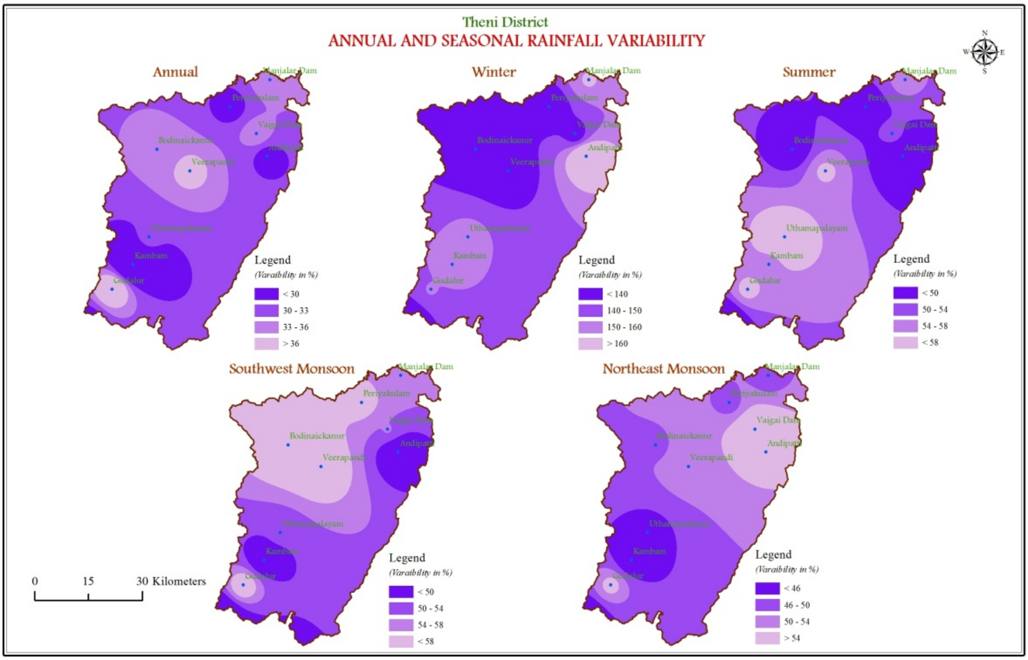

Fig. 3. Annual and Seasonal Variability of Rainfall in Theni District

Conclusion

- The study area has different topography such as Hilly region in south, southeast northwest and north and plain region in central part.

- The entire district can be divided into four zones based on their average annual rainfall distribution.
- Out of all stations Periyakulam, Manjalar Dam and Gudalur are the important stations for high rainfall received zones in the study area
- Veerapandi, Kambam, Uthamapalayam and Bodinaickanur stations get low rain in all seasons
- Central and western parts get low rainfall, whereas the north and southern parts get high rainfall and eastern parts gets moderate rainfall.
- The rainfall variability is very low in hilly areas such as Murugamalai forest of Periyakulam and southern part of Varushanadu hills.
- On the other hand high rainfall variability is noticed in the central plain region.

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IMPACT OF CLIMATIC CHANGES ON THE SUSTAINABLE DEVELOPMENT OF INDIAN ECONOMY

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Abstract

The most vulnerable economies in the world to the climate change are emerging economies. The emerging economies including India seem to have got stuck between growth and green growth. There are different sectors such agriculture, industry, forestry, food and livestock mostly affected by this climate. Indian agriculture, with two-third rain fed area remains vulnerable to various vagaries of monsoon, besides facing occurrence of drought and flood in many parts of the country. Mitigation of climate change in developing countries poses a fundamental challenge. Climate change will aggravate these risks and may considerably affect food security through direct and indirect effects on crops, soils, livestock, fisheries and pests. Building climate resilience and maintaining sustainable development in the economy, therefore is critical. This paper focuses on the impact of climatic changes on the Indian economy and the challenges towards the country to maintain the sustainable development. The paper also suggests the policy initiatives to be taken for maintaining the growth.

***Keywords**:* Vulnerable, Sustainable Development, Globalization

Introduction

Climate change refers to changes beyond the average atmospheric condition that are caused by both by natural factors such as the orbit of earth's revolution, volcanic activities and crustal movements and by artificial factors warming, which refers to the average increase in global temperature has become a megatrend that will lead to significant global changes in the future. The United Nations Frame work Convention on Climate Change (UNFCCC) defines 'Climate change' as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. The major characteristics of climate change include rise in average global temperature, ice cap melting, changes in precipitation and increase in ocean temperature leading to sea level rise. It is primarily caused by the building up of Green house Gas (GHGs) in the atmosphere. GHGs with which are responsible for global warming are both short and long lived.

According to the Intergovernmental Panel on Climate Change (IPCC), the global atmospheric concentrations of CO_2, CH_4, and nitrous oxide (N_2O) have increased markedly as a result of human activities since 1750 and now far exceed pre industrial levels. Climate changes are one of the most important global environmental challenges with implications for food production, water supply, health, energy, etc. It is a potentially catastrophic global externality and one of the world's greatest collective action problems. The distribution of causes and effects is highly uneven across countries and across generations. Enormous uncertainty surrounds existing estimates of future damages that may result from climate change, but these potential damages are to a considerable extent irreversible and may be catastrophic if global warming is unchecked. The objective of the study are: to study the impact of climatic changes on the Indian economy and to suggest the policy framework to meet these challenges.

Impact of Climate change on G20 Emerging Markets (GMEs)

The issue of climate change is now firmly on national and international agendas, subject to scrutiny by public and media, and is even shaping the strategies of a number of businesses. Internationally the UNFCCC (Convention) was set up in 1992 and entered into force in 1994. The convention laid the groundwork for concerted international action, which in 1997 led to the adoption of the Kyoto Protocol containing a legally binding quantitative time-bound target for developed countries.

Some of the fastest growing economies including India and Bangladesh are also the most vulnerable to the effects of climate change, according to new report. The nations at the most extreme risk are those already dealing with high poverty levels, dense population exposure to climate-related events, and a reliance on flood-or drought-prone agricultural lands, according to the climate change vulnerability index compiled by Maplecroft, a UK based consultancy group.

Continues fossil fuel driven growth could leave earth around 40◦C warmer in 2100 than 1990 and sea level 0.5m higher. This would extremely damage the G20 with economic damages possibly causing annual GDP to be 6.0% lower than it otherwise would be by 2010. While the GEMs have already undertaken action against climate change to varying degrees, it is found that accelerating these initiatives will yield further economic and social benefits for themselves and the world as a whole.

Impact of Climate change on Indian Economy

Although India ranks among top five countries in terms of GHGs emissions, its per capita emissions are much lower than those of the developed countries even if historical emissions are excluded. Its high emission is due to large population, geographical size, and economy. The most recent data available for India come from the assessment carried out by the Indian Network for Climate Change Assessment (INCCA) in May 2010. The key results of the assessment are that total net GHG emissions from India in 2007 were 1,727.71 million tons of CO_2 .GHG emissions from energy, industry, agriculture, and waste sectors in 2007 constituted 58 percent , 22 percent , 17 percent and 3 percent of net CO_2 equivalent emissions respectively.

Sustainable development has become a part of all climate change policy discussion at the global level, particularly due to adoption of agenda 21 and the various conventions resulting from the UNCED-1992. Sustainable development has become an integration concept embracing economic, social and environmental issues. It cannot be achieved without significant economic growth in the emerging countries. India has make a remarkable gains so far in sustainable development , as measured , for example , in three summary one is life-expectancy, a rise in forest cover despite of land pressure and literacy among young women, an indicator of future generations well being.

Climate change Threats and Vulnerabilities for India:

- It has enormous implications for the natural resources and livelihoods of the people.
- It will have wide-ranging effects on the environmental and socio-economic and related sectors.
- The INCCA report warns of impacts such as sea-level rise, increase in cyclonic intensity, reduced crop yield in rain-fed crops, stress on livestock, reduction in milk productivity, increased flooding and spread of malaria.
- Any uncertainty in agriculture can considerably affect the food systems and thus increase the vulnerability of a large section of the resource-poor population.
- Reduced water availability, owing to glacier retreat and decreased rainfall, and a growing population will increase water stress.
- India's forests are likely to experience a shift in forest type, adversely impacting associated biodiversity and regional climate dynamics as well as livelihoods based on forest products.
- Health is likely to be adversely affected by climate change. Heat stress, vector-borne diseases, water contamination are some of the projected health impacts of climate change.

Economic reforms implemented since 1991, have resulted in faster growth of the Indian Economy. India has already taken a number of actions on voluntary basis with own resources in pursuance of a sustainable development strategy.

Measures taken in order to maintain the sustainability and reduce the impact of climate change

- India adopted the National Action Plan on Climate Change (NAPCC) in 2008 which has both mitigation and adaption measures. It's a long-term, multi-prolonged and integrated strategies for achieving key goals in context of climate change.
- Through a multi-sector carbon strategy, it decided to reduce emission intensity by 20-25 percent of the 2005 level by 2020. Lower carbon sustainable growth considered as a central element in 12^{th} Five Year Plan.

- Apart from NAPCC, domestic state like Delhi, Gujarat and Haryana were also asked to prepare state-level actions plan to initially reduce the threat of climate change.
- The National Mission for Enhanced Energy Efficiency (NMEEE) considered as a key focus for government action that will cover 700 industrial units and achieve a saving of almost 17000 MWs of energy by 2017.
- The first Ultra-supercritical power plant is expected in 2017 for reducing emission intensity 60 percent of coal based power generating units.
- The Electricity Act 2003, together with National Electricity Power 2005 (NEP) and the Tariff Policy (TP) formulated for promotion of renewable energy resources.
- Up gradation of vehicular emission norms such Bharat Stage II, Bharat Stage III and Bharat Stage IV are the initiatives taken for making transport sector less emission intensive.
- Sustainable Habitat Mission implemented which focuses on energy efficiency in buildings, management of solid waste, public transport, infrastructure, disaster management, warming system for extreme weather events as a part of urban planning.
- Forest cover extended from 23.6% in 2008 to 33% in 2012 (MoFF 2008)

Suggestions

Beside all these actions taken by Indian Government in order to meet the sustainable development. The impact of vulnerability is not decoded by the extent of climate change, but also by the robustness of developmental process in the economy. The poor are the most vulnerable to climate change. Therefore, poverty eradication and improving standard of living will also reduce climate related vulnerability. There is a large population dependent on agriculture for their livelihood in India. Policy needs to be strictly formulating focusing on the improvement of crops, food security and production along with the innovative measure to reduce the uncertainty of climate change. The focus of the policy is unduly prescriptive (using Command and Control approach and less of Market based Instruments), and prevents innovation in systems, procedures and new technologies. There is a need to focus on performance norms to be met in the cost effective way, irrespective of systems, procedures and technologies. This would provide benchmarks for monitoring and enforcement, and also space for innovation. Community action is needed in order to have bargaining capacity and force the regulatory body to response the problem. The choices are more difficult in developing countries because they affect people's livelihoods. Such a 'Sterwardship" to succeed therefore needs to respond to people's needs, share information on choices and costs and ensure participation and ownership.

Conclusion

Global climate change has emerged as a threat to sustainability and serious endangers the Indian economy. It is the quality of development that would provide an insurance against the impacts of climate change and increase the adaptive capacity of the vulnerable. The success of the climate policy may be constraint by the magnitude of the impact of climate change. For a more reliable analysis of climate change impacts, efforts need to be made to develop integrated models consolidating the estimates produced by climate change scenarios, the simulation analysis based to agricultural characteristics, and the economic analysis reflecting the socioeconomic factors of agriculture.

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CLIMATE CHANGE TREND ANALYSIS AND ADAPTATION STRATEGIES IN NORTH CENTRAL ETHIOPIA

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Abstract

Climate change is one of the most important global environmental challenges, with implications for food production, water supply, health, energy, etc. Addressing climate change requires a good scientific understanding as well as coordinated action both at national and global level. Climate change is a key emerging threat to the lives and livelihoods of the rural poor in Ethiopia. Adaptation to climate change is a two-step process, which initially requires the perception that climate is changing and then responding to changes through adaptation. This study was conducted in selected rural kebeles of Bahir Dar Zuria district. The study employed both qualitative and quantitative methodologies and triangulation of data. It tried to show the significance of climate change by using forty-nine years of temperature and rainfall data, which were processed using INSTAT and XLSTAT software, in addition to the socio-economic data collected to assess the perception of farmers. Analysis of the historical climate data and its models in North Central Ethiopia revealed that there has been an increasing trend of maximum and minimum temperature and a general tendency of decrease rainfall. The mean average change of annual temperature indicates significant variations of temperature observations approximately by 1.5^{o}c. On the other hand, the average amount of annual rainfall change indicated by Mann-Kendall trend test and Homogeneity test results of p-value less than alpha=0.05, were significant. The households' interview data analysis also shows that regarding the direction of the change in temperature and rainfall, 78% of the sample households perceived an increase in annual temperature and 66.7% a decreased in annual rainfall. The adaptation methods used include - use of moisture stress resistant crops, changing the management and planting date, irrigation, crop diversification, mixed crop-livestock farming systems, and increased use of water and soil conservation techniques. Therefore, it is concluded that most of the farmers perceived the climate change by their field experience and started adaptation strategies. In this regard, much remains to be done by governmental and none governmental actors to harness the value of indigenous knowledge, to empower and genuinely allow full participation of farmers and to implement environmental sustainability, technological adaptability, adaptation programs and plans.

***Keywords*:** Adaption, Perception, Climate change, Trend analysis

Introduction

According to the Intergovernmental Panel on Climate Change IPCC, (2007), over the past 150 years, the global mean surface temperature has increased by 0.76°C. Global warming has caused greater climatic volatility such as changes in precipitation patterns and increased frequency and intensity of extreme weather events and has led to a rise in mean global sea levels. It is widely believed that climate change is largely the result of anthropogenic greenhouse gas (GHG) emissions and, if no action is taken, it is likely to intensify in the years to come. In Ethiopia, the average minimum and maximum temperatures have been increasing by about 0.25 ^{0}C and 0.1 ^{0}C respectively over the past decade and rainfall has been characterized by a very high level of variability over the past 50 years (NMSA, 2007). The fact that climate has been changing in the past and as trends suggest, may continue to do so in the future, implies the need to understand how farmers perceive climate change in order to guide strategies for adaptation in the future (Admassie and Adenew, 2007; Belay, 2005).

Adaptation to climate change is a two-step process, which initially requires the perception that climate is changing and then responding to new changes. Maddison (2006) addressed this two- step process of adaptation at the regional level for Africa, but results from this study are highly aggregated and hence have little relevance for addressing country specific perceptions and adaptations to climate change. However, it intends to capture the extent of trends of climate, farmers' perceptions, and Adaptation of climate change and the types of adjustments they have made in their farming practices in response to these changes in Bahir Dar Zuria district. Many African countries, which have economies largely based on weather sensitive agriculture, are vulnerable to climate change. The devastating effects of recent flooding and the various prolonged droughts of the twentieth century have demonstrated this vulnerability. Thus, understanding farmers' responses to climatic variations and climate changes are crucial in designing appropriate coping strategies (Yesuf *et al*., 2008). Considering the findings of climate change impacts in other regions of the world, some relevant questions can be asked about climate change in Bahir Dar Zuria district were - trends of climate, farmer's perception, adaptation strategies and the long-term approaches should be recommended to maintain the adaptive mechanisms. The general objective of this study was to assess the trends of climate, the perception of farmers on climate change, and the choice of adaptation methods in crop production systems in order to guide policy makers on ways to promote adaptation. The specific objectives include assessing the trends of climate and the perception of farmers about climate change, to assess choices for adaptation measures that farmers are practicing and to assess the significant adaptation strategies to halt climate change impacts.

Study Area

Bahir Dar Zuria district is located in North Central parts of Ethiopia at a distance of 564 km north-west of the capital Addis Ababa. It is one of the largest towns in the country by population number and socio economic characteristics. It is situated at an altitude ranging from 1700-2300 meters above sea level and has area coverage of 151,119 ha. The area receives an average annual rainfall ranging from 820 to 1250 mm. The minimum and maximum daily temperatures are 10^0C and 32°C respectively. The major crops grown are wheat, barley, millet, teff, dagusa and maize. The area has a total population of 182,730, of which 93,642 are men and 89,088 women (CSA, 2007). Urban inhabitants were not included reported.

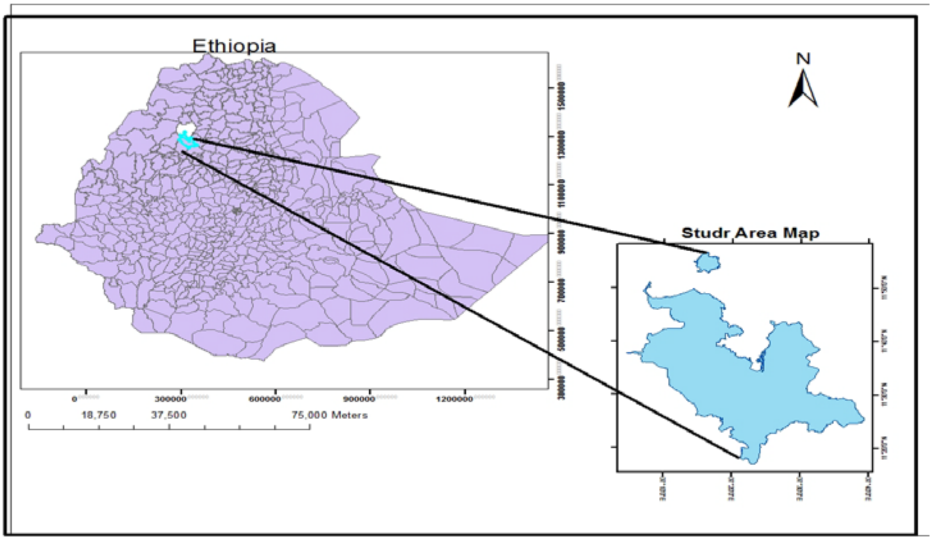

Fig. 1. Location of Bahir Dar Zuria District

Methods

The study employed both qualitative and quantitative methodologies and triangulation of data. It tried to show the significant of climate change trends by using forty-nine years temperature and rainfall data, which were processed and generated climate trend analysis using INSTAT and LEAP software. On the other hand, the socio-economic data were collected from three kebeles (sub-divisions of the district) which were selected purposely due to the rural setings and proximity. These selected kebeles were found approximately about 15 to 20 km from Bahir Dar town. Extension workers of the kebeles and households were randomly selected and primary data were collected by structured questionnaires, interviews and FGDs. Accordingly, a total of 75 households, 25 from each kebele, were participated after clustering of villages and randemizing the samples in the socio economic investigation of the study area. And finally the collected data were processed and analyzed by graphs, tables and percentages and stastically tested by Mann-Kendall trend test and homogeneity test using XLSTAT software.

Trend analysis Test

Precipitation and Temperature data shows a long-term change of data or some pattern changes in the given temporal scale series. XLSTAT software is employed to analyze the trend analysis and to consider seasonal component of precipitation at the same time. Hence, to describe a trend of a time series Mann-kendall trend test is used to see whether there is a decreasing or increasing trend or not. Mannkendall statistics (S) is one of non-parametric statistical test used for detecting trends of climatic variables. It is the most widely used method since it is less sensitive to outliers (extraordinary high values with in time series data) and it is the most robust as well as suitable for detecting trends in precipitation (Gilbert, 1987). Different software such as SPSS and microsoft excel can be used for trend analysis test. However, they are very sensitive to outliers Hence; Mann-Kendall trend test was used to detect the trend and normalized p-value for significant test. The total score for the time-series data is the Mann-Kendall statistic, which is then compared to a critical value, to test whether the trend in rainfall or temperature is increasing, decreasing or if no trend can be determined. Data for performing the Mann-Kendall Analysis should be in time sequential order. The first step is to determine the sign of the difference between consecutive sample results. Sgn(Xj - Xk) is an indicator function that results in the values 1, 0, or –1 according to the sign of Xj - Xk where j > k, the function is calculated as follows.

- $sgn(\mathrm{Xj} - \mathrm{Xk}) = 1 \text{ if } \mathrm{Xj} - \mathrm{Xk} > 0,$
- $sgn(\mathrm{Xj} - \mathrm{Xk}) = 0 \text{ if } \mathrm{Xj} - \mathrm{Xk} = 0$
- $sgn(\mathrm{Xj} - \mathrm{Xk}) = -1 \text{ if } \mathrm{Xj} - \mathrm{Xk} < 0$

Where Xj and Xk are the sequential precipitation or temperature values in months J and K(J > k) respectively whereas; A positive value is an indicator of increasing (upward) trend and a negative value is an indicator of decreasing (downward) trend.

Let X1,X2,X3 Xn represents n data points (Monthly)

Where Xj represents the data point at time J. Then the Mann-Kendall statistics (S) is defined as the sum of the number of positive differences minus the number of negative differences or given by:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+n}^{n} sgn(Xj - Xk)$$

Where $sgn(\mathrm{Xj} - \mathrm{Xk}) = 1 \text{ if } \mathrm{Xj} - \mathrm{Xk} > 0,$
$sgn(\mathrm{Xj} - \mathrm{Xk}) = 0 \text{ if } \mathrm{Xj} - \mathrm{Xk} = 0$
$sgn(\mathrm{Xj} - \mathrm{Xk}) = -1 \text{ if } \mathrm{Xj} - \mathrm{Xk} < 0$

Results and Discussion

After the secondary data was collected from the representative meteorological stations which are found within the study area, the climate trend analysis of the annual maximum temperature, annual minimum temperature, mean average annual temperature and the amount of rainfall were analyzed and interpreted. It is also statistically tested using homogeneity and Mann-Kendall trend test methods. Moreover; the perception of farmers' on the climate change, adaptation mechanisms, and the constraints they faced were analyzed in the following session.

Annual Maximum, minimum and Mean temperature Trend analysis

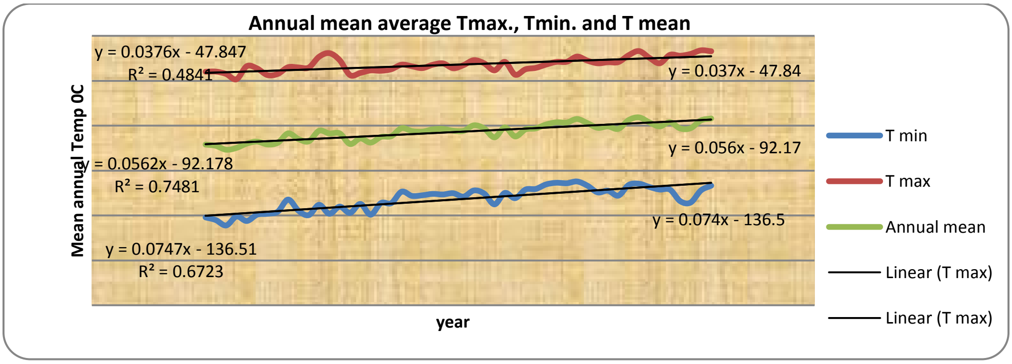

Fig. 2. Temperate Trend analysis of Bahir Dar Zuria District

As indicated in the figure above, the trend line indicates that a significant annual maximum temperature change were observed from 1960 to 2010. The average annual maximum temperature and annual minimum temperature were changed by a factor of 0.037 and 0.074 respectively as per the trend line indicated in figure 2. The mean minimum temperature change were more significant than the mean maximum temperature change. The mean average change of annual temperature indicates a significant variations of temperature observations increased by approximately 1.5^{o}c for the last 5 decades. The slope of the trend line in all the graphs (Tmax, Tmin and T mean) are positve value which explained the addition of significant value across the five decades time series analysis. Similar studies by the UNDP Climate Change Profile for Ethiopia (McSweeney et al., 2008) also shows that the mean annual temperature increased by 1.3°C between 1960 and 2006, at an average rate of 0.28°C per decade.

Test statistics of minimum and maximum annual temperature change

Table 1. summary statistics of Mann-Kendall Trend Test of annual maximum temperature

Variable	Obs.	Obs. with missing data	Obs. without missing data	Min.	Max.	Mean	Std	Alpha	P-value
Tmax.	49	0	49	25.17	28.10	26.72	0.658	0.05	0.000

H0: There is no trend in the series

Ha: There is an increasing trend from the year 1961 to 2010 time series

As the computed p-value, which is computed using exact method, is lower than the significance level alpha=0.05, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha. The risk to reject the null hypothesis H0 while it is true is lower than 0.01%. This means that mean maximum temperature change for the last 5 decades were significant.

Table 2. Summary statistics of Mann-Kendall Trend Test of annual minimum temperature

Variable	Obs	Obs. with missing data	Obs. without missing data	Min.	Max.	Mean	Std.	Alpha	P-value
Tmin.	49	0	49	8.064	13.797	11.720	1.453	0.05	0.0001

The p-value is computed using an exact method.
H0: there is no trend in the time series analysis of 49 years minimum temperature record
Ha: there is a change in the minimum temperature trend in the time series analysis of 49 years

As the computed p – value, which is computed using exact method, is lower than the significance level alpha =0.05, we should reject the null hypothesis. The risk to rejecting the null hypothesis while it is true is lower than 0.01%. Therefore, it is true that minimum temperature change was significant for the last five decades in the study area.

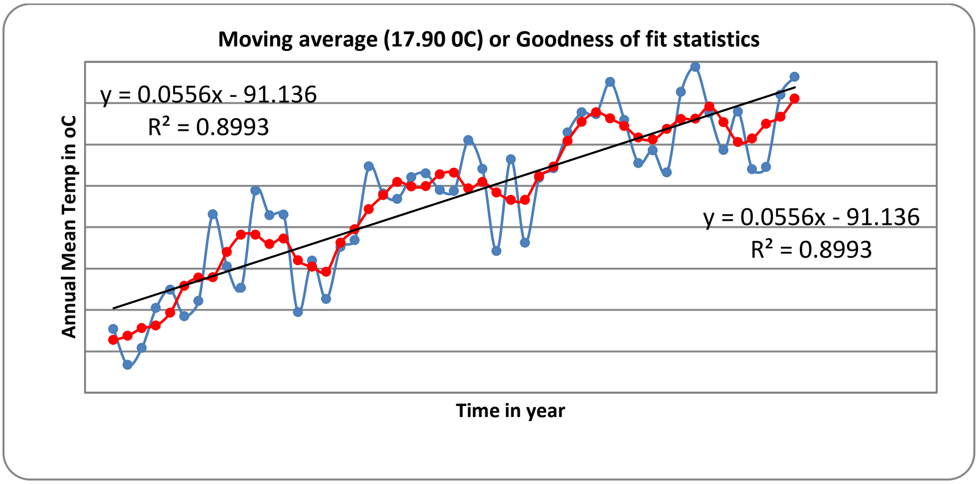

Fig. 3. Linearity relationship chart of annual mean temperature

R-square can take on any value between 0 and 1, with a value closer to 1 indicating that a greater proportion of variance is accounted for by the model. In this case, the R-square value of the annual minimum temperature data is 0.899 means that the goodness of fit (17.90) explains 89.9% of the total variation in the data above the average.

Figure 5 illustrate the difference across the mean average temperature data. Residual (or error) represents unexplained (or residual) variation after fitting a regression model. It is the difference (or left over) between the observed value of the variable and the value suggested by the regression model.

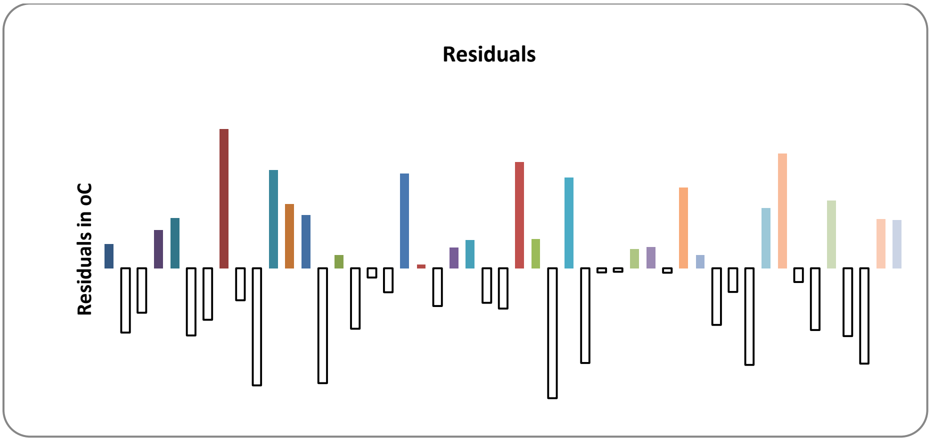

Fig. 4. Change in annual mean average temperature / residuals

Annual Precipitation Change

The change in the annual average precipitation amount of the study area has been analyzed and stated as follows. Annual precipitation change from the mean average has to be 66.70 mm as per the trend line. However, this value has been changed by the factor of -2.62. Negative sign of the slop of the trend line indicates that precipitation declining from 1961 to 2010.

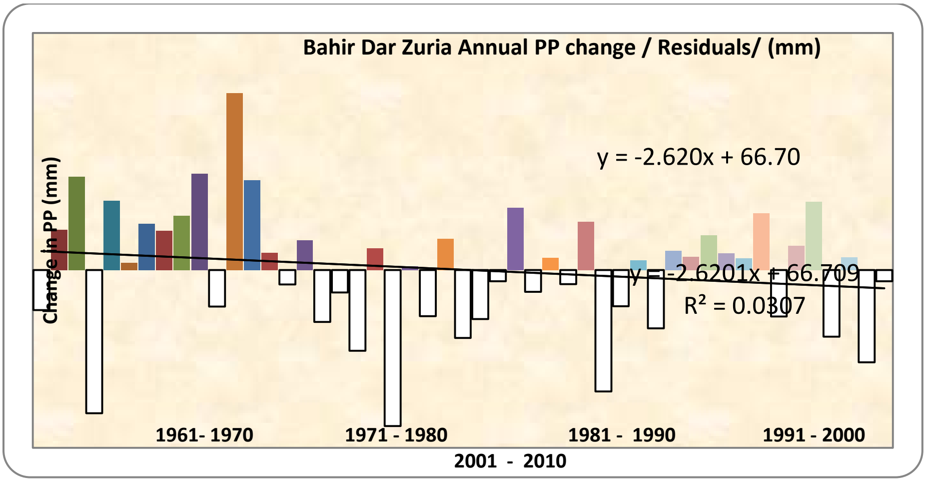

Fig. 5. Change in annual precipitation of the period 1961 to 2010 from the long years average precipitation

As the computed p - value is lower than the significance level apha=0.05, we should reject the null hypothesis Ho, and accept the alternative hypothesis. The risk to reject the null hypothesis while it is true is lower than 0.42%. Therefore we can conclude that rainfall amount of the past 49 years were hetrogeneous/variable/ with a general decline at Bahir Dar Zuria District. This reality also illustrated by figure 5. As indicated by figure 5, the annual rainfall amount in the first decade from 1961 and the remaining decades were significantly different. A significant decline was observed since 1975 onwards with a general decline.

Table 3. Rainfall Homogeneity Test of summary statistics

Variable	Obs.	Obs. without missing data	Min.	Max.	Mean	Std.	Alpha	P-Value
RF	49	49	894.60	2036.86	1436.50	228.262	0.05	0.004

HO: Annual Rainfall data is homogeneous

Ha: there is a year at which there was a change in the rainfall data or Rainfall data of Bahir Dar Zuria District for the past 49 years were not homogeneous.

Mann-Kendall Trend Test

Assumptions were Ho: There is no uniform rainfall trend for the last 49 years Ha: there is a general uniform annual rainfall trend in the time serious for the last 49 years

Test interpretation : As the computed p- value is greater than the significance level alpha =0.05, we cannot reject the null hypothesis Ho. The risk to reject the null hypothesis while it is true is 22.84%. In other words, annual rainfall amount for the last 49 years were changed irregularly. The consecutive annual rainfall difference value is not uniform in the time series analysis.

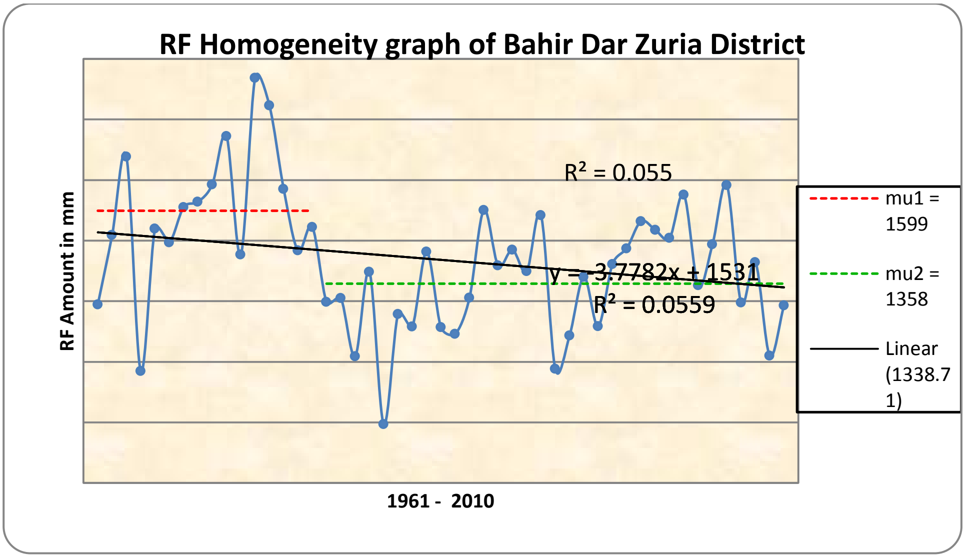

Fig. 6. Annual PP homogeneity graph

Table 4. Mann-Kendall Trend Test summary statistics of RF data.

Variable	Obs.	Obs. with missing data	Obs. without missing data	Min.	Max.	Mean	Std.	Alpha	P-value
RF.	49	0	49	894.6	2036.8	1434.5	226.3	0.05	0.228

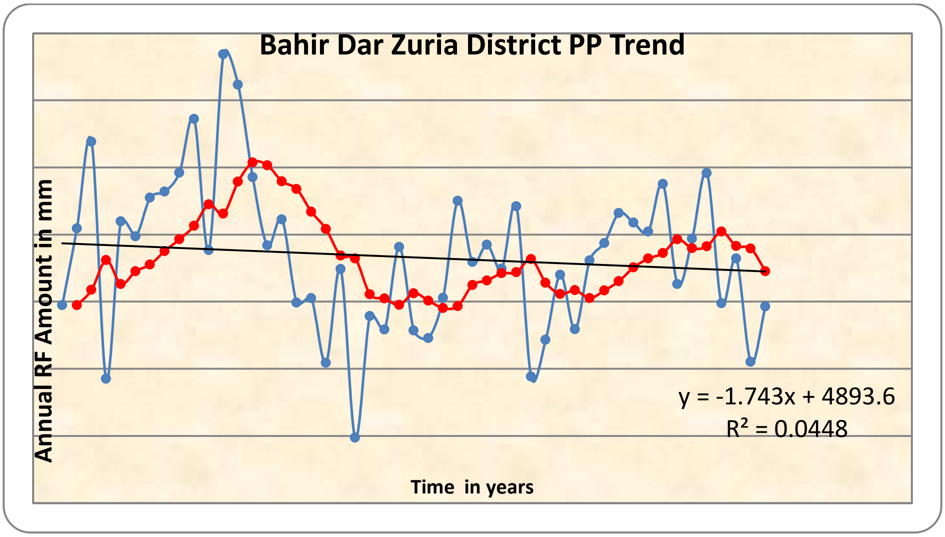

Fig. 7. Annual Rainfall change with a general decline

Farmers' perceptions of climate change

The survey instruments were designed to capture farmers' perceptions and understanding of climate change as well as their approaches to adaptations. Results shows that 80% of the sampled households have perceived changes in the annual temperature while the corresponding response to rainfall accounts for 84% in the last four decades.

Table 5. Farmers' perceptions of annual temperature and rainfall changes

Variable	Respondents in %	Variable	Respondents (%)
Temperature increased	78.0	Precipitation increased	17.3
Temperature decreased/	2.0	Precipitation/decreases inconsistent and or accidental	66.7
		late coming and early cases of summer rain	83%
No change	20.0	No change	16.0

Source: Field assessment - May, 2011

As indicated in table 1, farmers' perception for temperature change is very weal and their accuracy is supported by the surrounding weather recorded values of the meteorologists. Therefore, we conclude that most of the farmers in the study area have information or concept about climate is changing time to time. On the other hand, most of the farmers' response to the variation of rainfall shows that inconsistent and unconditional amount of rainfall were inhabited in the area. Moreover; late coming and early cease of rainy seasons and a general decline of annual rainfall amount is the prominent problem of agricultural activities.

Adaptation strategies and constrains faced

The adaptation methods most commonly used include the use of new crop varieties and changing the management and planting date that are more suited to drier conditions, irrigation, crop diversification, mixed crop livestock farming systems, diversification from farm to nonfarm activities, increased use of water and soil conservation techniques, and trees planted for shade and shelter. The adaptation measures that farmers report may be profit driven, rather than climate change driven. As most of the farmers' response, mid-July was the common date of every summer season for sawing serials crops, but, now a day, it is changed to early June since rain is coming early. The common types of trees planted for shading purpose include acacia, warka and zenbaba, whereas suspania and gravilia are for soil and water conservation purposes. On the other hand, farmers are practicing small-scale irrigation using streams since the coming and cease of rain is not certain. Therefore, one can assume that their actions are driven by climatic actions, as reported by farmers themselves. As shown in Table 2, most farmers did at least something in response to climate changes. The adaptation strategy most commonly used are cultivating diversified crops, changing the planting date, soil, and water conservation works, and planting water stress resistant trees for shades. On the other hand, the common constraints faced include soil fertility problems, lack of access for extension services, lack of information and access to credit services (Table 2).

Table 6. Farmers' perceptions of adaptation strategies and constrains faced

Variable	Respondents (%)	Constraints	Percentages (%)
Crop diversification	88.0*	Soil fertility	41
Changing planting date	82.0	Access to extension services	81
Changing the management	58.0	Lack of information	62
Saving and borrowing	54.6	Access to credit	61
Soil conservation	82.4	Land tenure	42
Planting trees	78.0	Poor potential for irrigations	82
No adaptation	10.0	No constraint	2

** The sum may not add up to 100 % due to repeated responses*

In the study area, farmer's ability to adapt is limited by their lack of knowledge about different adaptation measures, economic and technical resources, and their vulnerability is accentuated by heavy dependence on the climate, because of the rain fed system, diseases (malaria) and their poverty. Given the diversity of the constraints they have to face, the general capacity to adapt climate changes is currently very low. There are no good national action plans which take into account short or long term climate changes.

The effects of the climate change and climatic constraints in this area are numerous. The climate change is associated with the source of difficulties in the rural Ethiopia. The prolonged and increasing temperature, combined with the declining of the rainfall and the frequency of drought, as well as the marked degradation of the soil fertility, have resulted in a succession of bad crop years. Deressa *et al*. (2008) indicated that crop yield declined by 32.8% as a result of shocks such as drought, hailstorm, flood and etc. Farmers therefore try to develop their own strategies to mitigate and adapt climate impacts.

Conclusions and Recommendation

Ethiopia is highly affected country by climate change effects though difficult to generalize by this specific study at Bahir Dar Zuria district. Concisely the average annual maximum temperature and the annual minimum temperature are increased. The mean average change of annual temperature indicates a significant variations of temperature observations approximately by 1.5^{o}C, and the average amount of precipitation change over the past 49 years were significant as per the Mann-Kendall trend test and Homogeneity test results of p-value greater than alpha=0.05. The socio-economic data analysis also shows that 78% of the sample households perceived an increase in annual temperature and 66.7% a decrease in annual rainfall. It is known that government designed policies and strategies which take in to account the environmental protection and adaptation methods; however, it is not yet put in to effect. For instance, farmers training centres are established in each rural kebeles of the study area but the number of farmers trained were few. Lack of trained man power and other infrastructures are always mentioned as an obstacle to put policies and strategies in to effect.

The adaptation methods used by local communities include: - use of moisture stress resistant crops, changing the management and planting date, irrigation, crop diversification, mixed crop-livestock farming systems, and increased use of water and soil conservation techniques. Therefore, it is concluded that most of the farmers perceived climate change by their field experience and started adaptation strategies. In this regard, much remains to be done by governmental and nongovernmental actors to harness the value of indigenous knowledge, to empower and genuinely allow full participation of farmers and consider environmental sustainability, technological adaptability, adaptation programs and plans. Similar investigation has to be done on the areas of earth – atmosphere interaction systems like evapo - transpiration trends, wind speed and direction trends and humidity trends at Bahir Dar Zuria district in particular and in the country in general.

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CLIMATE CHANGE ASSESSMENT THROUGH TEMPERATURE AND RAINFALL VARIABILITY ANALYSIS IN ADILABAD DISTRICT OF TELANGANA STATE, INDIA

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Abstract

Climate is a dynamic phenomenon which changes from time to time and space to space. The change in climate may be recognized by the assessment of weather elements over a period of time. Among the weather elements analysis of rainfall and temperature provides the best results to interpret the magnitude of climate change. For the present study, analysis of rainfall patterns on annual and decadal basis has been carried out to understand the variations. From the decadal analysis of annual rainfall of Adilabad district revealed that there was an overall minimal increase in rainfall. However, the decadal analysis of seasonal rainfall indicated that the rainfall decreased in recent decades in all the seasons. Regression analysis indicated subtle variation in the rainfall distribution.

Keywords: Rainfall, Temperature, Climate, Regression, Weather

Introduction

Climate, a sensitive system consists of four basic interacting subsystems namely atmosphere, oceans, cryosphere (land Ice and sea ice) and land. Changes in one subsystem lead to changes in the other (Jager, 1983). It is a dynamic phenomenon as it fluctuates in all time scales: monthly, yearly, decadal, centennial and millennial (Hema Malini, 2002). In view of recent unprecedented occurrence of weather extremes at global as well as regional level, it is essential to examine climate variations at time scales of seasons to decades. Assessment of climate of a region is essential as it renders direct or indirect influence on living beings. The overall nature of climate of any region experiences is determined by its latitudinal location, elevation above sea level, relief in terms of orientation of hills and mountains and other topographical variations, the presence of water bodies and direction of prevailing winds. Analyses of at least 30 years of data of these elements provide a proper understanding of the climate of a particular region (Ayoade, 1983).

Climate of a region is defined as the synthesis of weather elements such as temperature, rainfall, relative humidity, pressure and wind (Bhaskara Rao *et al.,* 2007) and forms as basic ingredients to understand weather and climate of any region. Of all the climatic elements, temperature and rainfall are very significant which determine the biogeographical aspects of any region and which were considered as significant parameters in the weather assessment. These two weather elements are highly variable both spatially and temporally at all levels. Small variation of rainfall and temperature may disrupt the productivity of crops and economic sustainability and development of any region. Analysis of the past 140 years of temperature data of the world revealed that the global temperatures are rising at a rapid rate. It was also found that the 20th century was the warmest period in the last millennium with 1990s being the warmest decade, and 1998 the warmest year of the century (Dar, 2007).

The global climatic data show that average surface temperatures increased over the past century by about 0.4 ºC to 0.8 ºC (Oliver and Hidore, 2002) Earlier studies indicated that the micro-level changes of climate in terms of rainfall and temperature variations are due to albedo changes which in turn could be due to land use/ land cover changes (Chervin, 1979; Hema Malini, 1995; 2002). Charney et al. (1977) indicated that increase in albedo due to high evaporation causes reduced absorption of solar radiation by the surface leading to a continuous flow of latent heat into the atmosphere which lead to a decrease in rainfall. Meher- Homji (1994) suggested that under barren conditions, increased albedo leads to reduction in the incidence of rainfall. In contrast, increase in vegetative cover and wet land causes decrease in albedo and increased convective activity which results in more rainfall (Sarma et al, 2001). Hence, it can be noted that the alteration of albedo due to deforestation, draining of wet lands, desertification and afforestation are responsible for decrease or increase of rainfall. Human interference with the environment either by urban and industrial activities or by changing land use conditions is responsible for changes in weather elements. Changes in microclimatic environment would be reflected by way of increasing temperatures and changing rainfall patterns (Critchfield, 1974; Landsberg, 1984).). Of late, several research findings had also confirmed that the increase in global surface temperatures have been attributed to two important phenomena namely urbanization and industrialization (Prakasa Rao, 1983; Charlson, 1993**;** Bhanu Kumar et al*.,* 2007).

Human activities such as land use/land cover changes, and deforestation, draining of wet lands tend to alter the albedo of the earth surface which in turn influence the variations in the microclimatic elements such as rainfall, temperature, humidities, etc (Landsberg, 1984). Further, the process of urbanization creates concrete jungles which trap heat by multiple reflections, and the process of industrialization causes increase in green house gases (Hema Malini, 1984). In addition, consumption of fuel by vehicular traffic and domestic activities traps the heat at lower levels and raises the temperature near the ground (Bhaskara Rao et *a*l., 2007; Lakshmi Katam et al., 2007). According to Kawamura (1977), the rise in the urban temperatures is due to combustion of fuels, existence of haze and smog layer over the city, and the heat exchange due to turbulence which is increased by the material, shape and extent of the building.

The trend analysis of temperature and rainfall on different time scales is useful in the construction of future climates of any given region. Keeping that in view, an attempt is made in this paper to assess the trends in the climatic elements namely temperature and rainfall on decadal basis and to discuss the factors that are responsible for their variation in Adilabad district of Telangana State.

Study Area

Adilabad is one of the 10 districts of Telangana State and is located in the northern extreme portion of the State. The district is situated in between 18°40' and 19°56' N latitudes and 77°46' to 80°00'E longitudes (Fig.1). The elevation of the study area from the mean sea level is 233 m. The district forms border with the districts of Maharashtra and Chhattisgarh States and Karimnagar and Nizamabad of Telangana. The district covers an area of about 16,128 Km² and it is second the largest district of Telangana State (Adilabad Hand Book of Statistics, 2009; APSRAC, 2009; MANAGE, 2010). Adilabad town is the district head quarters and the district comprises 52 Revenue Mandals and 1748 villages. 44.8 percent of total area of district is covered by forests. The north western part of the district is plateau and gently undulating topography in the south. While the eastern half of the district is covered by NW-SE oriented structural ridges and plains. Sahyadri hills traverse the region from the north-west to the south-east for about 281 Km (Adilabadcity.info; APSRAC, 2009; en.wikipedia.org, 2010). The climate of Adilabad district is characterized by hot and dry nature of climate except during the south-west monsoon season (Adilabad Hand Book of Statistics, 2009). The average temperature of the district is 24.8°C.The mean monthly temperature of the hottest month is 37.4°C and coldest month is 9.4°C. During summer, the mean daily maximum temperature reaches up to 46 °C and the minimum about 30 °C. December is the coldest month (APSRAC, 2009).

Data Collection and Methodology

For the present study, both primary and secondary data have been collected from various sources. Data on monthly temperature were collected from the weather records of India Meteorological Department located in Adilabad town for 110 years from 1901 - 2010. To derive average temperatures for the entire district, data on temperature from the adjacent India Meteorological Department stations located around Adilabad district were collected and the average monthly temperature data of the 52 stations of the district were derived by adopting interpolation technique. Data on monthly rainfall of Adilabad town were collected from the weather records of India Meteorological Department for 110 years i.e. from 1901 - 2010. And for the remaining part of the district, data were collected from the Hand books of Adilabad district and Mandal Revenue offices. Analysis of Rainfall data for 53 stations was carried out by using various statistical techniques to understand the distribution, variability and trends in rainfall. The results are depicted in the form of tables and graphs.

Temperature Patterns

The average annual temperature of Adilabad district is 24.8 °C. The mean monthly maximum temperature is 31.5 °C and minimum temperature is 18.1 °C. The monthly average temperature for the hottest month (May) is 37.4 °C and for the coldest month

(December) is 9.4 °C. The annual range of temperature is 12.4 °C. Analysis of average seasonal temperature distribution indicated that among the four seasons, the district records maximum temperatures during hot weather season (32.1^{o}C) followed by south-west monsoon (28.2 ^{o}C) and north-east monsoon (25.1 ^{o}C). Cold weather season records very lower temperatures.

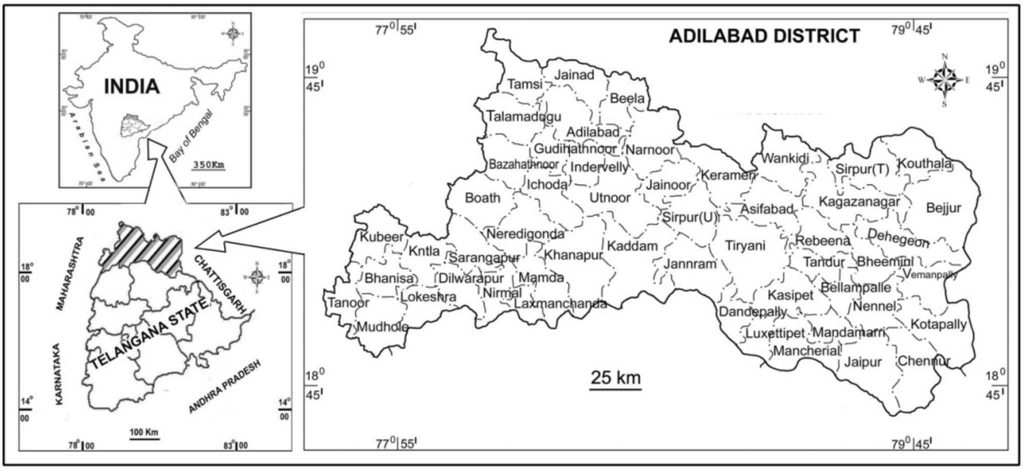

Fig.1.Location of Adilabad district, Telangana State

Trends in Temperatures: Annual temperature patterns

Due to changing environmental and meteorological conditions, weather parameters of a particular region also changes from time to time. The analysis of temporal variations in weather elements provides a better understanding of climatic variability in a region. The temporal analysis could be carried out on annual, decennial, centennial, etc., basis.

For the analyses of temperature, IMD data of Adilabad is taken in to consideration to represent the entire district since it is only the station maintained by India Meteorological Department. The study revealed that the Adilabad region indicated Increasing trend in the temperatures during the period between 1901 and 2010. The simple type of trend analysis of data on an annual basis sometimes obscures the actual trend of the climatic parameters. In order to reduce some of the minor fluctuations and to get a clear temperature trend in the form of a smooth curve, a statistical technique namely moving averages (also called running means or overlapping means) has been adopted in the present study.

For studying the trends of Adilabad, annual moving averages on five years and 11 years time-series were worked out for annual average temperature and graphically represented. Both the curves of moving averages of Adilabad indicated a clear increasing trend in temperatures between 1901and 2010 (Fig.2.)

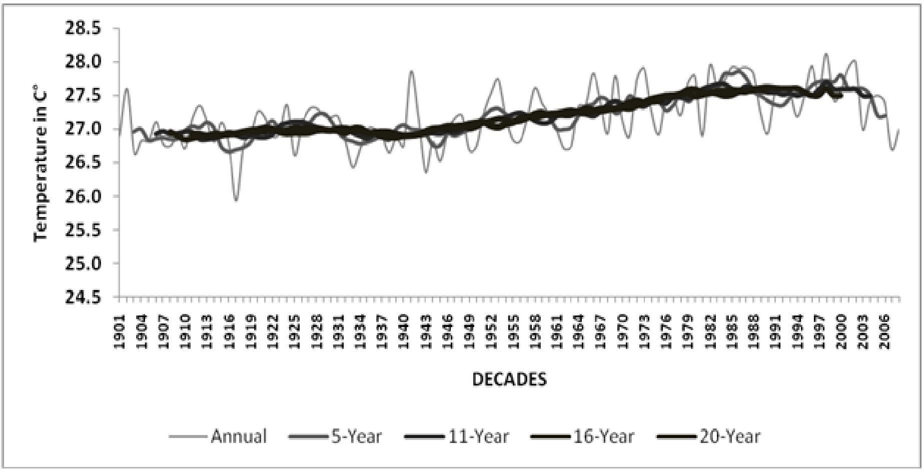

Fig. 2. Moving Annual Average temperatures of Adilabad District

Trends in decadal temperature patterns

Further, to understand long-term temperature changes, decadal data analyses were carried out for mean, maximum and minimum temperatures of the Adilabad district and decadal variations were presented in the table 1 and Fig.3.

Table 1.Trends in mean decadal temperatures of Adilabad

Decade	Decadal Temperatures in °C					
	Annual	Variatic	Maximur	Variatio	Minimur	Variatic
1901-1910	**26.9**		33.1		20.7	
1911-1920	**26.9**	**0.0**	33.1	**0.0**	20.8	**+0.1**
1921-1930	**27.1**	**+0.2**	33.3	**+0.2**	20.9	**+0.1**
1931-1940	**26.8**	**-0.3**	33.0	**-0.3**	20.7	**-0.2**
1941-1950	**26.9**	**+0.1**	33.1	**+0.1**	20.8	**+0.1**
1951-1960	**27.3**	**+0.4**	33.5	**+0.4**	21.1	**+0.3**
1961-1970	**27.2**	**-0.1**	33.4	**-0.1**	21.1	**0.0**
1971-1980	**27.4**	**+0.2**	33.6	**+0.2**	21.3	**+0.2**
1981-1990	**27.6**	**+0.2**	33.8	**+0.2**	21.4	**+0.1**
1991-2000	**27.6**	**0.0**	33.8	**0.0**	21.4	**0.0**
2001-2010	**28.3**	**+0.7**	34.3	**+0.5**	22.2	**+ 0.8**
Variation between 1901-1910 and 2001-2010	**+1.4**		**+1.2**		**+1.5**	

The analysis of decadal annual average temperature of Adilabad district indicated that the district as a whole is experiencing warming trend during the eleven decades period (Fig.3). The assessment reveals that temperature is steadily increasing in the study area since 1921-1930 decade with few exceptions. The increase was continuous since 1971-1980 decade. Maximum has been noticed during 2001-2010 decade in maximum as well as minimum temperatures by o.5 °C and 0.8 °C respectively over its previous decade. Marginal decline of temperatures was observed during 1921- 1930 and 1961-1970 over their respective previous decades. The overall increase between 1901-1910 and 2001-2010 decades was 1.4 °C. Thus the analysis revealed that Adilabad district is under warming conditions for four decades without interruption.

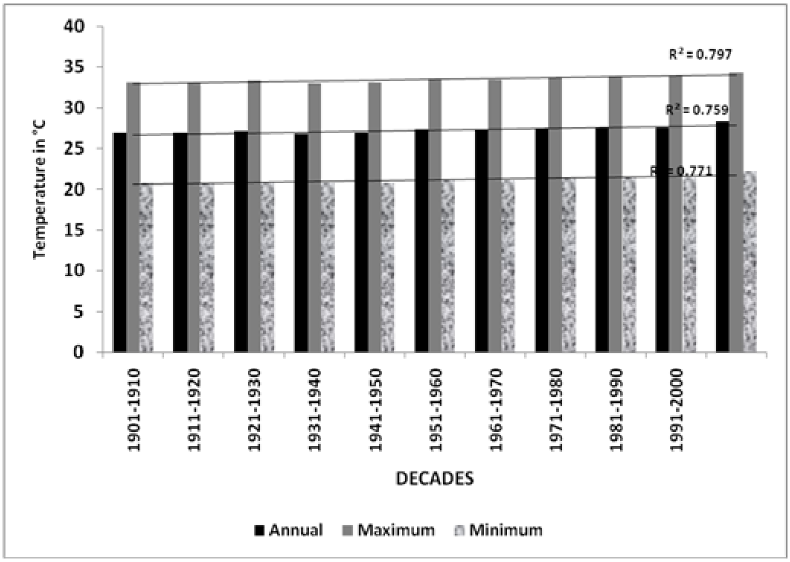

Fig.3. Decadal Variation Temperature distribution in Adilabad District

The difference between the decadal temperature of hottest and coldest months is known as decadal range. Under normal conditions, the difference between hottest and coldest months will be high. With variations of temperature the difference may increase or decrease. Increase in difference indicates cooling phase and decrease indicates warming phase of the climate. Table.2. and Fig.4., represents the range of decadal temperatures.

Table 2. Trends in the Decadal range of temperatures - Adilabad

Decade	Temperature in °C		
	Hottest Month	Coldest Month	Range
1901-1910	33.9	20.8	**13.1**
2001-2010	36.9	25.0	**11.9**
Variation between 1901-1910 and 2001-2010	+3.0	+4.2	**-1.2**

The analysis of decadal of temperatures indicated that the temperatures of the hottest month (May) increased by 3 °C during 2001-2010 when compared with 1901-1910. Similarly, the decadal temperature of the coldest month (December) increased by 4.2°C during 2001-2010 when compared with 1901-1910. The analysis of decadal range indicating that the decadal range was 13.1 °C during 1901-1910 decade and it was 11.9 °C in 2001-2010 decade. This means that the difference between the hottest month and cold month temperatures is gradually decreasing supporting the fact that the study area is under the influence of warming.

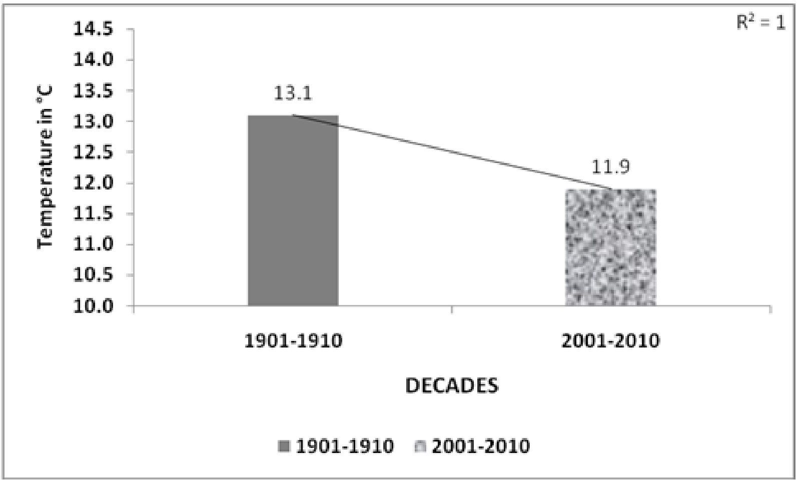

Fig.4. Decadal Range of Temperatures of Adilabad

Rainfall Patterns

The spatial incidence of rainfall in Adilabad district increases from the south-west direction towards the north east. The mean annual rainfall of the district is 972 mm. Of which, about 85% of annual rainfall is received during the south-west monsoon season (June-September). During this season the district receives an average rainfall of about 852 mm. During Northeast monsoon season (October-November), the district receives about 59 mm of rainfall. Among the seasons, cold weather season is the driest season (December – February) and receives an average amount of 20 mm. The district experiences an amount of 41 mm of rainfall in the hot weather season (March- May).

Annual Trends in Rainfall

To understand the changes in rainfall patterns of Adilabad district, analysis of rainfall has been carried out on annual as well as on decadal basis. Data on monthly rainfall collected from records of weather stations and rain gauge stations maintained by mandal revenue offices for the period from 1901-2010 were analyzed. The annual rainfall was graphically presented. The graph shows variable trend in the annual incidence (Fig.5). A linear trend analysis of Adilabad shows positive trend. For a better understanding of annual rainfall trends, moving average technique has been adopted and computed for the 5-years. 11-Years, 16- years and 20- years time cycles and was presented in Fig.5**.** The moving averages for Adilabad station indicates a positive trend (y=0.885X+950.92). Thus, from the analysis, it is evident that there is a very slight increase in overall rainfall.

Decadal annual and seasonal rainfall variations

To get a long-term perspective regarding trends in rainfall in Adilabad district, annual average decadal analysis of rainfall was carried out for eleven decades. To have a better understanding of the trends in the seasonal distribution of rainfall, decadal analysis of mean seasonal rainfall has been analyzed for all the four seasons namely south west monsoon season (June-September), Northeast monsoon season (October-November), Cold weather season (December-February) and Hot weather season (March-May) of Adilabad district for eleven decades. The results were incorporated in Table 3 and graphically represented in Fig.6.

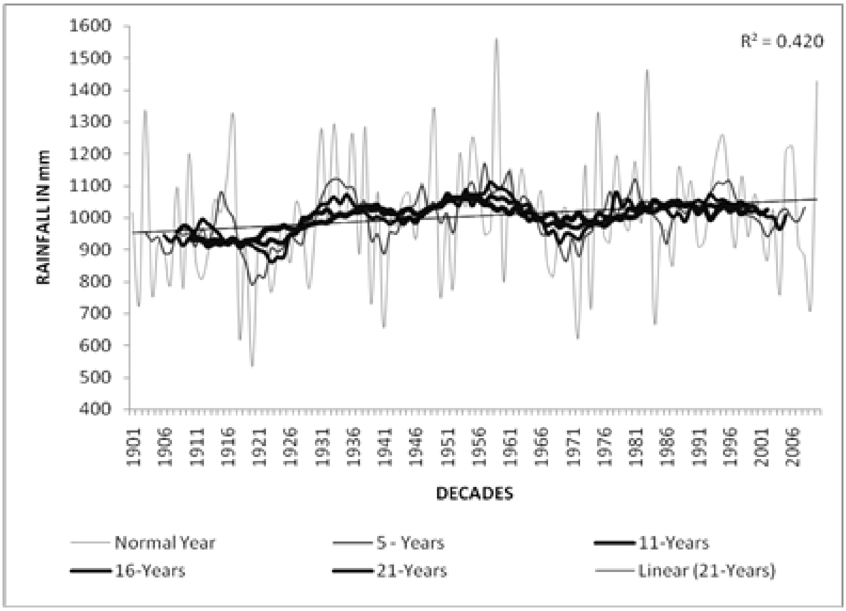

Fig.5 Moving averages of rainfall distribution of Adilabad District

Decadal analysis of rainfall is indicating an overall increase of 4 mm of rainfall observed when rainfall of 1901-1910 decade compared with 2001-2010 decade. The decadal average rainfall during South - West Monsoon season (June to September) of Adilabad district indicated that there was overall decrease of rainfall during 2001-2010 decade when compared to 1901-1910 decade by 19 mm. The decadal average rainfall during North-East Monsoon season (October and November) of Adilabad district indicated that the study area has experienced 3 mm of excess rainfall during 2001-2010 when compared with 1901-1910 decade. The decadal average rainfall during Cold weather season (December to February) of the district indicated that the region received 8 mm more of seasonal rainfall during decade 2001-2010 over 1901-1910 decade. Similarly the decadal average rainfall during Hot Weather season (March to May) indicated an increase of rainfall by 12 mm at the end of study period (2001-2010) when compared with the initial (1901-1910) decade. The decadal rainfall analysis indicated the rainfall increase at all the seasons from 1931 to 1971 and since then there was a decrease. The analysis revealed that except during hot weather season, Adilabad district is experiencing decreasing trend in rainfall in the recent decade i.e. 2001-2010 in all seasons. During 2001-2010, the study area indicated a decline in the rainfall at all seasons except during hot season. Increase in the rainfall intensity during hot weather season may be attributed to increase in the convective activity due to warming.

Table 3. Decennial distribution of average annual rainfall in Adilabad District

Decade	Rainfall in mm									
	Annual	Dev.	Seasonal Rainfall in mm							
			SW	Dev.	NE	Dev.	CW	Dev.	HW	Dev.
1901-1910	918		852		**28**		3		35	
1911-1920	862	**-56**	763	**-89**	**39**	**-11**	8	**+5**	52	**+17**
1921-1930	853	**-9**	764	**+1**	**43**	**+4**	7	**-1**	39	**-13**
1931-1940	1021	**+168**	913	**+149**	**50**	**+7**	6	**-1**	52	**+13**
1941-1950	947	**-74**	872	**-41**	**32**	**-18**	7	**+1**	36	**-16**
1951-1960	1015	**+73**	912	**+40**	**50**	**+18**	2	**-5**	51	**+15**
1961-1970	965	**-68**	887	**-25**	**29**	**-21**	8	**+6**	41	**-10**
1971-1980	905	**-60**	796	**-91**	**58**	**+29**	6	**-2**	45	**+4**
1981-1990	976	**+71**	868	**+72**	**49**	**-9**	7	**+1**	52	**+7**
1991-2000	981	**+5**	875	**+7**	**58**	**+9**	6	**-1**	42	**-10**
2001-2010	922	**-59**	833	**-42**	**31**	**-27**	**11**	**-5**	47	**+5**
Variation between 1901-1910 and 2001-2010	+4		-19		**+3**		**+8**		+12	

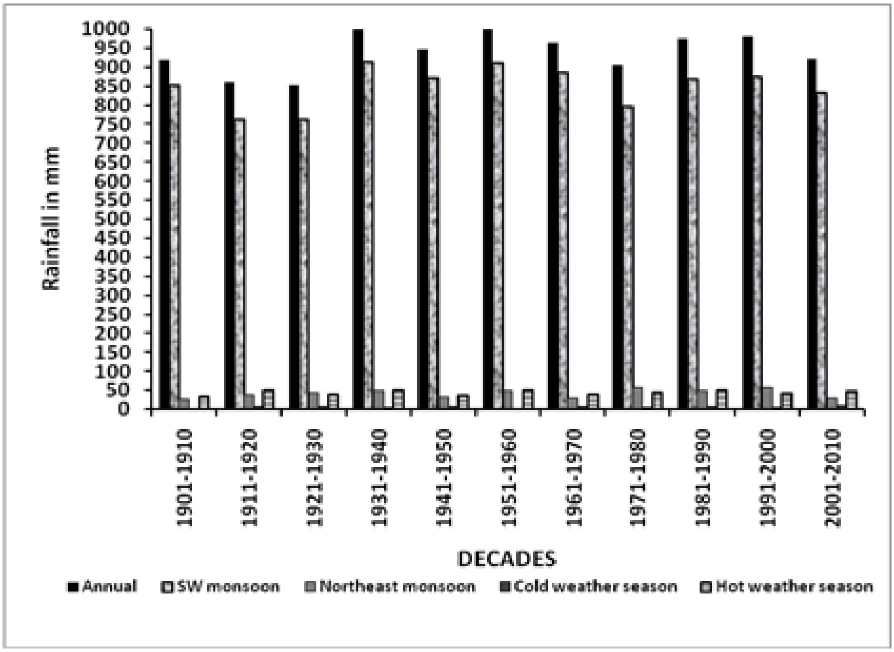

Fig.6. Decadal seasonal Rainfall of Adilabad District

Factors Responsible for Climatic Variations

Variations in climate may be due to human activities. The twin processes namely industrialization and urbanization are responsible for increase in population, increase in built up area, increase in traffic density, increase in fuel consumption etc. The need for more space for urban as well as industrial activities is responsible for changes in land use/land cover conditions in the district. All these changes are responsible for the variations in weather elements namely temperature, rainfall, humidity, wind patterns etc.

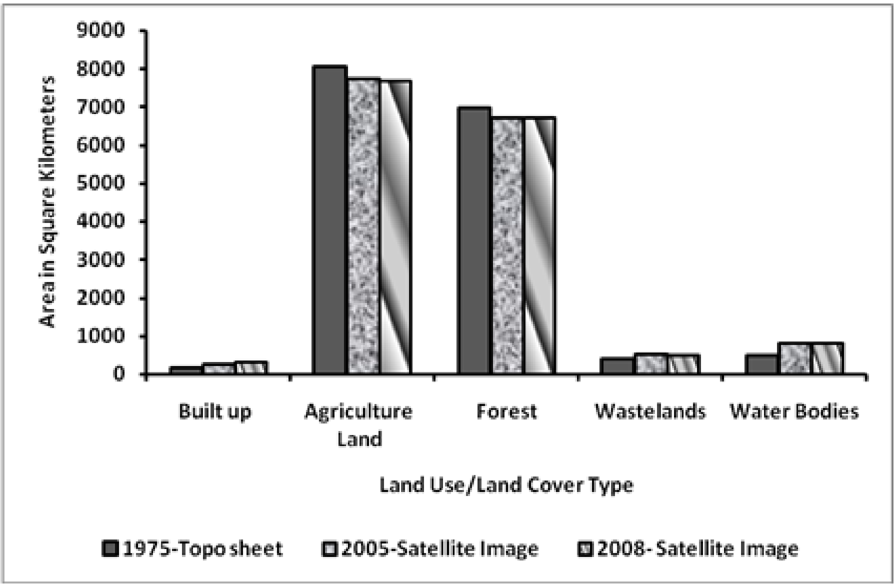

Fig. 7. Land use /Land cover changes in Adilabad district between 1975 and 2008

Population

In the past, the climatic variations resulted due to natural variations and the change was very slow and gradual. The average global temperature is increasing with high magnitude since 1980's (Hansen, 1991). The trend continued and so far 1990's decade was found to be warmest. A number of studies indicated that rise in greenhouse gases are the main contributory factors for the global warming. The twin processes namely urbanization and industrialization are the main contributory factors for the variations in the climate. These human activities include deforestation, paddy cultivation, burning of fossil fuels, application of fertilizer in agriculture and increase in the chlorofluro – carbons etc. All these factors are creating complex climatic responses, including rise in temperature.

Earlier studies on climate change indicated that over population is one of the causes for climate change as human activity increases. According to the scientists, countries namely China and India which are over populated are outstripping the resources in order to have more economic growth and causes rise in temperatures (Bongaarts, 1992). According to Arthur Westing (2010), population is a double edged environmental problem as it results in not only increase in population but also an increase in green house emissions because of increase in human activities in terms of urbanization and industrialization. According to him when world population was around 3.7 billion in 1970, the greenhouse gas emissions were initiated.

At present, population rose to 6.9 billion (86 percent of increase) and the worldwide emissions from fossil fuels increased to an estimated quantity of 29 billion tons from 14 billion tons (107 percent increase). Even after knowing the climate change implications, the emissions which were about 3.8 tons per capita in 1970 have risen to about 4.2 tons per capita at present. Thus population growth is directly responsible for the global warming on the surface of the earth. The chain causation of rise in temperature is suggested by EPA, 1990a; IPCC, 1991 a) as below.

Population growth → Increased Human activities → Increase in the emissions of green house gasses →
Increase in green house gasses activity in the atmosphere → Global warming

The population of Adilabad district which was 4.5 lakhs in 1901 increased to 27.3 lakhs by 2011 (Fig.2.26). This is 6 times more than 1901 population. Due to over growth of population, density increased from 28 persons per km^2 to 170 persons per km^2 between 1901 and 2001. As a result human activity also increased in all the economic sectors. For example, there were about 332 factories existing in the district during 2007-2008 which were increased to 387 by 2008-09. These factories include cotton ginning mills, rice mills, oil mills, spinning mills, saw mills, ceramics, cement factories, power plant etc. As a consequence, urban population is mostly concentrated in 15 towns of the district where employment is available. Automatically, built up area of the district is on an increase as a part of urbanization. The motor vehicles are increasing year by year along with the increase in population. For example about 127,922 vehicles were registered in Adilabad during 2007-2008, which increased to 141,846 by 2008-2009.

Land use/Land cover Conditions

Urbanization and industrialization together influence the land use/land cover characteristics of any region. The satellite remote sensing data with their repetitive nature have proved to be beneficial in mapping land use/land cover and changes with time. The statistics generated from satellite remote sensing data help in understanding the physical processes and changes in land use / land cover in space and time (Dubey, 2001; Sarma et al., 2001). Quantification of such changes is possible through GIS techniques even if the resultant datasets are on different scales/resolutions. For the present purpose, in order to understand the micro climatic changes that are taking place in the study area analysis of land use/land cover patterns and their changes was carried by processing IRS P-6 LISS III. The areal extent of each of the classes was computed by reprojecting the rectified toposheets (56/E/F/I /J/M/ and N series) and satellite images. The area under different land use/ land cover conditions presented in the Table .5 and Figure. 7.

In order to understand the changes in land use / land cover through time due to the conversion of one to other categories, a change matrix between the 2005 and 2008 of the study period was prepared (Table 6). Analysis of temporal data sets in GIS provides information in quantity of change that took place in each category of land use/land cover with respect to other categories during the period under study which in turn provide realistic trends in land use / land cover changes due to urban growth and helps to derive an effective land use planning. Table 6 and Fig 7., illustrates the trends in the land use / land cover transformations during the study period.

Table 5. Land use/ land cover in Adilabad District (2005 and 2008)

S.#	Land use/ Land cover categories	1975 (km^2) (Toposheet)	2005 (km^2) (satellite image)	2008 (km^2) (satellite image)
1	Built up	162.03	269.21	325.98
2	Agriculture Land	8071.24	7749.27	7700.99
3	Forest	6991.40	6736.12	6736.1
4	Wastelands	400.80	547.58	513.00
5	Water Bodies	490.41	813.39	839.50
	Total	16115.57	16115.57	1611.57

Table 6. Change matrix of land use / land cover features in Adilabad District during 2005 and 2008 (All values are in km^2)

2005 → / 2008 ↓	Built up Area	Agriculture Land	Forest	Wastelands	Water Bodies	2005 Total ↓
Built up Area	269.21	0	0	0	0	**269.21**
Agriculture Land	22.17	7700.99	0	0	26.11	**7749.27**
Forest	0	0	6736.12	0	0	**6736.12**
Wastelands	34.58	0	0	513.0	0	**547.58**
Water Bodies	0	0	0	0	813.39	**813.39**
2008 Total	**325.96**	**7700.99**	**6736.12**	**513.0**	**839.5**	**16115.57**

N.B. *The rows in the table represent 2005 and columns represent 2008*

The above change matrix, indicating that built up area of the district which was 269.21 km^2, increased to 325.96 km^2 by 2008. This increase was at the expense of agricultural land and wasteland. About 22.17 km^2 of agricultural land and 34.58 km^2 of waste land has been converted in to built up area. At the same time 26.11 km^2 of agricultural land was also converted into water bodies. As a result, agricultural land which was 7749.27 km^2 during 2005, reduced to 7700.99 km^2 by 2008. There was no addition or decline in the forested area. However, the reduction in the wasteland occurred from 547.58 km^2 to 513 km^2 in 2005 due to conversion of some of its land into built up area. There was large increase in the built up area and marginal increase in the water bodies.

Conclusion

From the above analyses, it was inferred that increase in population, built up area, number of roads and number of vehicles, more consumption of fuels, change in the land use/ land cover have affected the atmospheric environment which reflected in the increase in temperatures and change in the rainfall patterns in the district.

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IRRIGATION IMPACT ANALYSIS - A CASE STUDY OF MALAMPUZHA IRRIGATION PROJECT, PALGHAT DISTRICT, KERALA

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Abstract

Agriculture development, which is the source to increase the level of living of our teeming millions, is dependent upon adequacy and timely occurrence of rainfall. But nearly 70 percent of the cultivated area in the country lies in the region of medium to low rainfall where water deficiencies lead to drought conditions. The study relates to Malampuzha Irrigation Project, which was completed in 1967, with its distribution system and henceforth two time period i.e. before 1967 and after 1967 will be taken to bring about the changes in agricultural structure. The objectives are to understand the agricultural structure of the command area and find agricultural development. Further to find the spatial variation and find the impact of irrigation on command area agricultural economy. In the irrigation tract the percentage of input and output is the less by large farmers, than by the small farmers. This shows that the large farmers are most benefitted by irrigation

Keywords: Irrigation, Command area, Farmers, Economy

Introduction

Irrigation aims at the maintenance of soil moisture with a range required for optimum plant growth. There are many parts of the world where the moisture available in the soil from rain ,or from underground water is not sufficient from the requirement of plant life either all the time, or for part of the crop season where it is necessary to make up the deficiency by adding water to soil, such artificial application of water for growing crop is called irrigation. Irrigation is an art that has been practiced by centuries, handling the flow of water and observing the resulting yields, farmers gradually arrive at certain operational standards. These standards are nothing but the farmer's perception about the amount of seed, fertilizer, the amount of water to be retained in a plot of land, and these standards have only regional and sometimes local significance. They are aimed at maximum crop production under the given condition. with more and more land being brought under irrigation many of these standards are simply copied even when the physical and social condition in the newly developed regions differ considerably from those in existing projects where they have proven their values. As a result the effect of irrigation on yield of the crops, or the labour required for irrigation can differ greatly from one area to another, even if these differences in physical and social conditions are well understood.

Large canals of the world may well claim to be manmade rivers, have converted deserts into high productive agricultural lands, thus attracting large habitation and new centre of life and civilization, for instance irrigation from the river Nile is the source of food and prosperity in Egypt. Its entire cultivated area is dependent for its water supply on irrigation. Three quarter of the cultivated area in Japan is irrigated and grows mainly rice .Rice which is the staple food for more than half of the world's population, is grown except in small zones of very heavy rainfall almost entirely dependent on irrigation, canals, dams, and wells and are not only the backbone of their economy but are so intimately related to the life of the people that irrigation is very much a human problem. Irrigation agriculture is the most productive kind of farming devised by man. it is the most expensive , the capital cost of providing the water for irrigation agriculture are commonly so large that they cannot be fully met by the farmers themselves due to its nature of lump investment and government has to step into provide agriculture impact.

Agriculture development, which is the source to increase the level of living of our teeming millions, is dependent upon adequacy and timely occurrence of rainfall. But nearly 70 percent of the cultivated area in the country lies in the region of medium to low rainfall where water deficiencies lead to drought conditions. Provision of irrigation facilities is thus a necessity both as a measure against drought and for increasing agricultural production. In agricultural region, where the reliability of rainfall is less the benefits from irrigation could be enormous. Irrigation potential created, if utilized properly, not only brings about an increase in output but also reduce the fluctuation in agricultural productivity. It may have a very favourable impact in the demand for labour. The secondary effect in terms of increase in other economic activity may also be of significance. Moreover irrigation is known to be necessary condition for the successful adoption of improved practices.

The area of land which can be irrigated by the water available from a particular source is its irrigation potential, if land and other factors of production are in abundant supply. The irrigation potential of water source depends on the demand of water on one hand and the supply of water on the other. it would depend upon the type of crops to be irrigated. The demand of water in irrigation agriculture may be said to depend on climate and other natural circumstance and on the crops to be irrigated .the demand will be different, for instance if the water is to irrigate sugarcane from it is used to irrigate paddy. The area of land which can be irrigated by the water available from a particular source is its irrigation potential, if land and other factors of production are in abundant supply the irrigation potential of a water source depends on the demand of water on one hand and the supply of water on the other. It would depend upon the type of crop to be irrigated. the demand of water in irrigation agriculture may be said to depend on climate and other natural circumstance and the crop to be irrigated. The demand will be different, for instance if the water is to irrigate sugarcane from it is used to irrigate paddy, Aurther Hazilewood and Law Livingtone (1982)

Water as a main source of irrigation which tries to bring more area under cultivation and also under double crop will increase ping, so as to improve yield and total output.

The Muda irrigation project implemented between 1966 and 1974 designed to provide irrigation water for double cropping of rice on approximately 242,000 acre and the project was originally conceived as a means of substantially reducing Malaya's dependency on imported rice. The Muda study brings out that there is a resultant increase in farm income, this increase is however not been evenly distributed across the already unequal pattern of income distribution and therefore served to worsen that distribution, FAO (1975) The area to be brought under double crop implies that the potential is available, Whereas Punjab has the highest percentage of irrigated area among the states but a sizeable portion of it is not double cropped, Kahlon and Grewal (1975). The introduction of Sardar canal system has given benefit in two respect, it has increased the area under sugarcane from 3% to 7% of the net cultivated area and it has made to irrigate land by canal instead of well or tank, Baljit Singh and Shridhar Misra (1965)

On the other hand considerable change has been brought in the area under cultivation since irrigation facility is provided, In Nizamsagar irrigation project the significant impact being 1: 50 lakh acre of land is been brought under cultivation, Jassawalla M.T (1961). This further implies that the assured irrigation for the area earlier cultivated and the present increase in the area would require more employment, output will increase which will change the level of income of farmers, these are all direct or indirect benefits of irrigation, Dhekney B.R and Deshpande S.R (1976). The objectives are to understand the agricultural structure of the command area and find agricultural development. Further to find the spatial variation and find the impact of irrigation on command area agricultural economy.

Research Design

The study relates to Malampuzha Irrigation Project, which was completed in 1967, with its distribution system and hence forth two time period i.e. before 1967 and after 1967 will be taken to bring about the changes in agricultural structure. The impact of irrigation will capture on the living of the people change in productivity, intensity of cropping, inputs and innovation. For calculating benefits, we can proceed either on the basis of 'before and after' or 'With and without'. The first design has theoretical as well as practical disadvantages. Firstly, it would not be now possible to isolate the benefits of irrigation alone in the canal region as required under it. Secondly, no reliable data of input and output regarding farm business before the construction of the canal is available and hence the input and output cannot be compared with those prevailing before.

Hence the methodology followed for the impact evaluation is a control block analysis. To capture the isolated impact of canal irrigation on the agricultural economy. Three sets of control villages having no canal irrigation, one on the upper reach, one on the middle reach and the third at the tail end, and corresponding irrigated villages has been selected. The command area has been conceived as an experimental block and the villages where no canal irrigation is available has been conceived as a control block. Given any variable of the socio- economic structure of command area as E1 (experimental block) and the same control block as E0, the impact of irrigation on the variable can be said to be

E0 –E1. The difference or change in various aspect of command area economy compared to the control block is said to be the result of irrigation.

The three villages in command area and control block were selected in terms of spatial location taking into consideration the same geographical characteristic. The control block methodology was adopted mainly because there was no pre- project period data available, which could be made the base of a comparative study. The control block will represent to some extent the status of the command area prior to the introduction of irrigation. For detailed house hold survey 45 household , 15 each from three villages from the command area and 45 household 15 each from three villages from the control block were taken. These households were classified into three categories, large, small, and marginal farmers, and five households from each category within the class were selected randomly. It may be noted that the analysis of the selected villages in the control block and command area was done using the classification variable of land holding pattern. i.e. large farmers above 5 acres, small farmers less than 5 acres but more than 2 acres, and marginal farmers with less than 2 acres. This was done to capture the irrigation impact and water utilization and the agricultural variation across different land holding size.

Study Area

Palghat district in Kerala lies in the central part of Kerala, bounded on the North and North -West by Malappuram district, South and South-West by Trichiur district and on the East by Coimbatore district of Tamil Nadu. The Palghat district comprises of five taluks i.e. Palghat, Manarghat, Ottapalam, Alathur, and Chittur taluk, but the taluks covered by Malampuzha Irrigation project are Palghat, Alathur and Chittur taluks of Palaghat district and Talappilly taluk of Trichur district. The Latitudinal extension of the five taluks covered by the project is $10^0$15’ North Latitude to 11^0North Latitude and 76^0 East to 77^0 East Longitude. The Malampuzha River joins the Koraiyar river about 10 Km downstream, the largest irrigation reservoir in the state. Koraiyar river joins Kalpathy river which is one of the four tributaries of Bharatha Puzha. The catchment area of Malampuzha Dam is 57Sq Miles and irrigates an area of 20,592.71 Ha. Though Palaghat district receives rainfall during both seasons it is considered the driest in terms of rainfall received, compared with the other districts of Kerala. The reason that it receives rainfall in both seasons is mainly due to its geographical position and the significance of Palghat gap.

Methodology

The importance of irrigation in agricultural development hardly needs any emphasis. As far as Kerala is concerned water resource constitute one of the important economic assets of the state where an average annual rainfall of about 3000 mm. Among the major crops paddy continues to be major user of irrigation facility. Palaghat district in Kerala has the largest area under paddy i.e 1,71,022 hect, which is 20.02 percent of the total area under paddy in the state. This is largely possible because of the earlier mentioned fact of canal irrigation, as Palaghat district has large area covered by different irrigation projects. Growth of rice production in Asian countries show that irrigation is a major contributing force to output growth in the break- down of production. The irrigation contributes to increased output both through its effect on productivity (yield) and through its effect on land use intensity.

The chart 1 explains that irrigation contributes to increase production through its effect on both area and yield. Only if inputs like fertilizer and labour ore increased on land, the production would increase in terms of yield over input, and area to be covered by double cropping would increase in the gross cropped area, with an overall production going up.

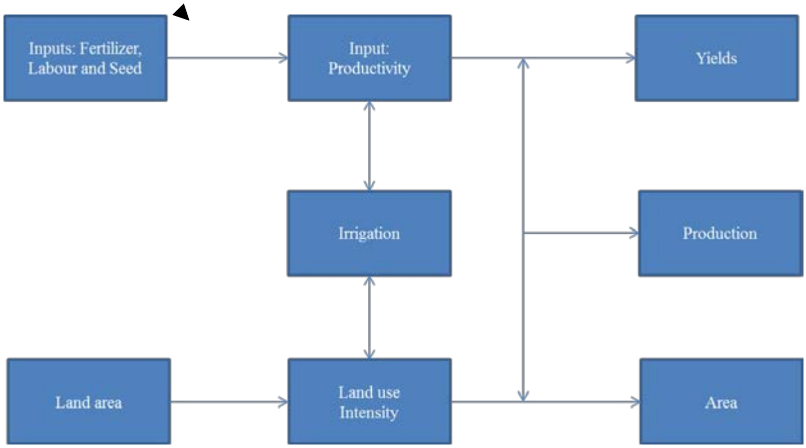

Chart 1. Effect on both Area and Yield

As far as cropping pattern is concerned both the command area and the control block rice is the only crop grown. The only difference being that the gross cropped area in the command villages exceed that of the control block. This is because of assured irrigation. Farm size plays an important role in the level of utilization of inputs which varies from that of the command area to that of the control block (table 1). In order to explain the influence of irrigation on farm size or input usage, farm manure, fertilizer ,seed, tractor, bullock, pesticides, and labour were considered, for all these the input cost across farm size with and without irrigation were looked in.

Table 1. Control and Command Villages

Control Villages		
Villages	**Total Area (in acres)**	**Cultivated Area (in acres)**
Ambalapara -I	5170.79	1379.57 (26.68)
Kongad -I	3564.22	890.07 (24.97)
Ozhalapathy	2912.39	373.97 (12.84)
Command Villages		
Villages	**Total Area (in acres)**	**Cultivated Area (in acres)**
Malampuzha -I	11658.98	1252.42 (10.82)
Kannadi - II	2899.31	1968.09 (67.88)
Pallassana	7204.83	3924.55 (54.47)

Conclusion and Findings

1. In the irrigation tract the percentage of input and output is the less by large farmers, than by the small farmers. This shows that the large farmers are most benefitted by irrigation.
2. There is a general increase of chemical fertilizer and farm manure in the irrigated tract.
3. The impact of irrigation has brought about change in cropping intensity in the irrigated tract.
4. When compared across the irrigated and un irrigated tract the increase in intensity is found to be high in large farmers
5. It is also observed that tractor s intensively used in the irrigated tract.
6. Irrigation has brought about major shift of cultivation from labour intensive to more capital intensive method.
7. Changes in the cropping pattern is not seen in the command area.

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News and Notes

THE INDIAN GEOGRAPHICAL SOCIETY

Department of Geography, University of Madras, Chennai – 600 005

Conduct of 7th Talent Test - 2017 for Geography students on 10th January, 2017

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The Indian Geographical Society is organizing the state wide **Seventh Talent Test - 2017** for final year UG and PG students of the Geography Departments in Tamil Nadu on **Tuesday, the10th January, 2017**. The Executive Committee of the Society has identified the following coordinators to organise this event successfully with the support of Principals of the respective colleges and HODs of Geography Departments.

Regional Coordinators

1**. Dr. G. Bhaskaran (Chennai Region),** Assistant Professor, Department of Geography, University of Madras, Chennai - 600 005 ***Mobile****: 9444414688,* ***email****: grbhaskaran@gmail.com*

2. **Mr.K. Balasubramani (Rest of Tamil Nadu),** Assistant Professor, Department of Geography, Bharathidasan University, Tiruchirapalli - 620 024 ***Mobile****: 9944060319,* ***email:****geobalas@gmail.com*

The Heads of the Geography Departments are requested to contact the coordinator/regional coordinators and conduct the Talent Test successfully.

General Information

1. Talent Test ***will be conducted in English language only*** for 1.30 hours consisting of 100 questions without any choice.
2. Syllabi for UG and PG talent tests are UGC NET Paper II & III respectively.
3. Final year UG and PG students of Geography are eligible for Talent Test.
4. The students should enroll their names with the concerned Head of the Geography Department on or before 06th January, 2017.
5. The co-ordinators would contact the Heads of nearby Geography Departments and send the representatives for conducting Talent Test.
6. The Head of the Geography Departments would collect the registration fee from the students of their Department and inform the coordinators accordingly.
7. Talent Test is scheduled on **10th January, 2017 (Tuesday) between 11.00 a.m. and 12.30 p.m.**

8. Registration fee for UG Students is Rs.50/- and for PG Students it is Rs.75/-. Only Cash should be collected from the interested candidates.

Details of Awards and Prizes

Prize	Award and Prize Amount	
	UG The IGS Founder Prof. N. Subrahmanyam Award	PG Prof. A. Ramesh Award
I	Rs. 5,000/-	Rs. 7,000/-
II	Rs. 3,000/-	Rs. 5,000/-
III	Rs. 2,000/-	Rs. 3,000/-

Prizes will be awarded to the winners of Talent Tests during ***National Workshop*** on Geoinformatics for Watershed Management organised during January 27 to 31, 2017 at Department of Geography, Bharathidasan University, Tiruchirappalli. All other participants will be given Certificate of Participation. Please visit IGS website for registration forms and further information: http://www.igschennai.org/

Dates to Remember

Last Date for the Enrolment: 06-01-2017 (Friday)

Date of the Talent Test: 10-01-2017 (Tuesday)

Information to Authors

The Indian Geographical Journal is published half-yearly in June and December by The Indian Geographical Society, Chennai. It invites manuscripts of original research on any geographical subject providing information of importance to geography and related disciplines with an analytical approach. The article should be submitted only through the Editor's e-mail: **editorigs1926@gmail.com**

The manuscript should be strictly ordered as follows: Title page, author (s) name, designation, e-mail ID, and telephone number, abstract, keywords, text (Introduction, Study Area, Methodology, Results and Discussion, Conclusion), Acknowledgements, References, Tables, Figures. You may refer IGS website (*www.igschennai.org*) for reference.

The title should be brief, specific and amenable to indexing. Not more than five keywords should be indicated separately; these should be chosen carefully and must not be phrases of several words. Abstract and summary should be limited to 100 words and convey the main points of the paper, outline the results and conclusions and explain the significance of the results.

Maps and charts should be submitted in the final or near-final form. The authors should however agree to revise the maps and charts for reproduction after the article is accepted for publication. Each figure should have a concise caption describing accurately what the figure depicts.

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Acknowledgements of people, grants, funds etc. should be placed in a separate section before the reference list. The names of funding organisations should be written in full.

References should be listed in alphabetical order, serially numbered at the end of the paper as per MLA format. The list of references should only include works that are cited in the text and that have been published or accepted for publication.

The manuscripts should be accompanied with a letter stating that the article has not been published or sent for publication to any other journal and that it will not be submitted elsewhere for publication. Further, the authors could also send name and address with e-mail ids and phone number of four referees to review the article.

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