APPLICATION OF REMOTE SENSING IN UNDERSTANDING THE RELATIONSHIP BETWEEN NDVI AND LST

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Abstract

Vegetation abundance mainly depends on local climate. The vegetation distribution is largely affected by various human activities. For instance, urbanization and industrialization are the dominant factors affect the vegetation distribution and its extend. But vegetation is one of the prime variables that influence the climatic variables of water vapour and atmospheric energy interaction. Remote Sensing of Land Surface Temperature (LST) has traditionally been used the Normalised Difference Vegetation Index (NDVI) as the indicator of vegetation abundance to estimate the LST and vegetation relationship (Adil Hussain et,al, 2014). In this study, the spatial variation of vegetation index in Devikulam Taluk have analysed using Landsat TM, ETM+ and OLI data for 25 years. The vegetation index generated from landsat imageries depict that thick vegetation extent have drastically decreasing. At the same time LST estimated from the same data indicates that LST have increasing steadily.

***Keywords**: NDVI, LST, Landsat imageries and Devikulam*

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1. INTRODUCTION

Vegetation cover is an obvious part of natural land cover. These natural land cover sometimes undergoes changes due to natural or man-made causes over time. Changes in vegetation cover directly impact on surface water and energy budgets through plant transpiration, surface albedo, emissivity, and roughness (Aman et.al., 1992). Knowledge of the earth's vegetation cover is an important one to understand land-atmosphere interactions and their effects on climate (Zhangyan Jiang et.al., 2006). To identify these changes remotely sensed repetitive coverage data is apt one. Anthropogenic activities strongly affect the dynamics of ecosystems in an area. For instance, the conversion of vegetation cover, with a predominant clearing of natural vegetation may have long term impact on sustainable food production, freshwater and forest resources, the climate and human welfare (Foley et.al., 2007). NDVI maps give an indication about the quantity of biomass. Sometime these maps are used as input into crop growth models and also for climate change models. Since surface temperatures directly related with surface physical properties, Normalized Difference Vegetation Index (NDVI) is ideal for estimating LST in the high range mountain landscape (Suresh. S et.al., 2016).

2. MATERIALS AND METHODS

2.1 Study Area

The area selected for the present study is Devikulam Taluk of Idukki district in the state of Kerala is located on the eastern slopes of Western Ghats (Fig.1). The study area stretches between the latitudes of $9^0$56'56''N to $10^0$21'29''N and longitudes of 77^0 48' 31''E to $77^0$16'14''E covers an area of 1140 Km^2 and is inhabited by 177621 persons with a literacy rate of 138527 (Census Report, 2011). June and September which are the months of south-west monsoon recorded at least two third amount of rainfall. Average annual rainfall in the rain fed regions ranges from 3,000 to 8890 mm and in the Marayur region it goes as low as 1270 mm (Satis Chandran Nair, 1994). Physiographically the study area is diverse in nature. Fluvial action is dominant one in the leveling up processes. Narrow ridges, steep slopes, cascades, spur, wooded narrow valley, open grassy summits etc,. are the major fluvial erosional features in Munnar plateau.

The high Kannan Devan Hills (KDH) and plateau around Munnar straddles Eravikulam, Anaimudi Shola National Park. They contain a matrix of shoala-grassland ecosystem, Eucalyptus plantations and tea estates. "Sholas" or small pieces of jungle which holds fine stands of teakwood, ironwood, balck-wood, bamboo and other valuable commercial timbers clothed the banks on one side, while on the other sweeping grass-lands rose to the blue cliffs above. Herds of wild goats, tigers, panthers, sambhur and munjac and many other species of south Indian fauna throve in the animal kingdom.

The drier tracts of Anchanad valley with its river head in the KDH and the eastern facing shoals drain towards Amaravathi River through Chinnar. The rain shadow region of Marayur is situated on the back side of Anaimudi. This region is covered by riparian forest, scrub forest, paddy fields, deciduous forests. Adimali is a foot hill region of Munnar plateau situated in the south eastern direction. In Adimali before 1980, the main crops under cultivation were rice as well as pepper and cardamom. Now almost 90% of the paddy fields have been modified for other purposes such as residential land, rubber plantations and banana fields. The study area was drastically changing since 1879. Munro in partnership with two brothers named Turner acquired a concession of land for the purpose of developing Cinchona and other plantations Speer. S.G (1953). In order to cater to the aspiration of the masses, the land use pattern of the study area was totally modified. Due to food shortage and famine (1941-44), the government opened forest lands on an emergency basis for food cultivation. The narrow paddy fields in mannamkandam, Vellathuval, Marayur and other villages which lay scattered in between the hill slopes had acted as the major source of food production. Orginally paddy fields were rich in fertility and the supply of water. When people started cultivation on the steep side slopes, without proper soil conservation measures, the eroded soil got deposited in the paddy fields and cultivation become difficult and less profitable Mani. K, (2011). Most of the native flora and fauna of Devikulam have disappeared due to severe habitat fragmentation resultant from the creation of the plantation. The annual mean temperature is also gradually increasing due to some climatic phenomena Suresh.S et.al, (2015) but it is mainly because of land cover changes.

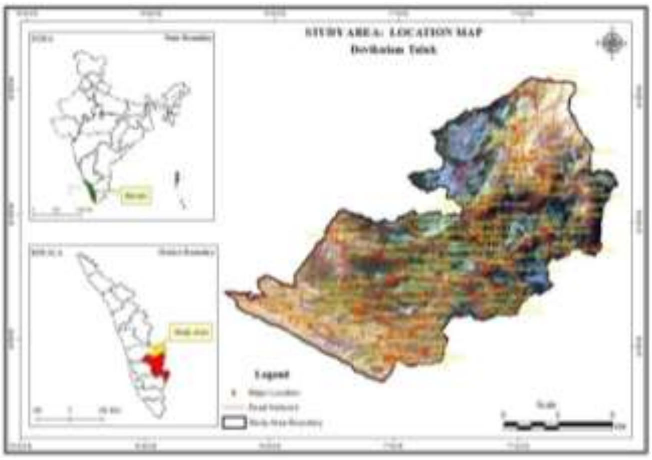

Fig 1: Study Area Map

2.2 Data

NASA landsat program provide different resolution multispectral satellite imagery for different periods at free of cost. www.land cover.org and www.earthexplorer.com are the major satellite imagery hub for the whole world. The data used for this study are given in Table.1.

Table 1: Remote Sensed data used for the study

Sensor	No. of Bands	Resolution (m)	Path/Row	Date of Acquisition
TM	7	120	144, 053	24th January 1990
ETM+	8	30	144, 053	14th January 2001
ETM+	8	30	144, 053	08th February 2010
OLI	11	30	144, 053	11 February 2015

2.3 Methodology

The study area from the full scenes of landsat data have been sub setted to the extent of study area using QGIS platform so that the image having same areal coverage to facilitate temporal comparison of images. A Normalized Difference Vegetation Index (NDVI) image had been generated for the year 1973, 1990, 2001, 2010 and 2015 respectively. Landsat satellites measure the vegetation differences by strongly absorption by the chlorophyll in the red spectral area and its reflection in the near infrared spectrum. So NDVI is a measure of the difference in reflectance between these near infrared (NIR) and red band (Red) wavelength ranges. The NDVI calculation equation developed by NASA is NDVI = (NIR-RED) / (NIR+RED). By solving this equation, the NDVI values can be scaled between a value of -1 to +1 (Jensen J.R, 1986). The value close to -1 (dark color) represent the land with lack of vegetation probably having visible soil or rock surface. The NDVI value has further been divided into three categories on the basis of vegetation cover. They are <0.2 represents water body and bare soil, 0.2 to 0.5 represents the mixture of bare soil and vegetation. The value > 0.5 shows fully vegetative area (Aneesh M.R., et.al 2015). To calculate LST for the images TM (1990), and ETM+ (2000, 2010) Landsat 7 Science Data User’s Handbook Procedure have been followed. Mono window algorithm procedure has followed for landsat 8 OLI data. Finally, the NDVI and LST mean value have been correlated.

3. RESULT AND DISCUSSIONS

3.1 LST Calculation using Landsat 7 Data Handbook Procedure for TM and ETM+ data

The thermal band images of TM and ETM+ images were used in order to prepare the thermal map. To convert DN to Radiance Landsat 7 Science Data User’s Handbook Procedure have been followed.

Table.2 Thermal Band Minimum and Maximum Value and Gain and Bias Value

Sensor	Lmin	Lmax
TM	1.2378	15.303
ETM+	3.200	12.650

At sensor radiances mentioned at a wave length region is generally stored in digital numbers (DNs) converted using a quantification system for the convenience of data storage. DN values have no unit and any physical connotation, therefore, need to be converted to radiance. To convert DN to radiance value for ETM+ data, the following formula is used. The ETM+ DN values range between 0 and 255. Sensor and its Lmin and Lmax value given in Table.2

$$L\lambda = (LMAX\lambda - LMIN\lambda) / QCALMAX - QCALMIN*(DN-QCALMIN)+LMIN\lambda \text{........ Eq.1}$$

Where
$L\lambda$ = Spectral Radiance at the sensor’s aperture in watts/(meter^2*ster*am)
QCAL = the quantized calibrated pixel value in DN
$LMIN\lambda$ = the spectral radiance scales to QCALMIN
LMAX = Spectral radiance scales to QCALMAX

QCALMIN = the minimum quantized calibrated pixel value (typically = 1)
QCALMAX = the maximum quantized calibrated pixel value (typically = 255)

The corresponding value for TM and ETM+ images were assign in the equation 1 and the same was executed in the ENVI-software using band math tool. The band math algorithm used in ENVI is nothing but mentioned in equation.1 that is

((15.303-1.238)/254)*(B1-1)+1.2378

where B1 is thermal band 6 of TM. Likewise the same algorithm with the changes of LMAXλ, LMINλ we can use it for the ETM+ thermal band 62 also.

To convert the radiance value which is derived from digital number to spectral radiance procedure by applying equation 1 is further used to derive temperature output depicting temperature in Kelvin. These have to be done by applying the equation.2 which is given below

$$T= \left[\frac{K1*\varepsilon}{CV_{R1}+1} \quad +1 \right] \quad \ldots\ldots\ldots\ldots\ldots\ldots Eq.2$$

Where
T is degrees Kelvin
CVR1 is cell value as radiance (from equation.1)
ε is emissivity (typically 0.95)

Table: 3 Thermal band Calibration Constants

Units	W/(m2.Sr.µm)	Kelvin
Constant	K1	K2
TM	607.76	1260.56
ETM+	666.09	1282.71

From the constant value (Table.3) and radiance value, the radiance value is converted from spectral reflectance to temperature degree Kelvin. The algorithm for TM band 6, ETM band 62 (B1) is deciphered as

1260.56 / alog(((607.76*0.95)/B1)+1)….TM Band 61

1282.71/(alog(666.09/B6+1))…..ETM Band 62

In the present day we often used temperature in Celsius. So that the output generated from equation 2 is simply convert to Celsius by applying the formula given below.

B6 – 273.15……………….Eq.3

where B6 is output derived from equation 2 containing degrees in Kelvin. Thus the land surface temperature figure (2,3,4) are derived.

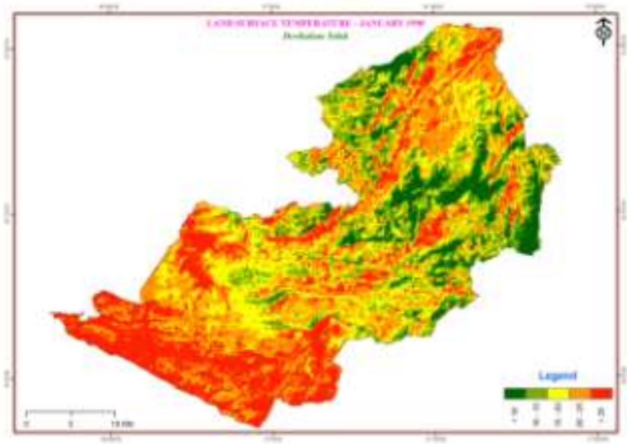

Fig 2: LST Map of 1990

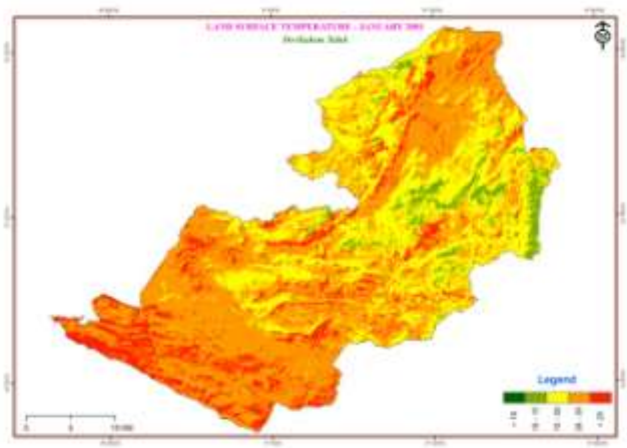

Fig 3: LST Map of 2001

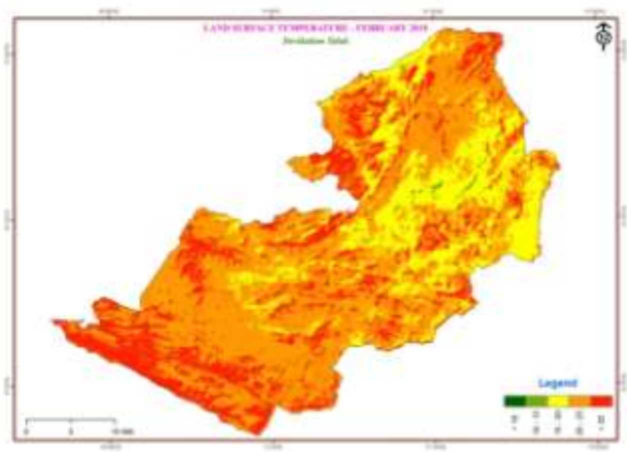

Fig 4: LST Map of 2010

3.2 LST Calculation using Mono Window algorithm for Landsat 8 data

The Landsat 8 TIRS sensors acquire temperature data and store this information as a digital number (DN) with a range between 0 and 255. The detail step by step procedure for Land Surface Temperature (LST) calculation is given below

LST= BT/1+W*(BT/p)*In(e))…… … Equation -1

Where:
BT= At satellite temperature
W=Wavelength of emitted radiance (11.5µm)
p = h*C/S (1.438*10^-2mk)
h = planck's Constant (6.626*10 ^-34JS)
s = Boltzmann Constant (1.38*10 ^-23J/K)
C = Velocity of light (2.998 *10 ^8 m/s)
p = 14380

The first step is convert digital number to radiance using the given below formula

Lλ is the Spectral Radiance at the sensor's aperture (watts/(m^2*ster* µm))

$$\mathbf{L\lambda = M_L Q_{cal} + A_L} \text{……… Equation-2}$$

Where:
Lλ = TOA spectral radiance (watts/(m^2*ster* µm))
M_L = Band Specific multiplicative rescaling factor from the meta
(RADIANCE _MULT_BAND_X, Where X is the band number 10 or 11)
A_L = Band specific additive rescaling factor from the metadata
(RADIANCE _ADD_BAND_X, Where X is the band number 10 or 11)
Qcal = Quantized and calibrated standard product pixel values (DN)

So, Lλ for the study area is;

Lλ = 0.0003342 * Band 10 + 0.1

The same to be executed for the Band 11

From the formula we can get *Band10 Radiance and Band11Radiance* as an output.

The Second step is Convert Band radiance (which is derived from equation 2) to brightness temperature using the thermal constant given in meta data file. The conversion formula is given below

$$\mathbf{T = K_2/In (K_1/ L\lambda+1) – 272.15} \text{…. Equation-3}$$

Where
T= At – Satellite brightness temperature in Kelvin (K)
Lλ = TOA spectral radiance (watts/(m^2*ster* µm))
K_1 = Band_Specific thermal conversion from the metadata (K_1 – Constant_Band_X, where X is the band number, 10 or 11)
K_2 = Band_Specific thermal conversion from the metadata (K_2 – Constant_Band_X, where X is the band number, 10 or 11)
272.15 = Convert Kelvin to ^{o} Celcius.

According to the equation 2, T can be calculated for the study area is

T = 1321.08 / Ln(774.89/"Band10Radiance + 1) – 272.15

The same to be executed for the Band11Radiance, where we can substitute K_1 and K_2 value for Band 11

From the formula we can get *BAND10SATTEMP and BAND10SATTEMP* as an output. It depicts the brightness temperature in degree celcius.

The third step is find out the average temperature of both *BAND10SATTEMP and BAND10SATTEMP* using the Cell statistics tool and select the mean statistics option and we can get *SATTEMPBAND1011* as an output. Here the minimum temperature is 12.58^{0}C and maximum temperature is 39.52^{0}C

The fourth step is deriving Land Surface Emissivity (LSE).

$$\mathbf{e = 0.004\ Pv + 0.986} \text{ ………….. Equation- 4}$$

e = Emissivity
Pv = Proportion of vegetation which is calculated using NDVI value
NDVI = Normalised Difference Vegetation Index
NDVI can be calculated in ArcGIS by applying the given formula

Float (Band5 – Band4) / Float (Band5 + Band4)………………………….Equation – 5

Where
Band5 = Infrared Band, Band4=Red band

From the NDVI result, NDVImin Value is – 0.0812195 and NDVImax value is 0.60394 (Map.2). We can substitute these value in equation 4 and derive proportion of vegetation (Pv).

$$\mathbf{Pv = (NDVI\text{-}NDVImin / NDVImax\text{-}NDVImin)^2} \text{….. Equation – 6}$$

In ArcGIS it can be done by applying this formula
Square ("NDVI" + 0.0812195 / 0.607394 – 0.0812195)
Now we can get *PROPVEG* as an output of Proportion of vegetation. Now we can calculate LSE by applying Pv value in equation 3

That is **0.004 * *PROPVEG+0.986***

Now we can get LSE of the study area which shows in map.3

The final step is calculate land surface temperature using equation 1. The output such as *BAND10SATTEMP* substitute for *'BT'* that is brightness temperature in ^{0}c, and *LSE* value replaced in *'e'* that is emissivity. The equation-1 is

LST= BT/1+W*(BT/p)*In(e)

In ArcGIS it can be done through this formula, i.e.

LST="BAND10SATTEMP"/1+"Band10" *("BAND10SATTEMP"/14380)*Ln("LSE")

Finally we can get the actual land surface temperature of band10 (LST) of the study area (Fig.5). Sun elevation 52.64 in landsat 8 metadata represents the time is probably the morning. Table.4 given the statistics of study area's LST. From the result the mean temperature is steadily increased from 19.57 in 1990 to 24.61 in 2015 (Fig:6)

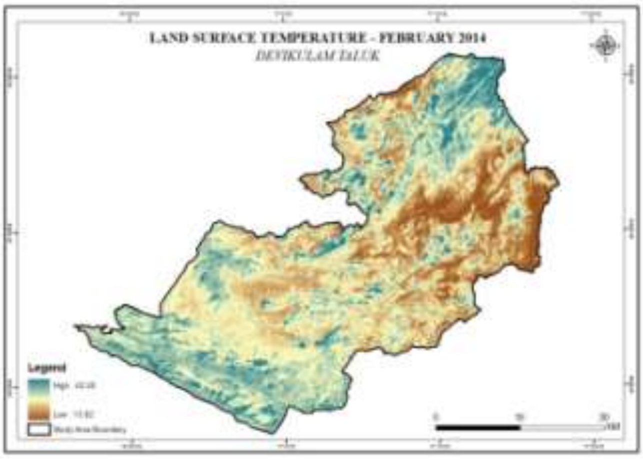

Fig 5: LST Map of 2015

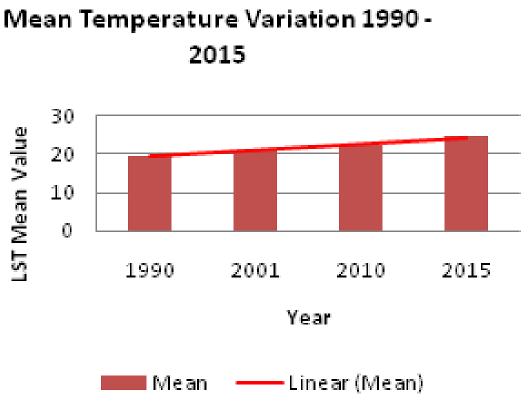

Fig 6: Mean temperature variation

Table: 4 Statistical inferences of LST from 1990 – 2015

Sensor	Year	Min	Max	Mean	S.D
TM	1990	2	45	19.57	7.24
ETM+	2001	9	38	21.18	3.58
ETM+	2010	11	44	22.54	3.41
OLI	2015	14	42	24.61	3.51

3.3 NDVI (1990 – 2015)

The landsat images were classified into three NDVI classes each. Figure 7, 8, 9 and 10 clearly illustrate the spatio-temporal variations of vegetation from 1990 to 2015. Table: 5 depict the vegetation distribution and its statistical value of different landsat images in Devikulam taluk. The mean value of all classified imageries is decreasing from 1990 to 2010. But the increasing trend is identified in 2015 (Fig.11). The area wise distribution of different vegetation classes (Table:6) for different periods illustrate mixture of bare soil and vegetation goes in ascending order from 1990 to 2015. In the same time fully vegetative area declining from 452.10 Sq.Km in 1990 to 4.90 Sq.Km in 2015 (Table:7). Though population increased in negative trend, due to booming tourism industry rapid urbanization occurred in Munnar, Marayur, Adimali, Mangulam, Vellathooval, Kocviloor, Kovilkadavu and Munnar-Adimali highway region. In Munnar town itself (within 2 Km buffer) morethan 300 authorised resorts are standout. The same effect reflects in the surrounding villages also. Bare soil and waterbody have increased from 1990 (58.16 sq.km) to 96.28 Sq.Km in 2015.

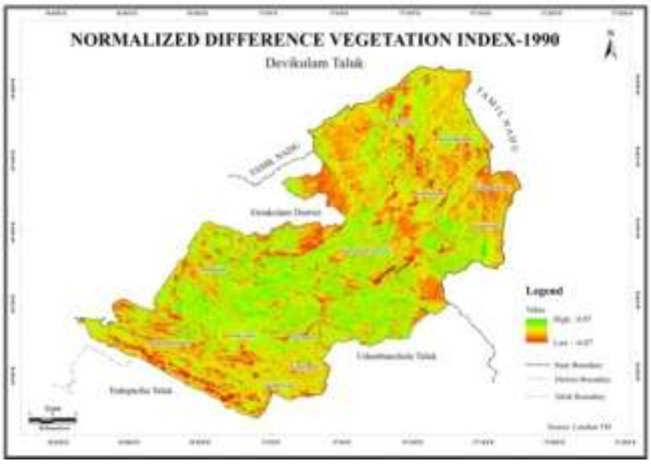

Fig 7: NDVI for 1990

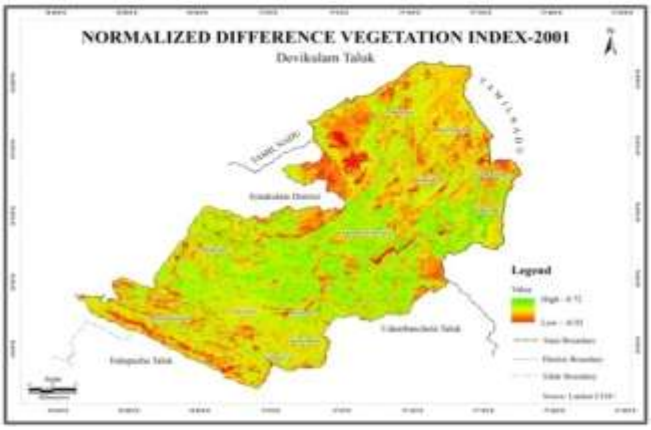

Fig 8: NDVI for 2001

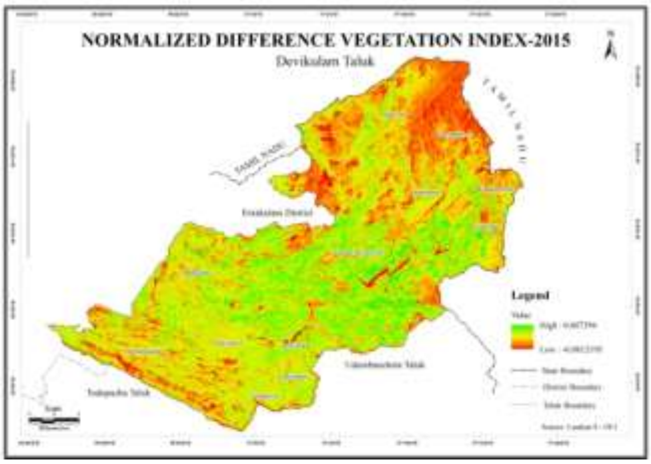

Fig 9: NDVI for 2010

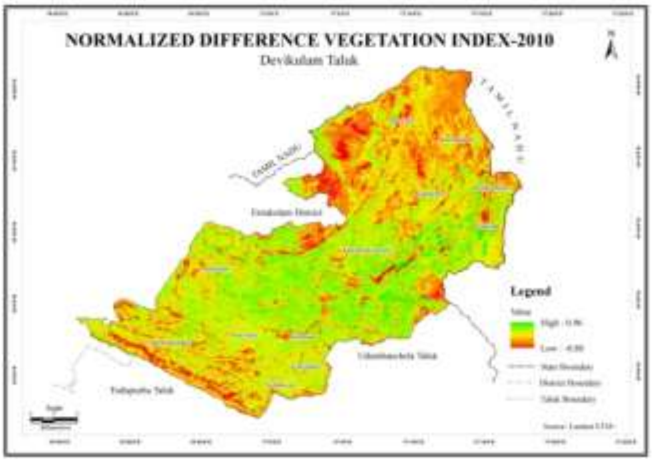

Fig 10: NDVI for 2015

Table: 5 Statistical inferences of NDVI

Sensor	Year	Min	Max	Mean	S.D
TM	1990	-0.87	0.97	0.44	0.14
ETM+	2001	-0.92	0.72	0.25	0.16
ETM+	2010	-0.88	0.96	0.23	0.14
OLI	2015	-0.08	0.60	0.32	0.08

Table 6: Vegetation Cover Area in Sq.km

Vegetation Cover Area in Sq.km			
Year	**< 0.2** (Water body and bare soil)	**0.2 – 0.5** (Mixture of bare soil and vegetation)	**> 0.5** (Fully vegetative area)
1990	58.16	625.41	452.10
2001	364.20	736.63	30.44
2010	397.71	724.75	9.93
2015	96.28	1037.27	4.90

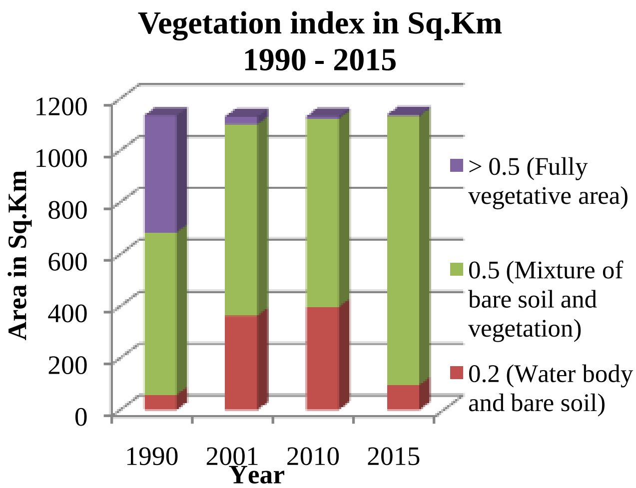

Fig 11: NDVI in Sq.Km

3.4 Relationship between NDVI and LST

From the two variables (NDVI and LST) result, LST mean value is increasing from 19.570C in 1990 to 24.610C in 2015. At the same time the fully vegetative area is decreasing from 452.10 Sq.Km in 1990 to 4.90 Sq.Km in 2015. The Pearson Correlation coefficient between two variables mean value have been calculated. Table: xxx gives the overall glance of statistical relationship between LST and NDVI. The correlation coefficient value of the two variables from 1990 to 2015 (4 period imagery) is -0.467 which means the variables are negatively correlated and the relationship between the two variables is good. If correlation coefficient will execute for 1990 to 2010 (periods imagery) the correlation value will be -0.92 and the relationship between two variable is too strong. From the result, LST is more or less decided by the natural vegetation of an area. NDVI is the good technique to determine the amount of vegetation in an area.

Table: 7 Statistical relationship between LST and NDVI

Statistical relationship between LST and NDVI	
Correlation Coefficient	- 0.467
X Mean (μ_x)	0.31
Y Mean (μ_y)	21.97
σ_x	0.09
σ_y	2.13
Regression Equation	25.23 + -10.51

4. CONCLUSION

Identified the relationship between NDVI and LST is the primary objective of this study. For that different landsat sensor data viz; TM for 1990, ETM+ for the year 2000 and 2010 and OLI data for 2015 have incorporated. NASA depicted methodology followed in NDVI calculation. In order to calculate LST from different Landsat series data, two kind of algorithm was involved. For landsat 5 and 7 data, Landsat 7 handbook procedure was applied. Monowindow algorithm had employed in Landsat 8 OLI data. Both NDVI as well as LST results analysed separately. The mean value of NDVI is steadily decreasing from 1990 to 2010. Only in the year 2015 it shows increasing value. On the other hand LST for the same data shows gradual increase of temperature. When the Pearson correlation coefficient statistical technique is used to identified the two variables relations, result indicates that the correlation is strong negative correlation. From the result it is easy to say that natural vegetation is paramount parameter to determine the LST and also their local climate. Moreover remote sensing is an efficient technology provides satellite data. Landsat series data is free of cost downloaded from www.earthexplorer.com website and it is suitable for measuring LST and NDVI in the study area.

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