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SPATIAL DROUGHT MONITORING IN THAR DESERT USING SATELLITE BASED DROUGHT INDICES AND GEO-INFORMATICS TECHNIQUES

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Abstract: Drought is a continuous process in Thar Desert Pakistan. It is required to assess the extent of this drought for future land use and adaptation. The effect of previous drought was studied on vegetation cover of Thar area, through combined use of drought indices and geographic information (GIS) techniques. Five years (2002, 2005, 2008, 2011 and 2014) were selected to analyze the drought conditions and land use pattern of Thar area. The drought indices used in this study included Normalized Difference Vegetation Index (NDVI) and Standard Precipitation Index (SPI). Images of past drought were compared with post drought images of our targeted area and land use maps were developed for spatio-temporal analysis. The results of the study revealed that vegetation in Thar showed an improving trend from 2002 to 2011 and then again began declining from 2011 till 2014. The rainfall occurred at below average rate and SPI values for each year were calculated to be negative, indicating below average rainfall. This actual precipitation data was then compared with the data obtained from TRMM satellite and R2 as well as Pearson correlation coefficients were calculated. The R2 values for the years 2002 & 2014 were 0.519 and 0.670 respectively. In the same manner, the values of Pearson correlation coefficient for the years 2002 & 2014 were 0.721 & 0.867 respectively. The results showed TRMM satellite's over-estimation in calculating rainfall data. Further, average temperature for five years under study was analyzed by graphical representation and it was revealed that temperature of Thar has increased by almost 1oC during the last decade.

Keywords: Drought Indices, MODIS, TRMM, Meteorological Data.

1. Introduction

Droughts is a natural phenomenon which can be caused due to many factors like insufficient precipitation, high temperature, high evapo-transpiration, depletion of ground water and exploitation of water resources etc. [1]. Being a normal part of the climate, drought can occur almost anywhere on earth. It usually exists in areas which experiences less than normal precipitation over a pro-longed duration of time, usually months and years [2].

Like many other parts of the world, most of the area of Pakistan is under extreme drought attack. Presence of drought for a longer period of time is extremely harmful and is challenging towards agriculture, livestock, lifestyle and health of humans, food security, water management, forestation and various others [3]. According to a report issued by the Economic Survey of Pakistan, drought is one of the factors responsible for poor growth performance in the country [4]. The main cause of drought in Pakistan is due to the failure of occurrence of rain in the monsoon season.

Remote sensing platforms can provide large amounts of data quickly and inexpensively relative to other means of collection and GIS can bring together vast amounts of information from a wide variety of sources and make the information quickly visible and applicable in emergency situations [5]. The data is mostly available in digital form i.e. remote sensing images, digital elevation model (DEM), field data of Global positioning System (GPS), data integration is a common method used for analysis and interpretation. Environmental, urban, precision farming, and agriculture are applications that have benefited from this integration [6].

The impacts of drought monitored by [6] in Great Southern Plains of the US. The values used in this study are the NDVI values which have been obtained from Terra Moderate Resolution Imaging Spectro-radiometer (MODIS) of the year 2001 and the LST (Land Surface Temperature) values. Another study carried out by [7] to develop relationship between meteorological drought indices from all 254 texas counties and Vegetation Condition Index (VCI) during 18 growing-seasons (March to August, 1982–1999). The results shows that environmental factors is a major hurdle that did not produce reliable relationship between VCI and metrological data and care must be taken during consideration in the study. Agricultural drought monitoring worked conducted by [8] in Indonesia. Satellite-borne remote sensing data are tested for monitoring drought extent in about 184.486 ha. The results revealed that vegetation health index fall more than half from 30.86 in 2000 to 14.66 in 2015. The severity mainly linked with by rising land surface temperature from 27°C in 2000 to 40°C in 2015 as well as decreasing tendency of NDVI values which causes agricultural fields more susceptible to drought.

Similarly different vegetation and drought indices were employed for drought estimation. Rasheed and [9-13]. However, a limited study is available in data scare region like Thar Desert. Therefore keeping in views importance of drought assessment, an effort is made to check spatial distribution of drought in Thar Desert using satellite based drought indices. The second objective of this study is to analyze the effect of drought on land use change within the Thar Desert.

2. Materials and Methods

2.1 STUDY AREA

The Thar is located approximately between Latitudes 24°15′N and 25°45′N and Longitudes 69° 45′E and 70° 45′E in the southern part of Sindh Province as shown in Fig.1. Most of the Thar Desert is situated in the Sindh province and is one of the biggest deserts of the world. Of the time it runs short of tears to express the pains of suffering and sorrow from frequently arrived drought. The desert area of Tharparkar district, generally known as Thar, consists of the talukas of Mithi, Chachro and Nagar and parts of the Diplo and Umerkot talukas.

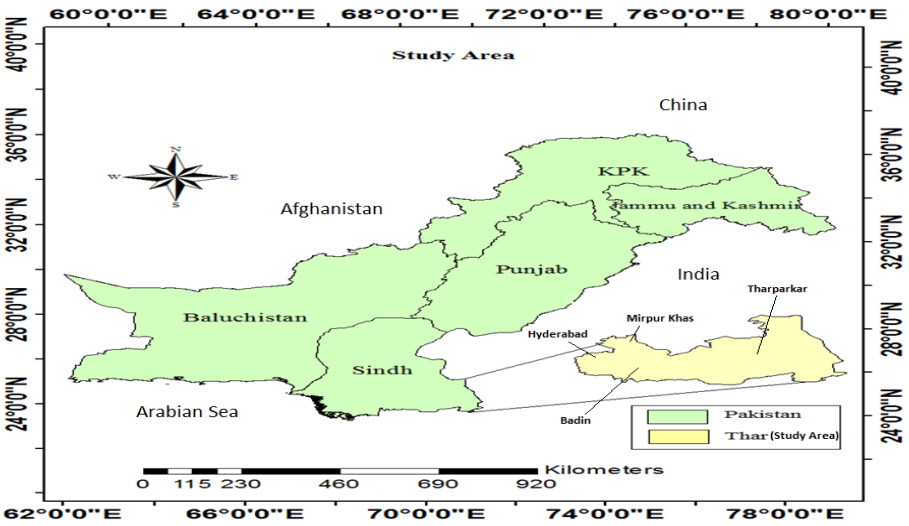


Figure 1: The Administrative Boundary of Thar Desert, Pakistan

The total area of the desert is 22,000 square kilometers and the population is between 0.7 and 0.8 million. The animal population is estimated at 1.5 to 1.8 million. Except for the south-eastern part of the Nagar taluka, the desert consists of sand dunes between which are flat plains where agriculture can take place.

2.2 MODIS Data:

MODIS 250 m vegetation data was employed for estimation and for mapping the presence of drought. For drought forecasting, we used a time series of 8-day composite clear-sky MODIS product MOD09Q1, tile numbers h24/v05, h24/v06 from 2013-14 and 2002-03 which were mosaicked together, masking, reprojection and subset to the area and converted into vegetation index respectively.

2.3 Climatic Data

The metrological data including Precipitation data and Temperature Data (minimum & maximum) is obtained from Pakistan Metrological Department for the year 2002 and 2014 to monitor the effects climatic parameters on vegetation change.

2.4 Drought Indices

The Normalized Difference Vegetation Index (NDVI) and Standard Precipitation Index (SPI) were used in this study to montinor spatial variation of drought in Thar Desert. NDVI is an Index of plant "greenness" or photosynthetic activity, and is one of the most commonly used vegetation indices to analyze health status of crop [14].

$$\boldsymbol{NDVI = (NIR - RED)/(NIR + RED)} \qquad \textit{(eq. 1)}$$

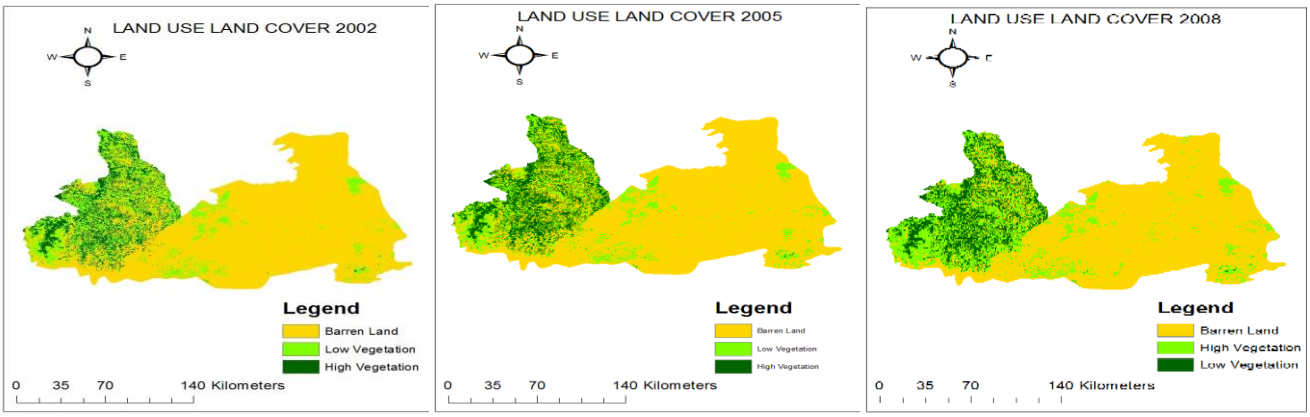
SPI is given as the ratio of difference between the normalized seasonal precipitation and its long-term seasonal mean to the standard deviation. It is calculated for different time scale with precipitation as the only input parameter.

$$\boldsymbol{SPI = \frac{X_{ij} - X_{im}}{\sigma}} \qquad \textit{(eq. 2)}$$

3. Results and Discussions

3.1 Land Use Land Cover Classification:

The spatial map of land use land cover classification using MODIS for the years 2002,2005,2008,2011 AND 2014 are described in Fig. 2 to understand the change detection occurred in the Thar Region.



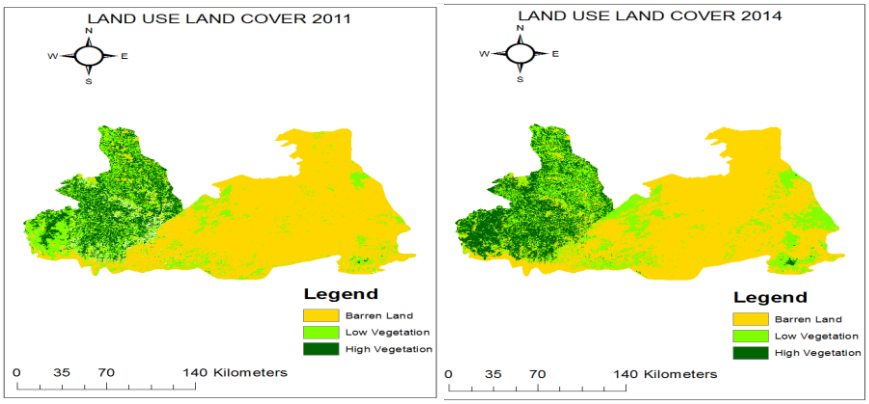


Figure 2: Comparison of Land use/Land cover classification based on MODIS from (2002 to 2014)

The Figure 2 showed 15 years land use land cover classification with 3 years intervals. The Land use land cover maps indicate that vegetation cover in Thar Desert showed as improving trend from 2002 to 2011 and then again declined in the year 2014. This indicated the presence of drought in Thar till date. The summary of classified area is described in Table. 1

Table 1: Summary of LULC Change in Thar Region

Year	Area (mha)		
	Barren Land	Moderate Vegetation	High Vegetation
2002	2.736	0.595	0.379
2005	2.667	0.597	0.445
2008	2.476	0.789	0.445
2011	2.350	0.791	0.570
2014	2.638	0.649	0.423

As evident from the table 3.2 that most of the part of Thar showed barren land. In the year 2002, due to high temperature throughout the year and extreme shortage of rainfall, the total barren land was approximately around 2.74 mha. A very low vegetation including shrubs etc. were present on the land measuring 0.595 mha. Dense vegetation was present on western part of Thar on a total land of 0.379 mha. Year 2014 is showing an improving trend in vegetation as compared to the year 2002 and thereby displaying an increase in vegetative cover. The barren land has declined down to 2.182 mha. The low vegetative cover in 2014 covers a total land area of 0.901 mha. The high vegetative cover present on the eastern side of Thar has showed an improvement and is now covering a total area of 0.627mha. This situation indicates that over the years, the drought area of Thar is showing an improving trend but there is still presence of drought in the central and western parts of Thar which needs proper addressing and attention.

3.2. Rainfall Pattern of Thar

The rainfall data of Thar was obtained from Pakistan Meteorological Department for the years 2002 and 2014. The variation of rainfall in Thar and its adjoining areas are shown in Fig. 3.

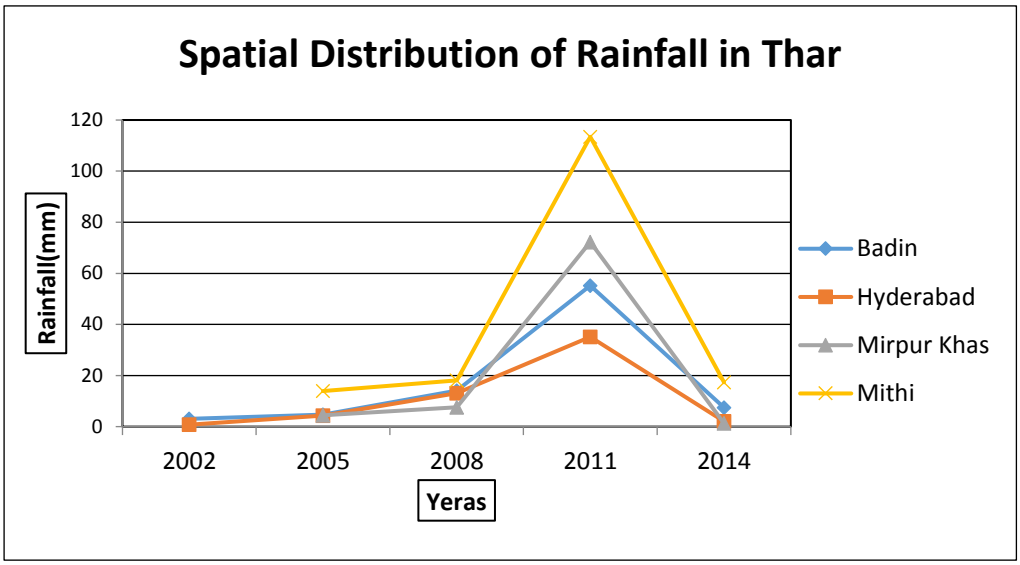


Figure 3: Average Precipitation in adjoining districts of Thar from 2002 to 2014

The graphical representation of the data shows that precipitation trend in Thar Desert has improved over the past couple of years and this is the main reason for declining barren land and increasing vegetation area as discussed in the previous section. While comparing both years under observation, the overall precipitation trend seems to be increasing but still the average rainfall is at a much lower side compared to normal average precipitation necessary for an agricultural area.

3.3 Rainfall Data Validation at district level year 2002 and 2014

A comparison was done at district level by comparing rainfall statistics of that district and result extracted from the Tropical Rainfall Measuring Mission (TRMM) Satellite and presented in Figures. 4(a) and 4(b).

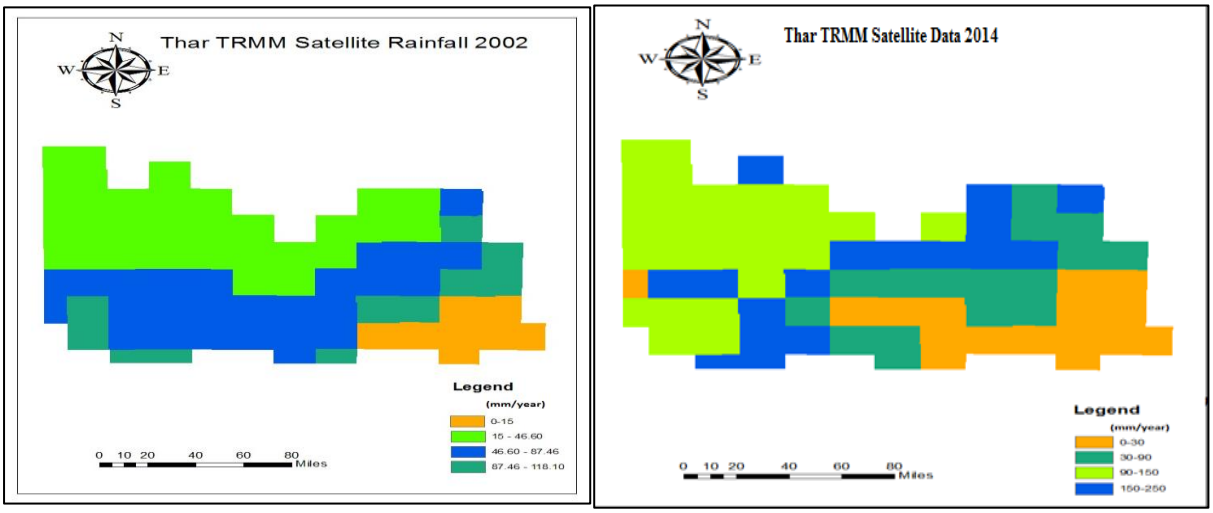


Figure: 4(a) Relation between Reported and TRMM (2011) and Figure 4(b) Relation between Reported and TRMM Rainfall

The gepspatial analysis of rainfall in Thar region is shown in Figure 4(a)(b). It is observed rainfall intensity is decreased in last 12 years which indicated the occurance of drought conditions. Moreover, According to FAO, an area where the average rainfall is below 200mm is considered to

be drought prone area. As evident from above graphical representation, all areas of Thar received below average rainfall in the year 2002.

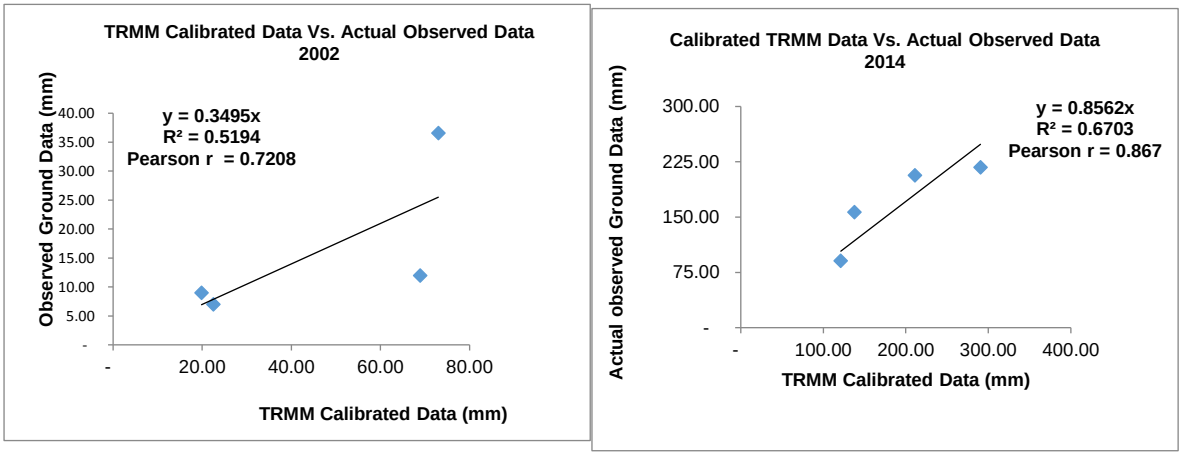


Figure:5 (a) and 5(b) Representation of TRMM Satellite Rainfall in Thar and adjoining areas for the year 2002 and 2014

Figure 5(a) and 5(b) showed the relationship between the actual observed data received from PMD and TRMM satellite data. A higher relationship was observed between TRMM and observed rainfall for year 2014 as compared to 2002 with R2 and Perason coefficient are 0.662 and 0.897. The difference between R^2 could be due to low pixel and temporal resolution information and non-schematic approaches of departments to collect meteorological the data.

3.4 Average Temperature of Thar

Temperature data was also obtained from Pakistan Meteorological Department for the years 2002 and 2014. The graphical representation of the data shows that average temperature has increased by minute amounts in the districts Badin and Mithi. While temperature showed a declining trend in the districts Hyderabad and Mirpur Khas. The spatial distribution of temperature from 2002 to 2014 is described in Fig.6

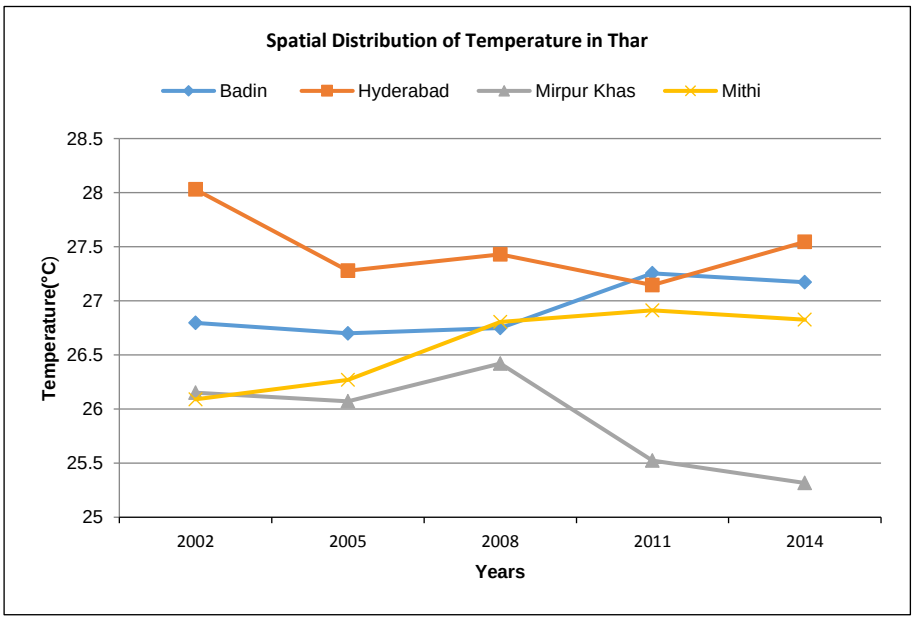


Figure:.6 Mean Annual Temperature in Thar Desert (2002 & 2014)

Temperature data obtained from PMD in Figure 6 showed that there is a rise in average temperature in Badin, Hyderabad and Mithi districts of Thar while there is drop in tempetaturte observed in the district Mirpur Khas. The above normal temperature, however, still indicates the presence of drought in Thar.

4. Conclusion:

The spatial distribution of drought over Thar Desert was studied using NDVI Index. Land use land cover maps indicate that vegetation cover in Thar Desert showed as improving trend from 2002 to 2011 and then again declined in the year 2014. This indicated the presence of drought in Thar till date.The precipitation data obtained from PMD showed that the precipitation occurred at below average level. The values of SPI were also calculated to be negative which indicated absence of adequate rainfall in Thar. However, the precipitation trend seemed to have improved while comparing 2014 with 2002. The actual precipitation data was compared with TRMM satellite data. The results revealed over-estimation of TRMM in calculating the rainfall data. The further more research will need on drought indices by incorporating other factors like soil condition, temperature and fertility of land and ground water level.

5. References

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