Spatio-temporal Analysis of Land Surface Temperature and Vegetation index in the Drought prone area of Bolangir District of Odisha

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Abstract-*Land surface temperature (LST) could be a key parameter for surface energy balance and concrete meteorology studies. LST is plagued by the characteristics of the land surface like vegetation cowl and its kind, land use-land cowl and surface impenetrability. Incessant urbanization has resulted in several fold increase within the geographical region and it's caused vital changes within the land surface. The distinction in altitude of 2 points, that are placed on totally different elements of a massive study space, is also giant. The aim of this study is to analyze the result of amendment in elevation over LST. LST knowledge from Moderate Resolution Imaging Spectro radiometer (MODIS) and digital elevation model from ASTER are used. Consistent inverse linear trend is discovered between LST and elevation for all the study seasons.*

Keywords-Land Surface Temperature, NDVI, MODIS

INTRODUCTION

The growth and development of vegetation is primarily controlled among others by precipitation and temperature and thus climate is considered as the ultimate ecological controller. NDVI (Normalized Difference Vegetation Index) data set has been used universally to study vegetation conditions, and their relationship with climate variation. Hence, relating vegetation attributes using NDVI to seasonal variation in climate provides a valuable input to understand and characterize the effect of climate on vegetation growth. Also, relationship between time series NDVI and rainfall provides useful information for drought monitoring and development of famine early warning system in regions with sparse terrestrial rainfall networks. The MODIS LST (Land surface temperature) products are created as a sequence of products beginning with a swath (scene) and progressing, through spatial and temporal transformations, to daily, eight-day and monthly global girded products. LST is a key parameter in land surface processes, not only acting asana indicator of climate change, but also due to its control of the upward terrestrial radiation, and consequently, the control of the surface sensible and latent heat flux exchange with the atmosphere. For example, energy exchanges at the land-surface boundary are largely controlled by the difference between the skin temperature and the surface air temperature, the air and the surface reacting with different time and space scales to external forcing while still being complexly interconnected. Satellite imagery was comprehensively applied to monitor and assess vegetation dynamics, drought condition, land surface moisture, cropping system and desertification. Vegetation indices are useful for detection and monitoring large area vegetation stress resulted from drought or soil over saturation following flooding and excessive rains. The combination of NDVI and land surface temperature provides information on the vegetation and moisture status Thee scatter plot of remotely sensed temperature and spectral vegetation index often exhibits a triangular (Carlson, 1994) or trapezoidal (Moran, 1994) shape and is called the NDVI-Ts space if a full range of fractional vegetation cover and soil moisture content is represented. The objectives of MODIS mission is to improve predictions and characterizations of natural disasters like droughts and as a next generation scientific satellite sensors, MODIS has particular advantages over NOAA AVHRR for land surface temperature detection and biomass estimation. Taking advantage of these characteristics, MODIS is expected to determine land surface temperature accurately and by integrating MODIS thermal infrared data into land surface monitoring can address two main problems in current drought monitoring schemes. First, accurate temperature observations from remotely sensed data can overcome very coarse spatial resolutions of weather stations at relative low costs and secondly it can be an appropriate tool for real time drought monitoring, which has not been successfully accomplished by current remotely acquired measures, such as vegetation indices, due to a lagged vegetation response to drought (Park, 2004).

It has been long recognized that atmospheric and land surface processes are correlated with each other. Climate and meteorological processes determine land surface characteristics such as the vegetation distribution, energy balance, and watershed hydrology (Neilson 1986; Lu et al. 2001). Land surface processes in turn affect atmospheric temperature, humidity, precipitation, and radioactive transfer (Lu et al. 2001, Weiss et al. 2004). Meteorological and climatologically conditions both impact and are influenced by vegetation distribution and dynamics (Sellers et al. 1996; Betts et al. 1997; Bounoua et al. 1999). Satellite sensor data have been playing an increasingly important role in monitoring drought-related vegetation condition. Because of the close relationship between vegetation vigor and available soil moisture, especially in arid and semiarid areas, satellite derived Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) products have been used to evaluate drought conditions.

- **OBJECTIVES**

The objective of this study was to analyses the spatio-temporal dynamics of MODIS Land surface temperature and Normalized vegetation index over a period of eleven years and to compare effectiveness of satellite derived drought indices applied to drought assessment in normal and drought years. The specific objectives are as follows:

1. Land use land cover and NDVI mapping of the whole district.
2. To study the spatial and temporal dynamics of land surface temperature.
3. To study the spatial and temporal dynamics of vegetation index.
4. Computation of indices to characterize of vegetation anomaly in a drought and normal year.
5. To study the correlation of NDVI and rainfall.
6. To study the correlation of NDVI and land surface temperature

- **STUDY AREA**

Bolangir district is situated in the valley of rivers Ang and Tel, which are having important tributaries like Lanth, Sonegarh and Suktel. The district is flanked in the North West by the Gandhamardhan Hills and the north east by the rock infested Mahanadi. The district was formed on 1st Nov, 1949. Sonepur was carved out as a separate district in 1993. The district is bounded by

- Sonepur in the east
- Nuapada in the west
- Kalahandi in the south
- Bargarh in the north

The district is named after the headquarter town of Bolangir which lies between
20° 11'40" - 21° 05'0S" North latitude.
82° 41'15"- 83° 40'22" East longitude.

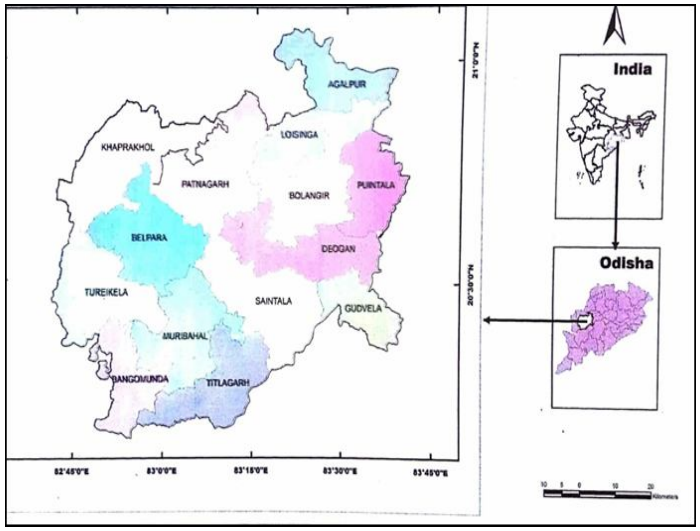


Figure1. Base map of study area

Materials and methods Materials

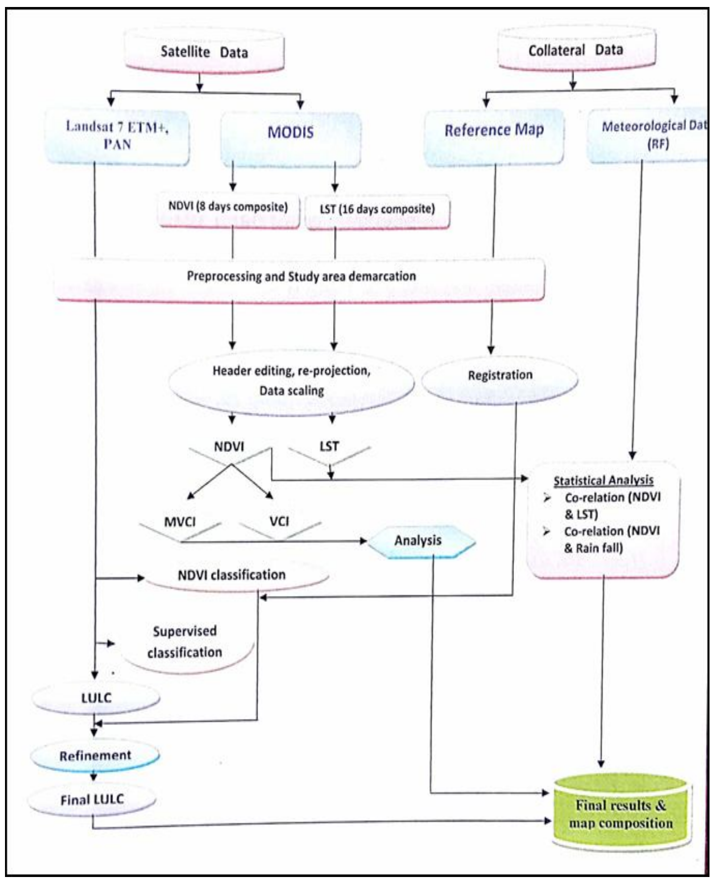


Figure 2. Flow chart showing the Methodology

Collateral data

- Survey of India topographical sheet No.64P, 640 and 64L of Balangir on 1:25,000.
- The meteorological data lias been collected for Bolangir station. The parameter includes rainfall data of Bolangir District for the period of2004 to 2011.

Satellite Data

- Landsat7 ETM+ 30 meter and Panchromatic 15 meter resolution data for study area delineation and land use, land cover mapping.
- Moderate Resolution Imaging Spectro-radiometer (MODIS) value added product of NDV1 and night time LST for 16 and 8 day composite respectively during 2001 and 2011.

Landsat7 (ETM+ and Panchromatic) satellite data characterization

The Enhanced Thematic Mapper Plus (ETM+) instrument is a fixed "whisk-broom", eight- band, multi spectral scanning radiometer capable of providing high-resolution imaging information of the Earth's surface. It detects spectrally-filtered radiation in VNIR, SWIR, LWIR and panchromatic bands from the sun-lit Earth in a 183 km wide swath when orbiting at an altitude of 705 km.

Landsat 7 ETM+ data are acquired at three different resolutions. The multispectral bands (bands 1-5, 7) are collected at 30 meters, the thermal band (band 6) is collected at 60 meters, and the panchromatic band (band 8) is collected at 15 meters.

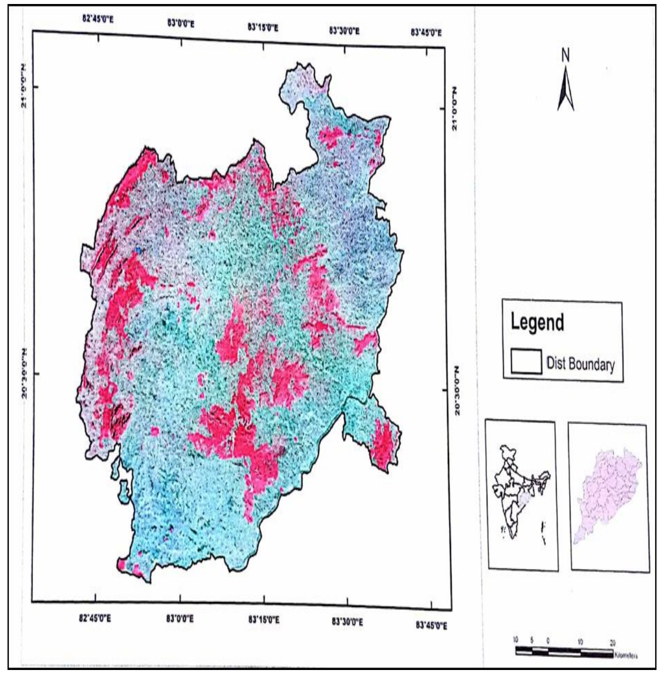


Figure 3. Satellite Image of Study Area(Landsat Panchromatic,2001)

Moderate Resolution Imaging Spectro-radiometer (MOD IS)

MODIS is an earth observing system (EOS) instrument on board Terra and Aqua platforms, launched in December 1999 and May 2002 respectively. The sensor scans ±55° from nadir at an altitude of 705 km in 36 spectral bands with instantaneous field of view (IFOV) of 250 m to I km respectively at nadir with bands I to 19 and 26 in visible and NIR range and rests are in TIR region (3-15 pm). 1:30 hr, 10:30 hr, 13:30 hr and 22:30 hr.

The thermal infrared signature received by satellite sensors is determined y temperature, surface emissivity.

Table 1. Data set characteristics of MODIS

1	Area coverage	1100 x 1100 km
2	Image dimension	1200 x 1200 (row / column)
3	Spatial resolution	1 km (~ 926 m)
4	Projection	Sinusoidal
5	Data format	HDF-EOS

MODIS Land Surface Temperature (LST) product

The split window method uses two spectral close bands in the thermal infra-red wavelengths, and assumes that the differential radiance between these bands is a linear function of the atmospheric absorption at those wavelengths (due primarily to water vapor). The emissivities in MODIS bands 31 and 32 are inferred from the land cover types based on T1R BRDF models that simulate the scene emissivity from the proportions, surface structures and spectral emissivities of the components in the scene. The day / night LST method retrieves land surface temperature and band emissivities simultaneously from pairs of daytime and nighttime MODIS data in seven TIR bands.

Table 2. Area for different Land use/Land cover classes

Land use Land cover classes	Area in sq. km_
Forest	1121.91
Forest blank	12.53
Built up	110.5
Waste land	395.48
Fallow land	90.82
Scrub land	500.77
Moist land	120.42
Water body	77.23
Agriculture	3892.82
Sand	24.11
River	115.51
Total	6462.1

Spatiotemporal dynamics of LST

Zonal statistics were extracted for 8 day composite MODIS Terra derived land surface temperature. The week wise mean. maximum and minimum land surface temperature data for the year IOOI-Z01 l.The temporal profiles of mean. maxllttumflld minimum land surface temperature is presented in (Fig. 4.5 and 6). The spatial average of all these data is calculated through a programme written in spatial modeller in ERDAS and the result is presented in(Fig 7).lt is found from the above mentioned figures that the meanLST follows almost a plateau with minor fluctuation up to I29 DOY after which a sharp rise occurs. the peak is arrived at around I66-l93 days. The mean LST curve then decreases and again follows a plateau. The temporal trend of maximum LST also more or less same as that of mean LST though LST minimum does not follow any specific pattern as the weekly variation is very significant specially in the summer and monsoon. The post monsoon weekly variation in LST min is not that much significant for all the years. in the month of january. the highest LST of28-3l °C observed at the southern and south west part ofthe district (Fig.7) which increases gradually over the months and attains a value 0f> 45 °C just before the onset of monsoon. Due to cloud cover some data are missing during the months of July and August. The LST value is also higher in the southern and S W part in the post monsoon period also. The LST of the above mentioned area remains at around 28-32 °C during themonth of December.

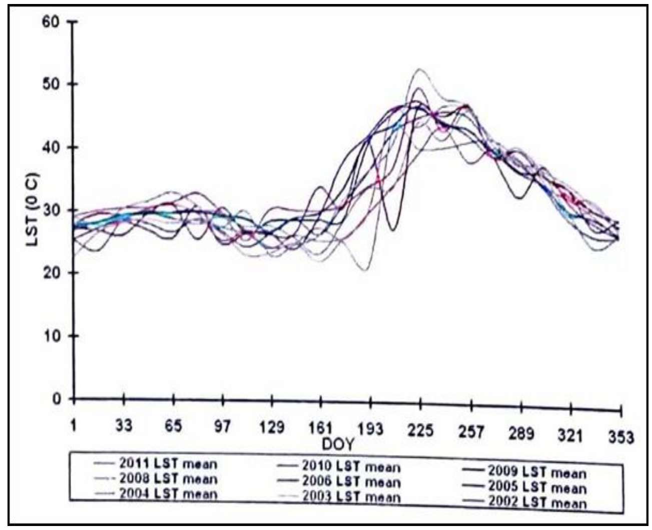


Figure 4. Temporal profile of LST Mean

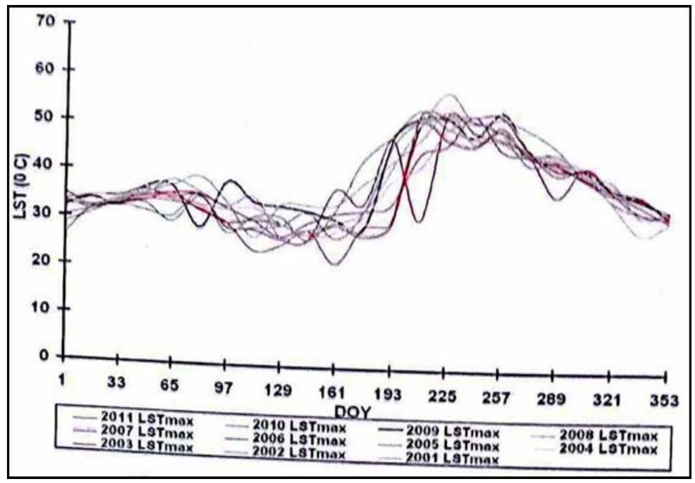


Figure 5. Temporal Profile of LST Maximum

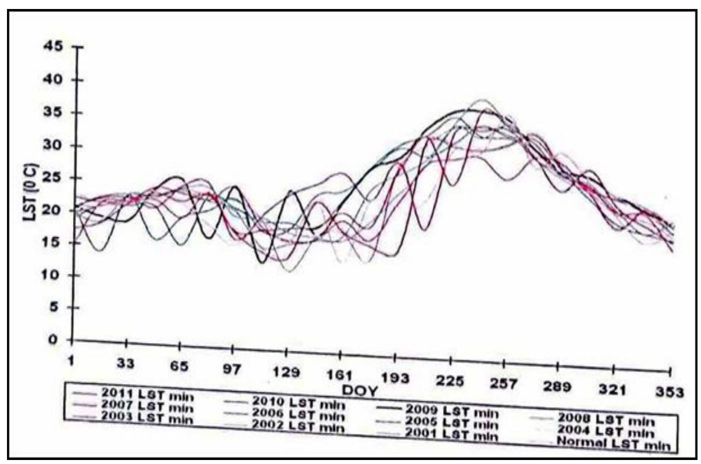


Figure 6. Temporal Profile of LST Minimum

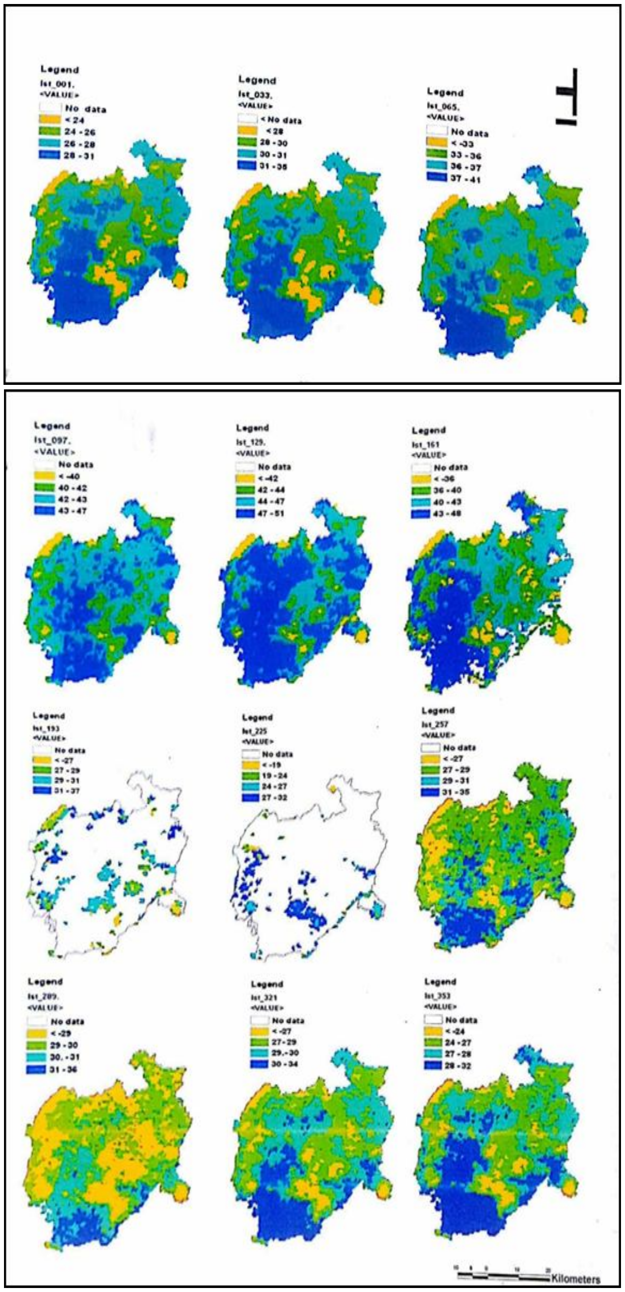


Figure7. Spatial profile of LST MEAN

Spatio- temporal dynamics of NDVI

Zonal statistics were extracted for 16 day composite MODIS Terra derived Normalized Difference Vegetation Index (NDVI). The mean, maximum and minimum NDVI data are presented for the year 2001-2011. The temporal profiles of mean and maximum NDVI is presented in (Fig.8 and 9). The spatial average of mean NDVI for all the time period is calculated through a programmer written in spatial modeller in ERDAS and the result is presented in (Fig.10.) The mean NDVI remains above 0.3 throughout the year and for most years except 2004,2006 and 2009,the curves follow the same pattern with minimum NDVI at around 129 DOY which gradually increases and reaches the maximum value at around 260 days and again gradually falls to the minimum value. NDVI mean for 2004.2006 and 2009 follow a reverse trend which might have correlation with rain fall pattern. It is observed from the (fig.10) that the southern portion of the district is having sparse vegetation throughout the year. The least vegetation cover is observed just at the onset of the monsoon and the highest vegetation cover is observed in the month of September following monsoon. The southern part of the district happens to be more droughts prone as observed in the spatial profile of mean NDVI.

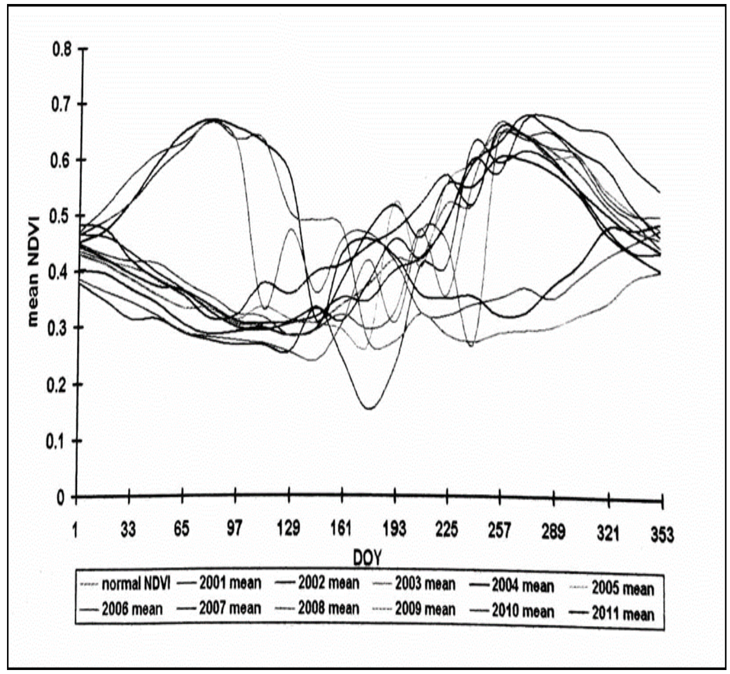


Figure 8. Temporal profile of NDVI, Mean

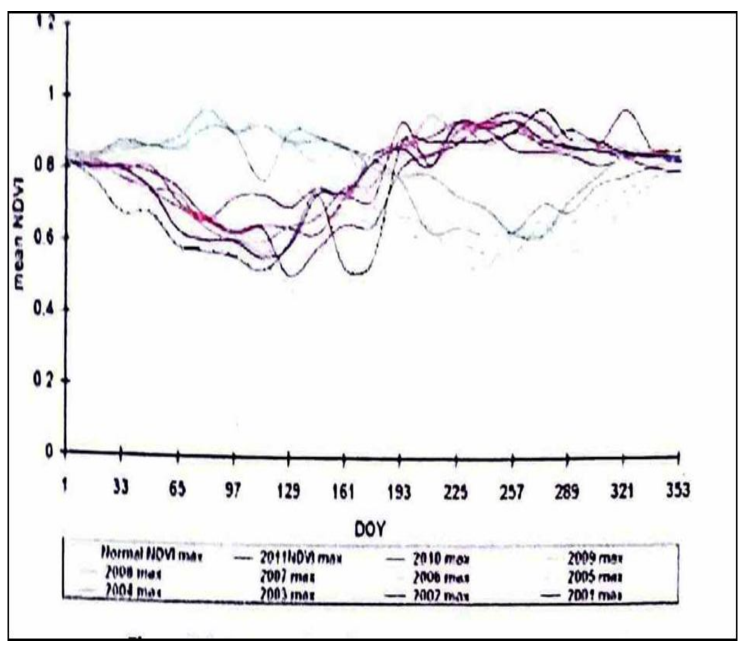


Figure 9. Temporal Profile of NDVI, Maximum

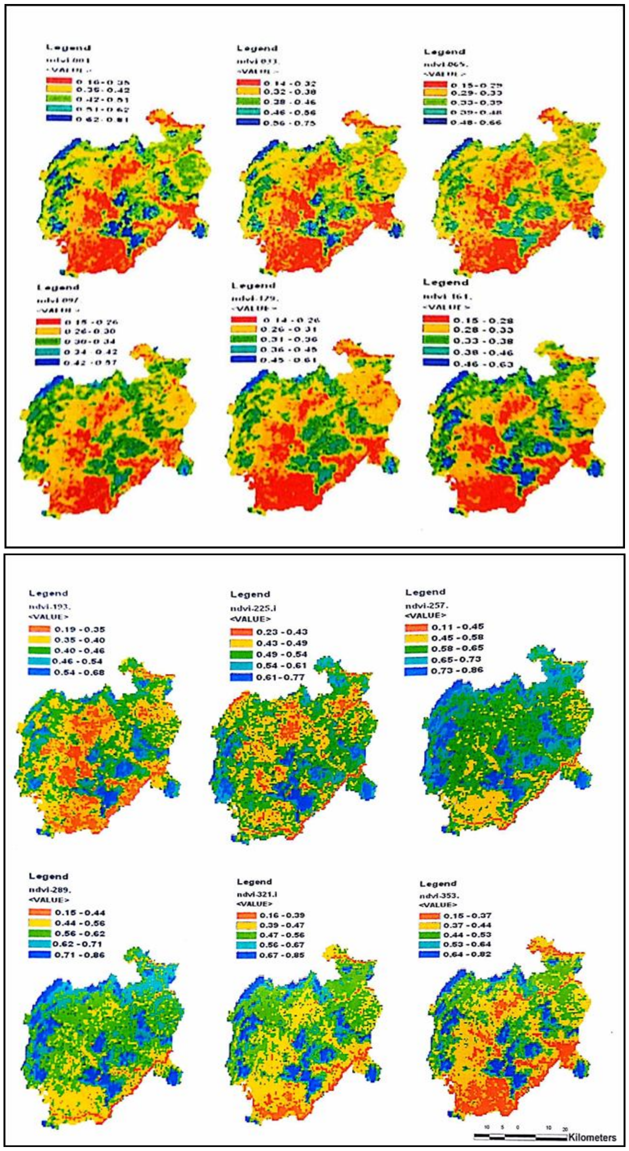
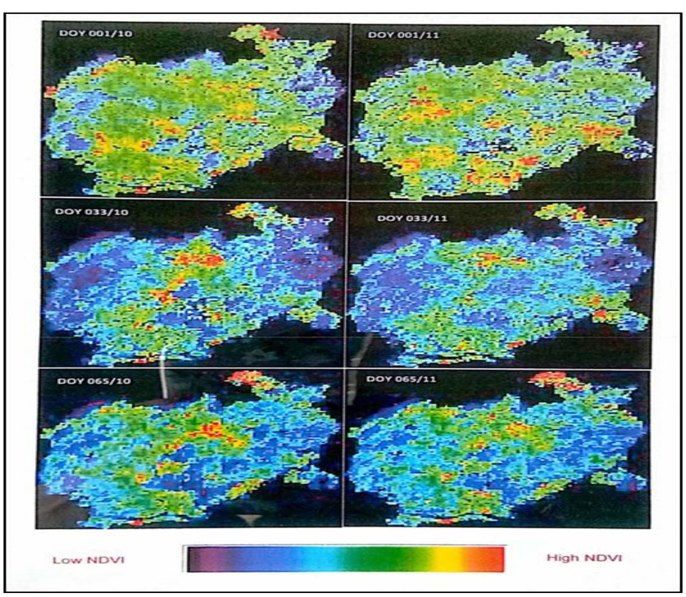
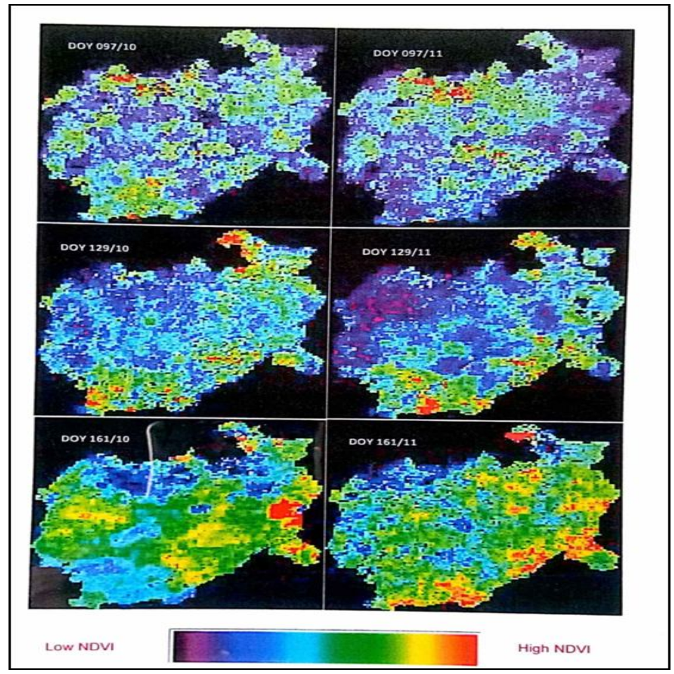
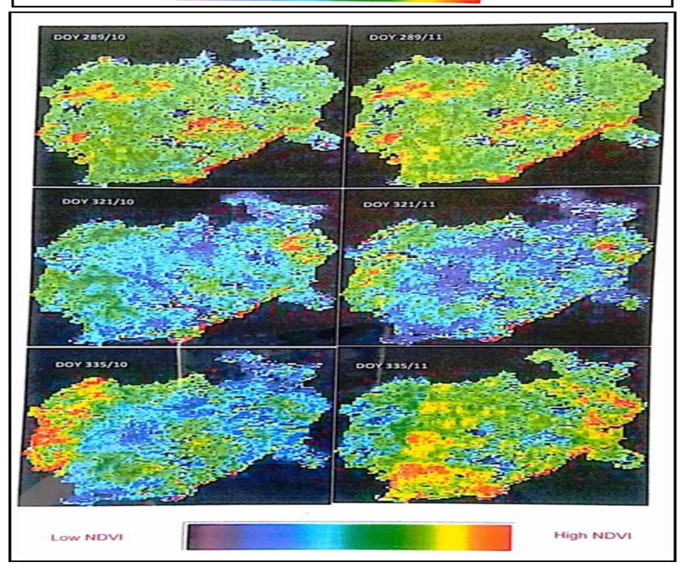
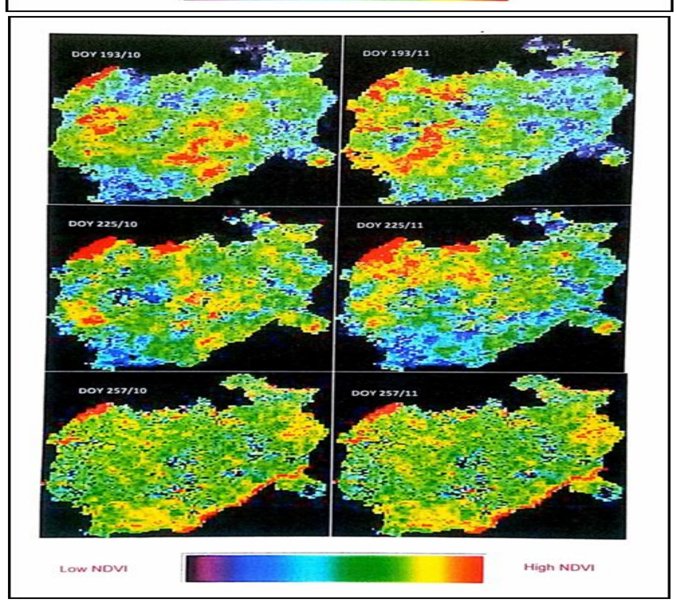


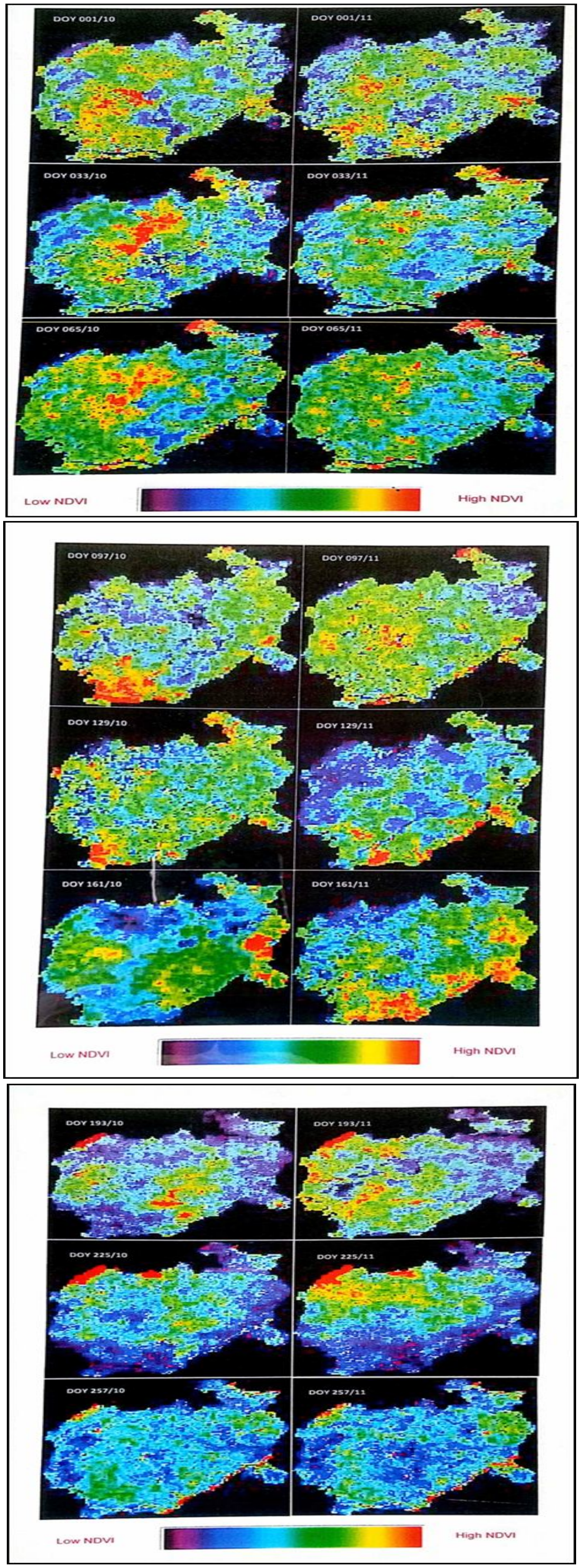
Figure 10. Spatial profile of NDVI Mean











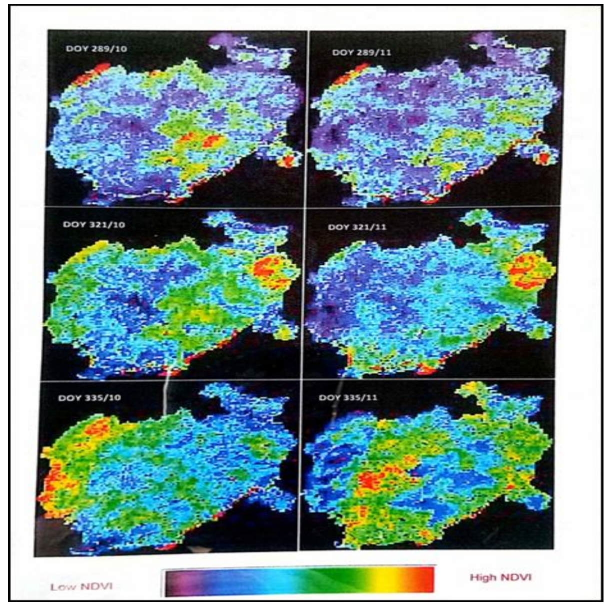


Figure11. Spatial Profile of MVCI 2001-2011

Anomaly in vegetation index

In order to depict the trend of NDVI in a drought year, the anomaly in mean NDVI over the years was computed and expressed in terms of MVCI and VCI. For this purpose 2010 and 2011 NDVI values were used. The following formulae were used to compute these two indices.

Kogan [5] proposed a vegetation condition index based on the relative NDVI change with respect to minimum historical NDVI value. It was defined as following:

$$VCI = \frac{NDVI(x,y) - NDVI_{min}(x,y)}{NDVI_{max}(x,y) - NDVI_{min}(x,y)} \times 100\%$$

Correlation of NDVI with rainfall

The mean annual rainfall from 2004 to 2011 were presented in fig. 12. It was found that highest rainfall occurred in 2008 followed by 2011.In order to study the correlation of NDVI with cumulative rainfall scatter plots were drawn and correlation coefficients are computed for each year(Fig. 13-20). Negative correlation exists for years 2004, 2006 and 2009.lt is noticed that for these mentioned years only the NDVI trend follows the reverse direction. The value of correlation coefficient is higher for the years where there exist a positive correlation between mean NDVI and cumulative rainfall. For those years where negative correlation exist, the value of correlation coefficients are also very low.

It is found from the above mentioned figures that the mean LST follows almost a plateau with minor fluctuation up to 129 DOY after which a sharp rise occurs, the peak is arrived at around 166-193 days. The temporal trend of maximum LST also more or less same as that of mean LST though LST minimum does not follow any specific pattern as the weekly variation is very significant specially in the summer and monsoon. The post monsoon weekly variation in LST min is not that much significant for all the years. In the month of January, the highest LST of 28-31 °C observed at the southern and south-west part of the district

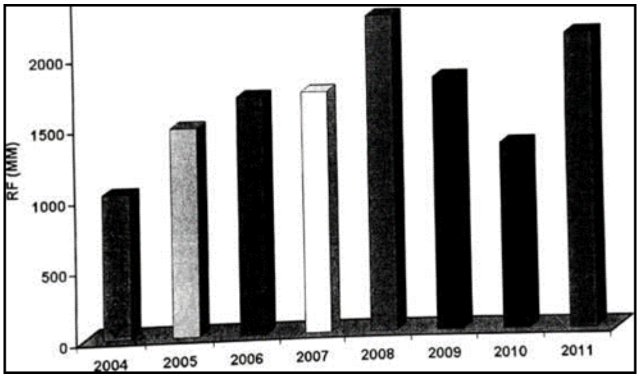


Figure 12. Mean annual rainfall from 2004-2011)

Correlation of mean NDVI & cumulative rainfall(Figure13-20)

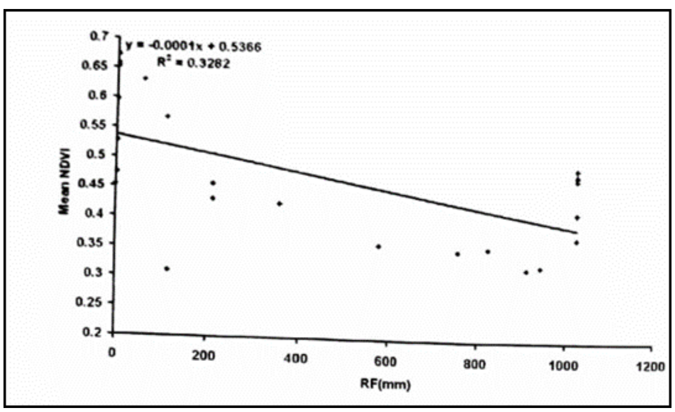


Figure 13. 2004

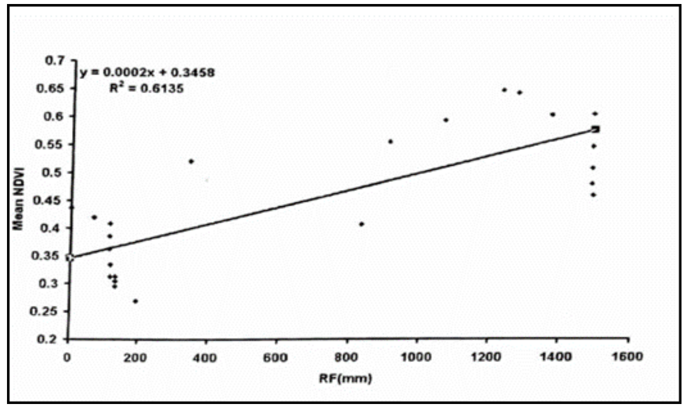


Figure 14. 2005

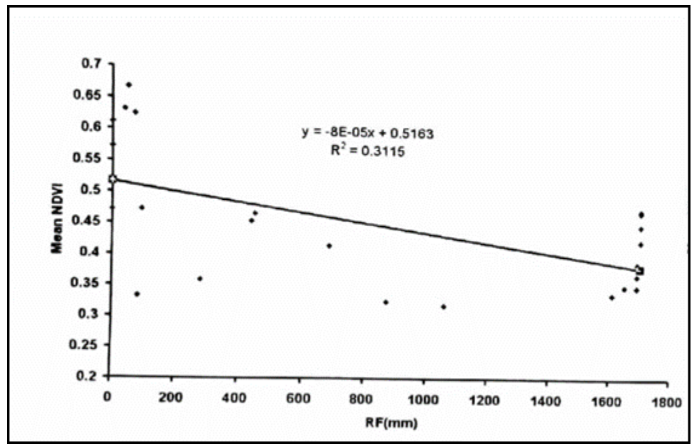


Figure 15. 2006

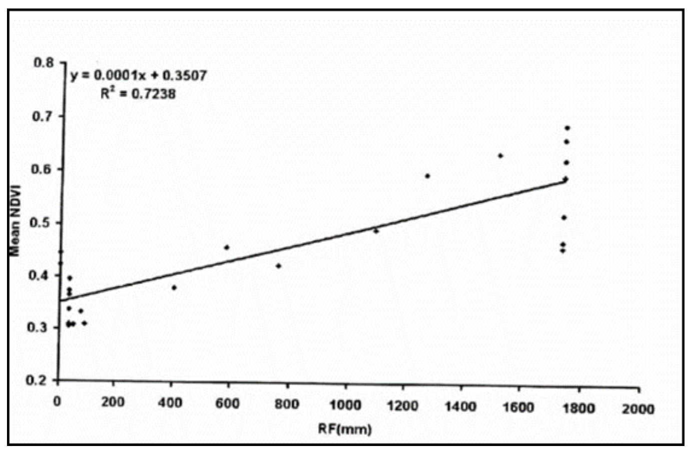


Figure 16. 2007

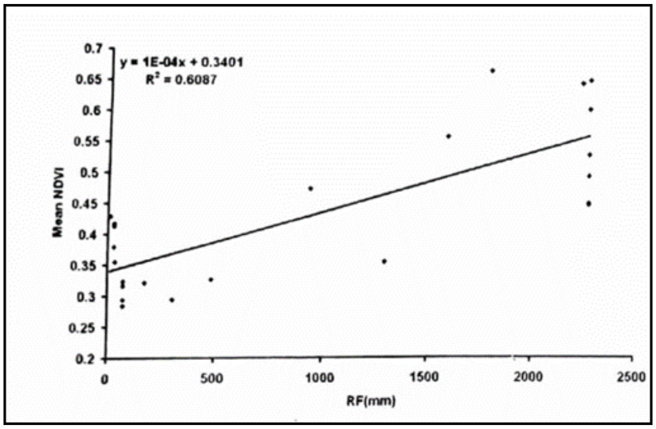


Figure17. 2008

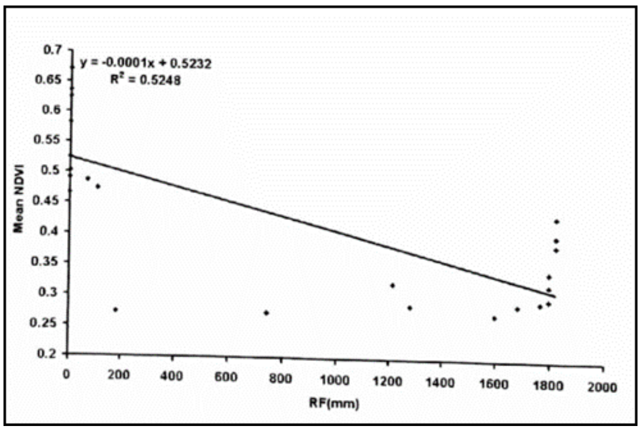


Figure 18. 2009

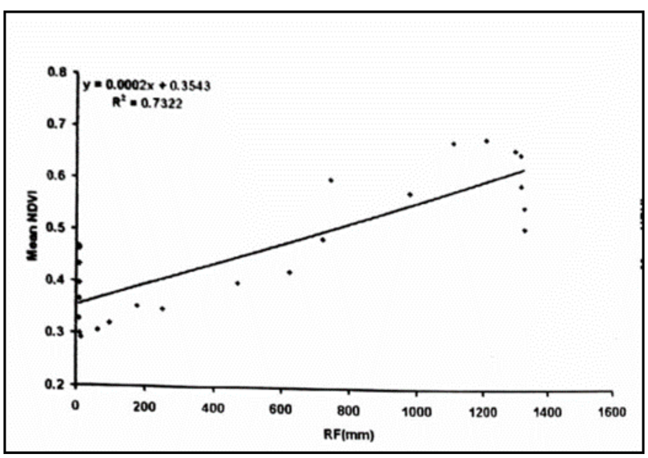


Figure 19.2010

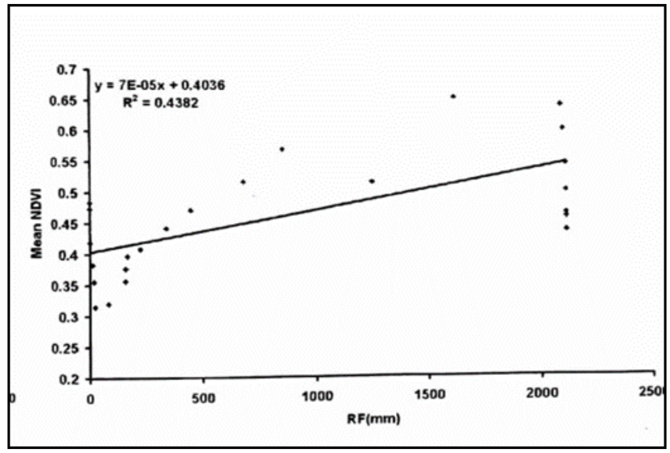
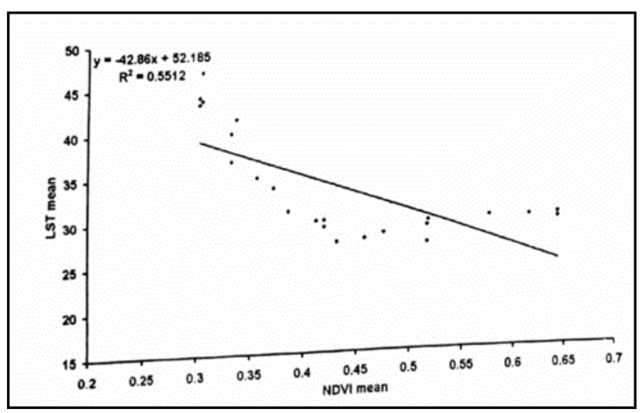
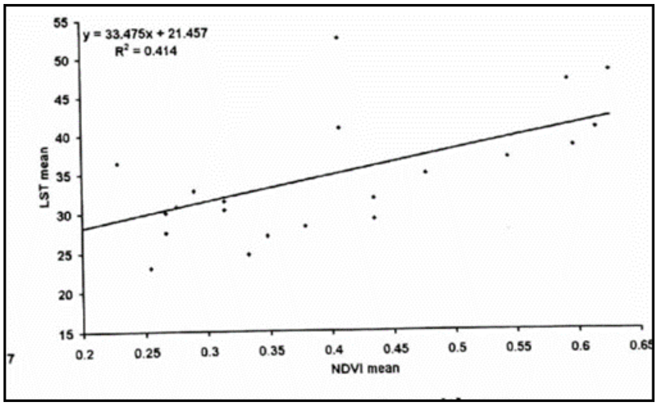


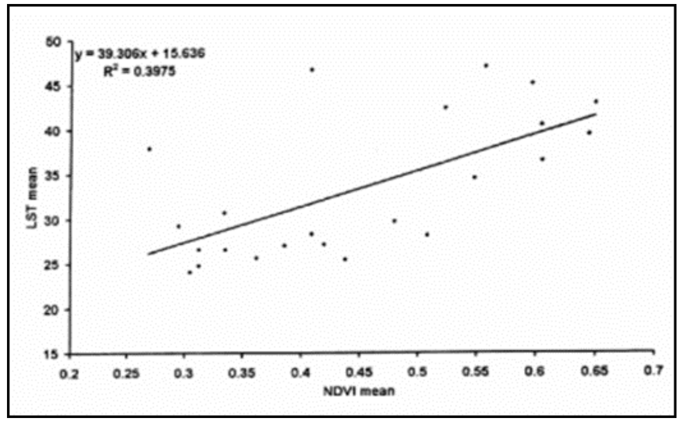
Figure 20. 2011

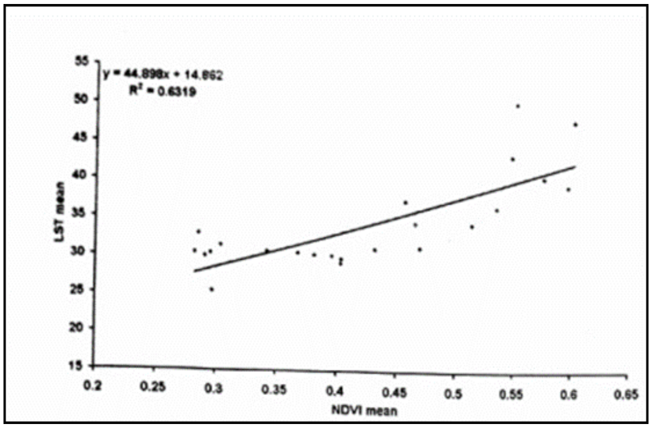
Correlation of NDVI with LST

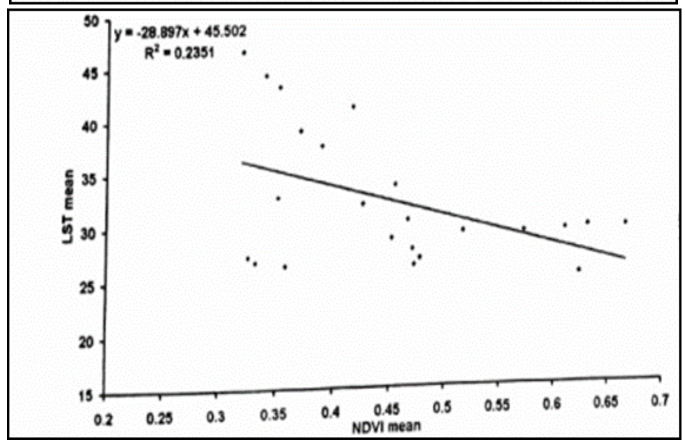
The correlation between LST and NDVI depends on the season and time of the year. In order to study the correlation of NDVI with LST scatter plots were drawn and correlation coefficients are computed for each year (2001-2011 has in the Fig. 21-32).Scatter plots of mean NDVI vs. LST shows that NDVI is positively correlated with mean LST for most years with exception for the years 2004, 2006 and 2009.for the above mentioned years NDVI and LST shows negative correlation. Negative correlation may be due to high evaporative cooling associated with high NDVI values where as positive correlation implies that the temperature remains conducive for the growth of vegetation.The correlation coefficient is highest for the year 2002 and lowest for the year 2006.

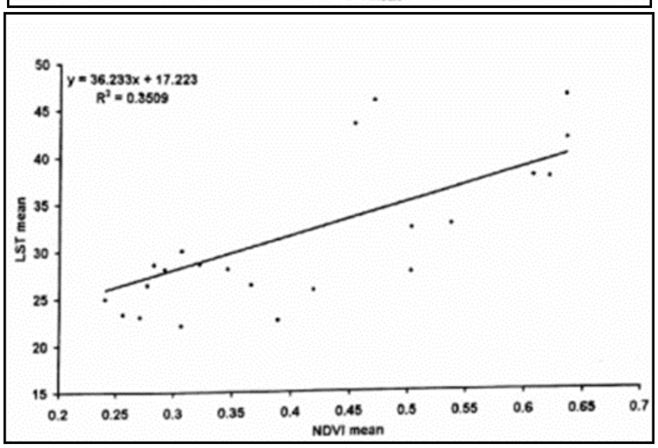


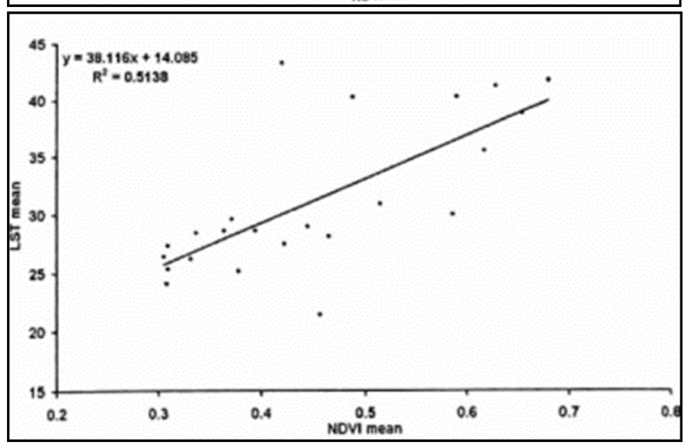

y = 33.475x + 21.457
R² = 0.414
LST mean
NDVI mean

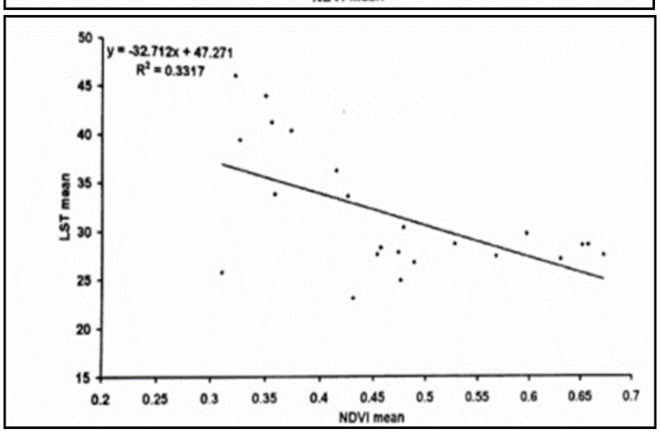

y = 39.306x + 15.636
R² = 0.3975
LST mean
NDVI mean

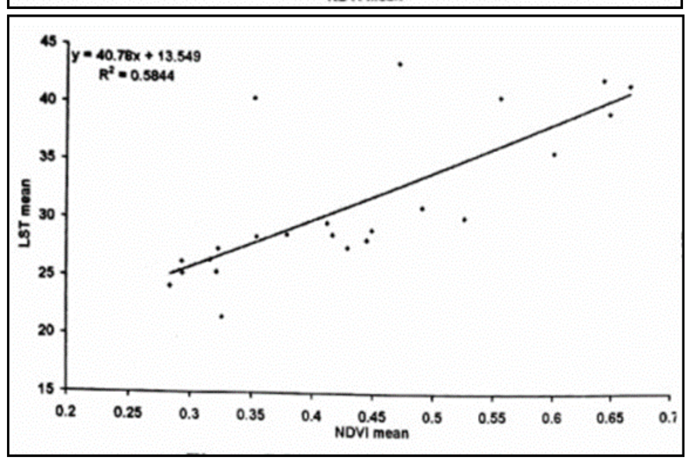

y = 44.898x + 14.862
R² = 0.6319
LST mean
NDVI mean


y = -28.897x + 45.502
R² = 0.2351
LST mean
NDVI mean


y = 36.233x + 17.223
R² = 0.3509
LST mean
NDVI mean


y = 38.116x + 14.085
R² = 0.5138
LST mean
NDVI mean


y = -32.712x + 47.271
R² = 0.3317
LST mean
NDVI mean


y = 40.78x + 13.549
R² = 0.5844
LST mean
NDVI mean

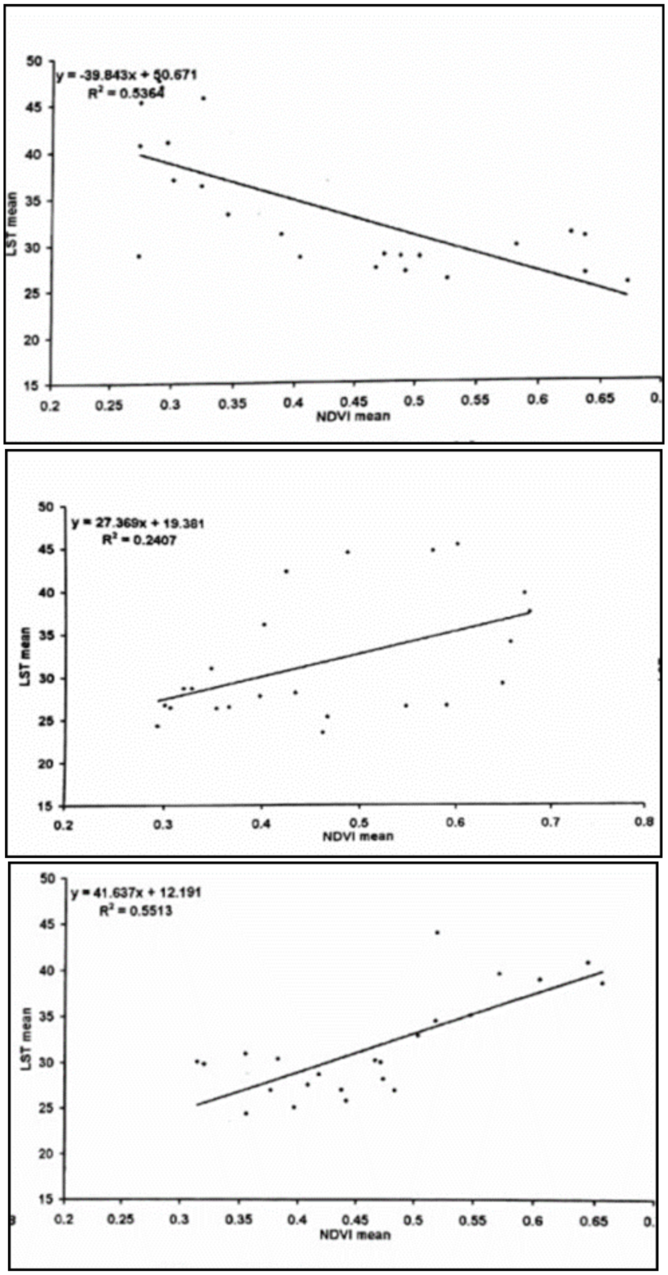


Figure 21. Correlation with mean NDVI & mean LST, 2000-2011

Conclusion

The salient findings of the present study are as follows:

1. The NDVI classified map of the Bolangir district shows that the NDVI class 0.1-0.2 occupies the highest area.
2. The mean LST follows almost a plateau with minor fluctuation up to 129 DOY after which a sharp rise occurs; the peak is arrived at around 166-193 days. The mean LST curve then decreases and again follows a plateau.
3. The temporal trend of maximum LST also more or less same as that of mean LST though LST minimum does not follow any specific pattern as the weekly variation is very significant specially in the summer and monsoon.
4. The least vegetation cover is observed just at the onset of the monsoon and the highest vegetation cover is observed in the month of September following monsoon.
5. The southern part of the district happens to be more droughts prone as observed in the spatial profile of mean NDVI.
6. The spatial distribution of higher VCI value is more in the normal year of 2011 for DOY of 161.193 and 225 compared to the drought year of 2010. This difference is almost negligible after the DOY of 193.
7. The spatial distribution of MVCI is more or less similar to that of VCI in the post monsoon period.

Scatter plots of mean NDVI vs. LST and NDVI shows that NDVI is positively correlated with mean LST for most years with exception for the years 2004, 2006 and 2009.for the above mentioned years NDVI shows negative correlation with rainfall and LST.

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