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A NOTE ON CLIMATE CHANGE ANALYSIS USING GEOSPATIAL TECHNOLOGY IN WEST CENTRAL INDIA (CASE STUDY)

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Abstract: We know that in west central India Climatic spatio-temporal variations are affecting agricultural production. In this paper Sangli district of Maharashtra has been taken as a case study area during the period 1979 to 2013 (35 years). The result shows that, decadal variations in annual precipitation; the number of rainy days gradually decreased, while precipitation intensity and extreme precipitation days and extreme rainfall intensity remained relatively stable. The annual precipitation intensity trends are consistent, whereas overall average temperature also increased. Due to variations in the precipitation values during the period, different dry spell area were observed at different time scales exhibited in 35 years.

Keywords: Annual rainfall, Potential Evapotranspiration, Geospatial techniques, agricultural production.

Introduction

Drought is one of the main natural causes of agricultural, economic, and environmental damage Burton, I. R. W. Kates, and G. F. White [1]. It is very difficult to observe their characteristics in terms of intensity, magnitude, duration, and spatial extent Sergio et al [12].

An important factor affecting on plant growth is water availability, water demands, and land degradation in climate. Daily, monthly and annual distribution of rainfall in certain area, the occurrence of extreme events are happened. The lack of rain water during the growing period of plants is very important. Lands in arid and semi-arid regions are affected by climatic variations and thus lead to improper plants growth.

Large quantity of water deficit for assessing the land degradation and desertification was caused due to Climate parameters such as air temperature, rainfall, aridity index, Potential Evapotranspiration (ETo), rainfall seasonality and rainfall erosivity.Precipitation in extreme conditions will result global climate change will further enhanced the imbalance of the

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spatio-temporal distributions of water resources (Trenberth 1998; Ragab and Prudhomme 2002).

Gridded point data for 48 points covering the study area collected from Indian meteorological Department, Pune. We use geospatial technology analysis for analyzing about seven parameters such as a) annual precipitation; b) average annual air temperature, c) UNEP aridity index, d) rain erosivity, e) rain seasonality, f) wind speed and g) Potential Evapotranspiration in west central India.

Liao Y, Chen D and Xie Y. [5] ascertained different precipitation thresholds and found that the spatial distribution of precipitation in China was highly correlated with the distribution of drought and flood disasters.

Xu X, Zhang X, Dai E and Wei S [16] studied about the spatio - temporal variations in rainfall intensity across China and noticed an increase in moderate and light rain intensities, while larger than moderate rainfall intensities were relatively stable.

Ren Z, Zhang M, Wang S, Qiang F, Zhu X and Dong L [10], studied about daily precipitation data from 76 meteorological stations in the Yellow River Basin for the period 1961 to 2011, spatial trends shows that extreme precipitation index was decreased from the southeast to the northwest.

Yin.J, Yan. D, Yang Z, Yuan . Z, Yuan .Y and Zhang [18] observed and studied about the grain production for security in China. They observed that about 20.4% of the sown area, yield was 23.6% of the whole nation’s grain yield. Due to seasonal and climatic changes in china, the areas become more sensitive.

Huiping Huang, Yuping Han,Mingming Cao, Jinxi Song, and Heng Xiao. [4] Interpreted the Aridity index is the ratio of potential evapotranspiration to the Precipitation and it is an important indicator of climatic changes over the region. On basis of climate data collected from 599 stations in China during 1960–2013,

Several Geospatial techniques such as GIS technology, Morlet wavelet, Mann-Kendall test, and principal component analysis are used to investigate the temporal variation of aridity index and its impacts.

A drought is an event of prolonged shortages in the water supply, below average precipitation, surface water or ground water. Drought is a recurring feature of the climate in most parts of the world. It can have a substantial impact on the ecosystem and agriculture of the affected region and harm to the local economy. Annual dry seasons in the tropics significantly increase the chances of a drought developing and subsequent bush fires. Periods of heat can significantly worsen drought conditions by hastening evaporation of water vapour.

Deficit monsoon has become chronic with 18of the last 69 years witnessing below-normal rains. In India, since 1951, it has been observed eighteen years affected severe droughts 1951, 1965, 1966, 1971, 1972, 1974, 1979, 1981-2010 1982, 1987, 2002, 2004, 2009, 2014, 2015, 2016 and 2017, 2019. [see urls [19], [20], [21]]

Droughts are the major vulnerable threat in Maharashtra. The Deccan plateau constitutes 50 percent of the drought-prone areas of the state. Twelve percent of the population lives in drought-prone areas. About 90 per cent of the land in the state has basaltic rock, which is non- porous and prevents rainwater percolation into the ground and thus makes the area drought prone.

Materials and Methods

The main objective of the study in this paper is to identify dry spell areas using climate data so as to identify the severity of drought condition in Sangli district of Maharashtra.

Study Area

Sangli district a study area shown in Fig.1 is located in the southern parts of the State and lies between $16^0$42’ to $17^0$37’ north latitude and $73^0$42’ to $75^0$40’ east longitudes covering an area of about 8596 km^2. It is bounded on the north by Satara and Solapur districts, on the west by Ratnagiri district, on the south by Kolhapur and on the east and south east by Bijapur district of Karnataka State.

There are ten tehasils in the district viz Tasgaon, Kadegaon, Palus, Khanapur, Atpadi, Valva, Shirala, Miraj, Jath and Kavthe-Mahakal.

According to Census of India 2011, the district having 8 census towns and 728 villages. The total geographical area (TGA) of the district is 8596 km^2 which constitutes 2.81% of the total area of the state.

Sangli has a semi-arid climate with three seasons, a hot, dry summer from the middle of February to the middle of June, a monsoon from the middle of June to late October and a mild cool season from early November to early February. The total rainfall is about 22 inches (580 mm).

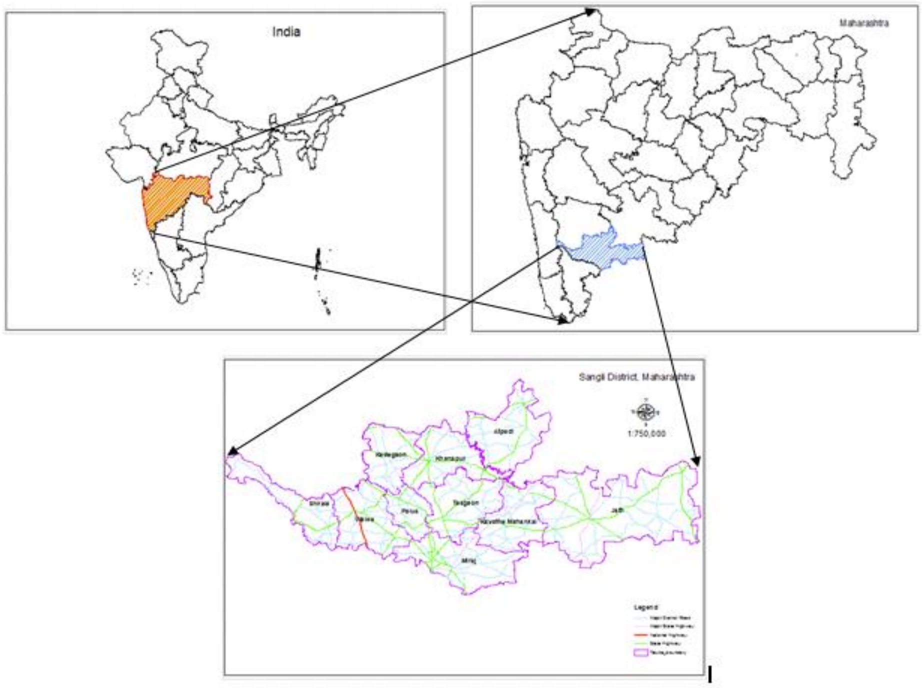

Fig. 1 Location map of the study area

Data used

Here we used data about Daily precipitation, maximum, minimum, air temperature, wind speed (at 2m above ground surface), humidity, vapor pressure collected from gridded data of (I) cell size (0.25°× 0.25°) from Indian Meteorological Department, Pune, (ii) gridded cell of size 0.31°× 0.31°air temperature and wind speed data of the National Centers for Environmental Prediction ([22], [23]) for 35 years of the period 1979 to 2013.From the available gridded climate analysis has been done for deriving seven different climate indicators to assess the dry spell areas.

Methodology

Geospatial technology including remote sensing, GIS, GPS encourages the critical analysis of vast dataset. Particularly GIS based framework offers the scientific understanding between the different dataset. In the present study Kriging tool has been extensively used to get proper spatially classified valued maps on different data layers. Fig.2 shows the different steps adopted in methodology.

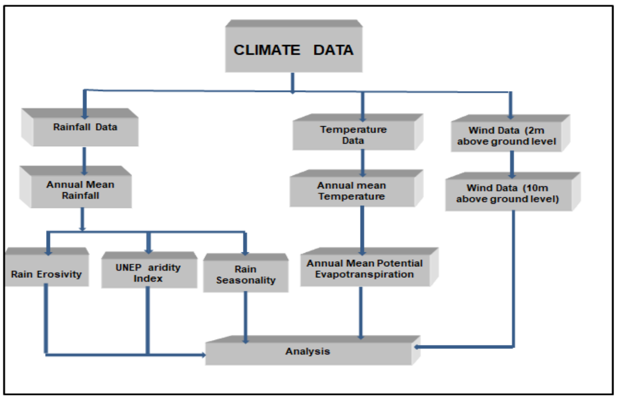

Fig.2 flow chart

1.1 Average annual rainfall

Arid and semi-arid climatic conditions with a lower amount of rainfall and higher rates of evapotranspiration will significantly decrease the soil moisture content available for plant growth causing lower biomass production (Agricultural University of Athens 2012). Average monthly rainfall of 48 points was calculated for the period 1979–2013.

The study area covering 48 points was calculated accordingly. Using spatial interpolation technique, rainfall spread across the entire area was calculated. The Following Fig.3 indicating the annual rainfall for years 1979, 1985, 1995, 2005 and 2013.

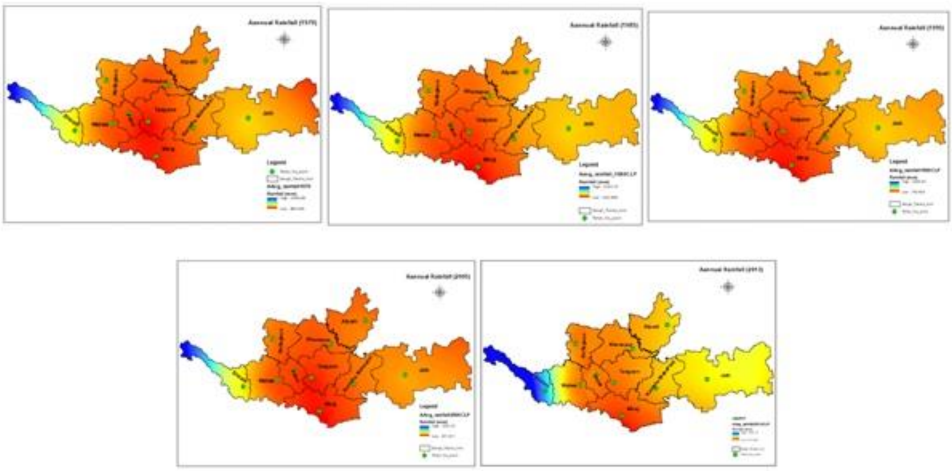

Fig.3 Annual Rainfall (1979,1985,1995,2005,2013)

1.2 Average annual air temperature

Since air temperature is a critical environmental factor in determining water stress, transpiration in growing vegetation, soil water evaporation, soil salinity and soil alkalinity [2] Higher temperature will have a negative effect on desertification. Monthly temperature was collected and annual mean air temperature (in ^{o}C) has been calculated for 48 points in the study area. Using geospatial interpolation technique database was be generated and depicted in fig.4 given below:

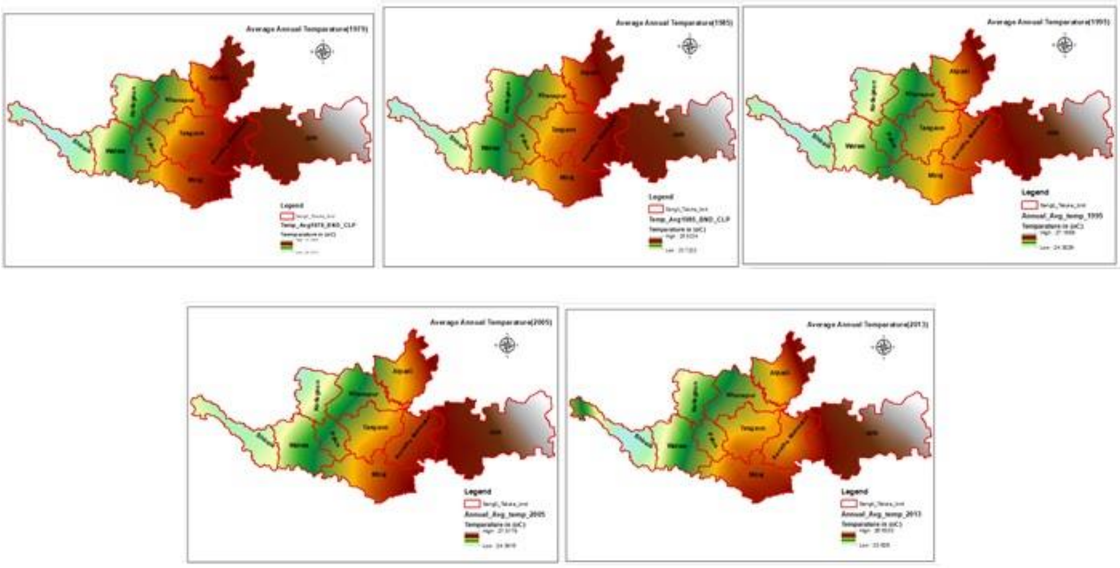

Fig.4 Mean Air Temperature

1.3Average annual Potential Evapotranspiration (PET)

Potential evapotranspiration is an important parameter for the assessment of salt affectedareas(Agricultural University of Athens, 2012). The areas under high evapotranspiration are more vulnerable to salinisation and thus lead to desertification. The purpose of including PET in the drought index calculation is to obtain a relative temporal estimation. Given below is the procedure to calculate PET(mm):

$$\text{PET (Thornthwaite, 1948 formula)} = 16K\,(10T/I)^{m} \ldots\ldots \quad (1)$$

where T is the monthly-mean temperature (8C); I is a heat index, was calculated, sum of 12 monthly index values *I* has been made.

Then PET being derived from mean monthly temperature using the formula

$$I = (T/5)^{1.514} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

m is a coefficient depending on I:

$$m = 6.75 \times 10^{-7} I^{3} - 7.71 \times 10^{-5} I^{2} + 1.79 \times 10^{-2} I + 0.492;$$

and K is a correction coefficient computed as a function of the latitude and month,

$$K = (N/12) \times (NDM/30) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Here NDM is the number of days of the month and N is the maximum number of sun hours.Annual potential evapotranspiration has shown in fig.5.

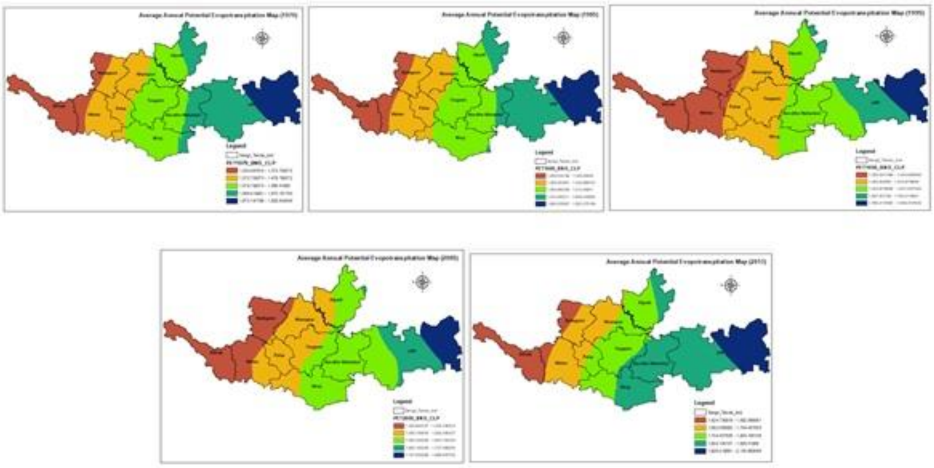

Fig.5 Annual potential evapotranspiration

1.4 Aridity index

Aridity index can be defined as the ratio between mean annual precipitation (P) and mean annual evapotranspiration (E To). The aridity index classifies the type of climate in relation to water availability. It is a critical environmental factor affecting the evolution of natural vegetation.The higher the Aridity Index of a region, greater the water resources variability and scarcity in time and more the vulnerability of area leads to desertification [2]. United Nations Environmental Programme (UNEP) aridity index (UNEP 1997) was calculated for the period 1979–2013 using equations (4) as follows and average annual Aridity has been expressed in fig.6

UNEP Aridity Index:

$$\text{Aridity index} = \frac{\text{Average annual rainfall (mm)}}{\text{Average annual PET (mm)}} \qquad \ldots\ldots \quad (4)$$

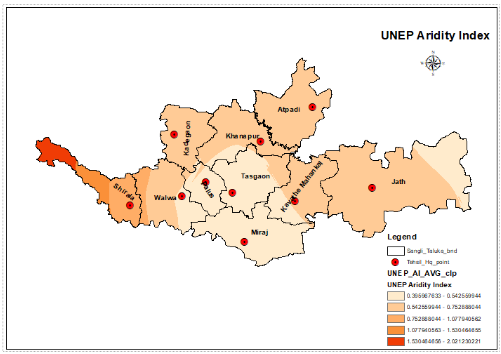

Fig. 6UNEP Aridity Index

Table 1. Aridity index classes and their description

Class	Description
> 0.65	Humid
0.50 – 0.65	Dry sub-humid
0.20 – 0.50	Semi arid
0.05 – 0.20	Arid
< 0.05	Hyper arid

1.5 Calculation of Average wind speed

Increase in the wind speed above the critical limit will cause land degradation and desertification in arid and semi-arid regions. When the terrain is sufficiently dry and significant proportion of the natural vegetation, especially the annual vegetation is dead. As rain moistens, it provides a greater resistance to the wind. Suppose new plants start sproutingthe resistance. As the wind speed used in the study was measured at 2 m height, it was converted to the standard height of 10 m using the equation given by FAO as follows:

$$u_{10} = \frac{\ln (67.8 \times 10 - 5.42) \times u_2}{4.87} \qquad \ldots\ldots (5)$$

where u_{10} and u_2 are the wind speeds (m/s) at 10 m and 2 m above the ground surface, respectively. Following table shows the wind severity and its effect on crop in the study area.

Table 2: Wind Speed ranges

Range of wind speed at 10m height	Description
0 - 2	Slight effect on crop
2 - 3.5	Moderately effected the crops and cropland
3.5 - 4.5	Severely effected
> 4.5	Very severely effected

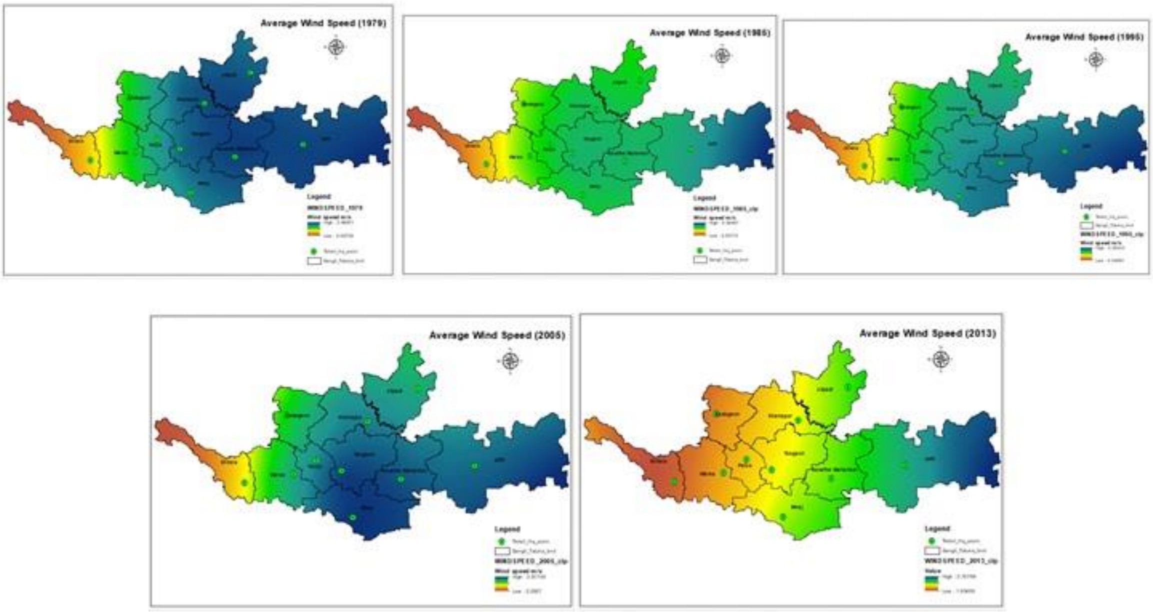

Fig.7 Wind Speed

1.6 Calculation of *Rain seasonality*

Rainfall seasonality is depending on the temporal distribution (monthly). It affects soil erosion, plant species composition and growth rate. Very high inter-annual rainfall and sudden and high-intensity rainfall variability causes long drought [2].

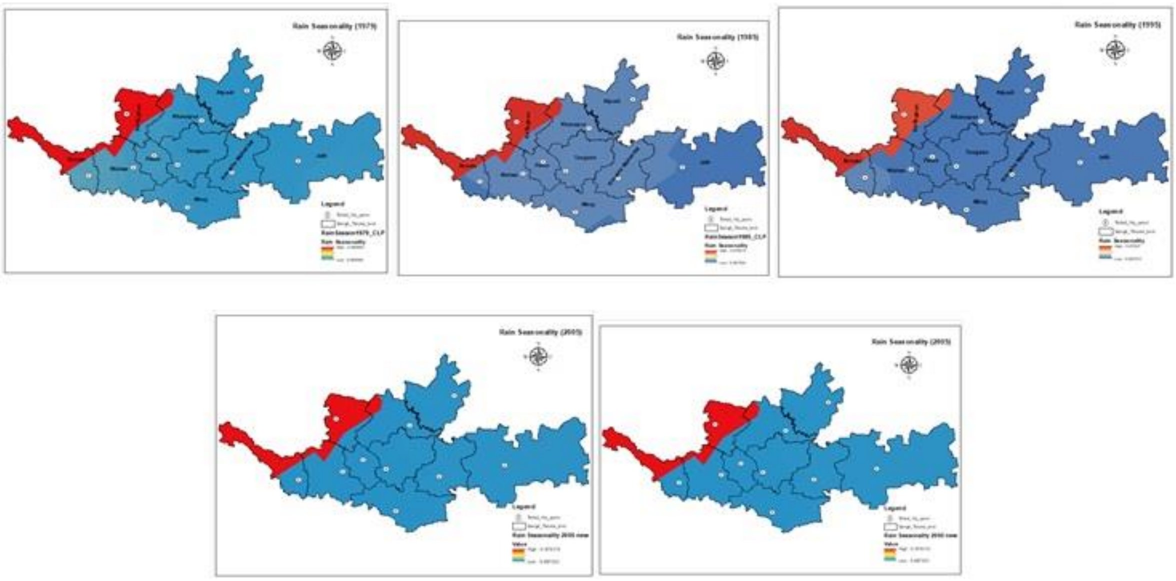

Fig.8 Rain Seasonality

Hence, higher rain seasonality will give a negative effect on desertification. Rain seasonality (SL*i*) was calculated for the period 1979–2013 using equation (6) [2] as follows:

$$SL_i = (1/R_i) \sum_{n=1}^{12} \left| X_{in} - (R_i/12) \right| \qquad \ldots\ldots\ldots\ldots(6)$$

Where *Ri* s the total annual precipitation for a particular year (mm) and *X in* is the monthly precipitation for month *n* (mm). Ranges of the Rain seasonality described as shown in table.3

Table 3: Rain Seasonality

Range	Description
< 0.20	Precipitation spread throughout the year
0.20 – 0.40	Precipitation spread throughout the year, but with a definite wetter season
0.40 – 0.60	Seasonal with short drier season
0.60 – 0.80	Seasonal
0.80 – 1.00	Marked seasonal with long dry season
1.0 – 1.20	Most precipitation in < 3 months
> 1.20	Extremely seasonal

1.7 Calculation of *Rain erosivity*

Rainfall erosivity is the sum of the ratio of Square of the total monthly precipitation to mean Annual precipitation (mm). Rainfall erosivity depends primarily on rainfall intensity and amount of total rainfall. High-rain erosivity indicates the greater erosive capacity of the overland water flow. Therefore, the high-rain erosivity will lead to high risk of desertification. It was calculated monthly and accumulated annually. Using modified Fournier index (FI) Rain erosivity was calculated for the period 1979–2013 using equation (4) (Agricultural University of Athens 2010a) as follows:

$$FI = \sum_{i=1}^{12} Pi^2 / p \qquad \ldots\ldots\ldots\ldots\ldots(7)$$

Where Pi is the precipitation total in i^{th} month , and p is the mean annual precipitation total (mm). The Fournier index is then classified as follows:

Table 4: Rain erosivity and classification

Description	Range
Very low	< 60
Low	60–90
Moderate	91-120

High	121-160
Very high	>160

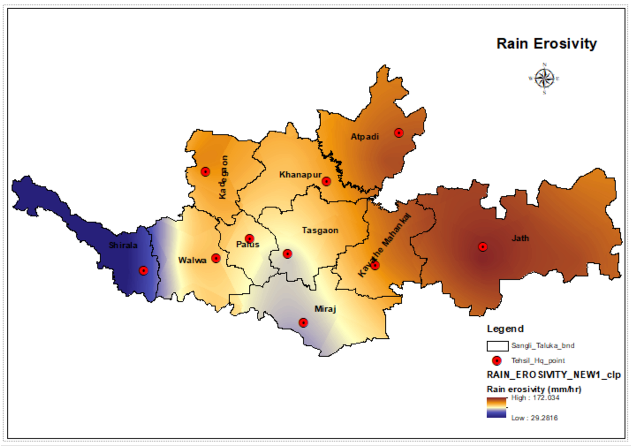

Fig. 9. Rain erosivity in Sangli district, Maharashtra

1.8 Results and discussion

Using spatial techniques, seven different parameters were calculated. Annual precipitation for 48 points is calculated and the results depicted in the form of maps. First and the foremost parameter annual average precipitation is concern, there were drastic variations in the annual precipitation, ranges from 285mm to 750mm and figure 2 shows, more than 60% of the TGA. Annual mean temperature has increased for the period 1979 – 2013. Therefore, degree of dryness will be more.

Potential Evapotranspiration data has proved that, one tehsil namely Jath was very severely affected, 2 tehsils Atpadi and Kavathemahankal and parts of Tasgaon was also affected severely. Whereas parts of Miraj tehsil and parts of Khanapur are moderately affected due to less amount of rainfall and other climatic conditions. UNEP has derived formula for Aridity Index, it has five ranges for different regions. Data has been organized, calculated and depicted using geospatial techniques, the results depicted in map proves that, the study area has scarcity of water. But most of the area was affected by water scarcity was moderate to severe.The rain seasonality was also analysed for the entire area and for period mentioned therein, Most of the precipitation has occurred seasonally i.e. from mid of June to September.

As per the available data, wind speed at 10m above ground level was calculated using the formula (5) and resulted depicted in the form of maps as shown in fig.6 clarified that, there are climatic changes during the period 1979-2013. Rain erosivity is the water flow of a region or an area. The results clarified that, about 80% of the areas are affected moderate to severely and that leads to severe drought or desertification. In brief, that author(s) feels that, majority of the area falls under DPAP area, due to climatic variations. Hence all seven climatic parameters are essential to evaluate the water intensity of the study area.

Conclusions

The study analysed seven climate parameters using geospatial techniques. The methodology revealed the risk areas and threat from water severity and its associated effect responsible to leads desertification. The parameters shows there should be a proper action plan for the Drought prone areas and it is suggested that cropping pattern should be on rotation basis. Otherwise the area may severely face water scarcity.

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