AN ALGORITHM FOR LAND SURFACE TEMPERATURE ANALYSIS OF REMOTE SENSING IMAGE COVERAGE OVER DEHRADUN DISTRICT, UTTARAKHAND, INDIA

Kamlesh Khanduri*

Prabhir Singh**

Neetu Verma**

Avtar Singh**

Abstract:

Estimation of LST from remotely sensed data is nowadays usual. LST is a key parameter in the physics of land surface processes because it is involved in the energy balance as well as in the evapotranspiration and desertification processes (Peres and DaCamara, 2004). This study investigates the thermal variations of the different land use/cover types in Dehradun district retrieved from Landsat ETM^{+} imagery of October, 2005. Band 2, 3, 4 and 6 of the imagery were used in the landuse classification, estimation of NDVI, land surface emissivity values, and satellite sensor temperature. Correlation analyses were conducted to investigate land-cover based relationships between LST and impervious surface and green vegetation fractions for an analysis of the causes of LST variations. Results indicate the built up area and the wasteland and non forest area have the highest land surface temperatures of 18-25^{0}C and respectively, vegetation and water bodies have 8-14 ^{0}C. The cultivated land area has land surface temperatures between 15-16^{0}C.

Key words: *Land surface temperature, Remote Sensing, Land use, Land cover*

* D.Phil Research Scholar, Dpt.of Geography, HNBG University, JRF, FSI, Dehradun, Uttrakhand, India.

** Technical Associate, JRF, Forest Survey of India, Dehradun, Uttrakhand, India.

Introduction:

Land surface temperature (LST) is generally defined as the skin temperature of the ground for the bare soil surface, LST is the soil surface teperatue and dense vegetated ground, LST can be viewed as the canopy surface temperature of the vegetation. The satellite sensor measures the infrared radiance from the surface towards the satellite; this radiance is corrected with respect to the influence of a clear (i.e. nearly non scattering) atmosphere; the resulting radiance is converted to a temperature according to Planck's law it is called "Land Surface Temperature". The urban environment with its anthropogenic activities contribute to the reduction in outgoing longwave radiation by hindering the loss of sensible heat and distribution of heat (Oke, 1982; Bonan, 2002 and Ifatimehin, 2007a) which result in the build up of ambient land surface temperature in the urban centres of 2 – 3 degrees higher than the surrounding suburban environment (Pickett, 1997) where there is a relatively greater cover of vegetation, cultivated lands as well as greater areas of wet soils (Adebayo and Zemba,2003 and Ifatimehin, 2007b).

The focus of this research is placed on the application of a methodology to examine the interplay between LST and land-use and land-cover (LULC) distribution characteristics. A Landsat ETM+ image of 2005, October that covers the Dehradun District, Uttrakhand was used in conjunction with other types of spatial data for the analysis. The specific objectives were twofold: First, to employ spectral mixture modeling (NDVI & Landuse Classification) to derive satellite images and result characterize and secondly, to prepare LST and analyze the causes of LST variations, which were derived from Landsat thermal infrared data.

The Study Area:

Dehradun District, is the administrative capital of Uttarakhnad State between longitudes 77o34'43''E to 78o18'22''E and latitudes 29o56'50''N to 31o02'53"N. It has an estimated area of 3018 sq. km and with an estimated population of 16, 98,560 based on 2011 population census (Fig 1).The Dehradun district is a longitudinal topographic depression situated in the foothills of Lesser Himalaya of Uttarakhand. The Doon valley covers 85.7% area of Dehradun district. The Dehradun district The Valley is believed to have been formed due to folding of Siwalik

sediments of Upper Tertiary age. It is bounded in the north by the Main Boundary Fault (MBF) or Krol Thrust. To the south the Siwaliks abut against Gangetic alluvial plains. (Rao, 1977).

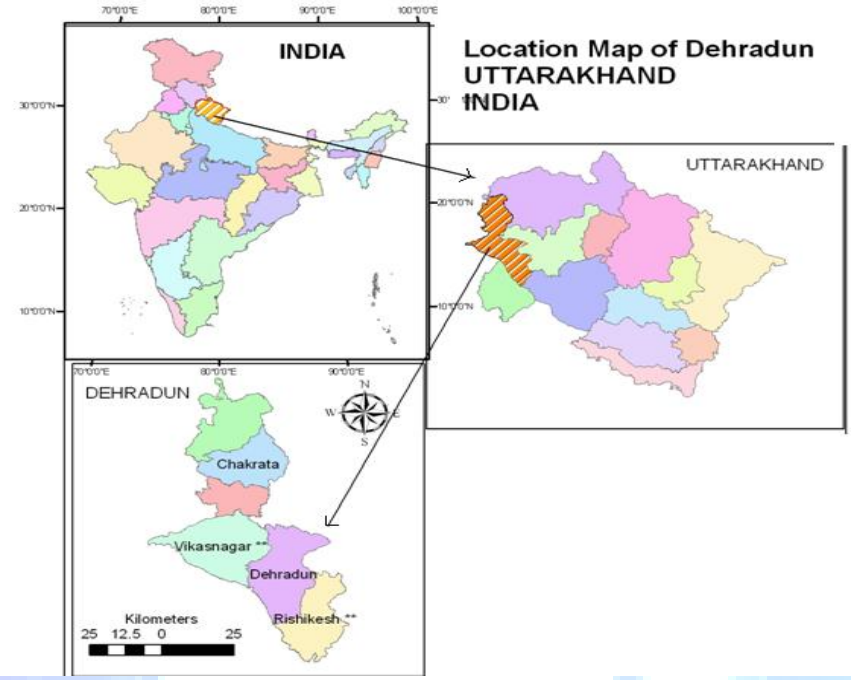


Figure.1 Location Map of Study Area

Dehradun has a rich vegetation cover although the major portion of Dehradun is occupied by the Sal (shorea robusta) but miscellaneous forests are also found here. The hydro-geological and meteorological conditions (231.5 cm. annual average rainfalls) of the Doon valley are responsible for the condition for the different types of forest cover. A presence of large proportion of clay soil and better drainage act as favourable conditions for the growth of Sal trees. One can easily visualize Doon valley as it must have been in past, covered by dense forests interspersed within swampy grasslands, a situation that must have prevailed several centuries ago (Palanidurai, K.V., 1992). Land use of the district is dominated by forest and cultivated area as they respectively cover about 66.13% and 17.12% of the total area. During parst independence era, urbanization in the valley has become most powerful agent of transformation. As per census 2001, urban population of Dehradun District reached 58.1% of total population and this urban

population account for 31.0% of the total urban population of Uttarakhand state. After creation of Uttarakhand state in 2002, Dehradun city became state capital which ushered the era of rapid expansion in Built up area beyond municipal limits. There has been massive expansion in construction activities for industries, institutional infrastructure and residential colonies.

Methodology:

Landsat 7-Enhanced Thematic Mapper Plus (ETM+) image with dated 16 October 2005 was used in this research. The acquisition date has a highly clear atmospheric condition, and the image was acquired through the USGS Earth Resources Observation Systems Data Center, which has corrected radiometric and geometrical distortions of the image to a quality level before delivery. The image was further rectified to a common Universal Traverse Mercator coordinate system based on 1:50, 000 scale topographic maps, and was resample using the nearest neighbor algorithm with a pixel size of 30 m by 30 m for all bands including the thermal band. Surface temperature is an important parameter in understanding the exchange of energy between the earth surface and the environment. Normally the surface temperatures are derived from the TIR band radiance values of ETM+ sensor. The surface temperatures are extracted using the simplified Plank function (Markham & Barker, 1986).The methodology of study district is given below.

(a) Conversion from Digital Number to Radiance

L = LMIN + (LMAX - LMIN) * DN / 255

Where

L = Spectral radiance

LMIN = 1.238 (Spectral radiance of DN value 1)

LMAX = 15.600 (Spectral radiance of DN value 255)

DN = Digital Number

(b) Conversion from Radiance to Surface Temperature

(c) Temperature in Kelvin

Where

(d) K1= Calibration Constant 1 (607.76)

(e) K2 = Calibration Constant 2 (1260.56)

(f) TB = Surface Temperature

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{L} + 1\right)}$$

(c) Conversion of Kelvin to Celsius

(a) TB = TB -273

(d) Calculation of NDVI for ETM+,TM Satellites Images

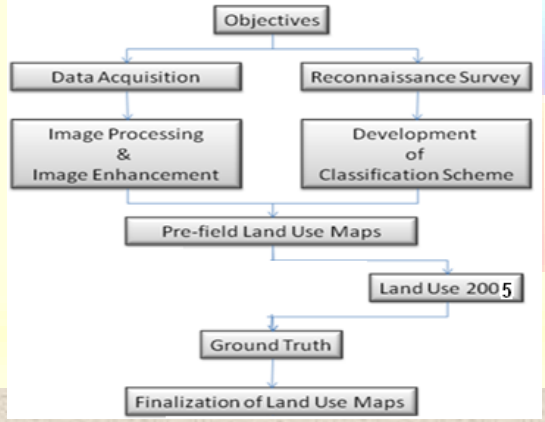
NDVI = (NIR - Red)/(NIR + Red)

Where

NIR is near infrared reflectance (band4)

Red is red infrared (band3)

(e) Classification of Landuse from ETM+,TM Satellites Images



Results and Discussion:

The study is based on unsupervised classification, LST classification and field verification of the 2005 image. The effects of urbanization were clearly evident through the decrease in the area of low density built up spaces and sparse vegetation. In land use classification built up area has covered 4.25% area, followed by very dense forest 15.93% and moderate dense forest 21.56%. 13.74 % and 38.74% area is included in open forest and cultivated land, whereas scrub land and water bodies have covered 0.94% and 0.76% area of the total landuse area is shown figure.2. In general, NDVI (Normalized Difference Vegetation Index) cover for the study area. In this case, NDVI is brought for ETM+ images. In this study the high temperature zone having negative NDVI indicates non forest, bare land and built up area construction surface. The low temperature zones have positive NDVI value indicating the dense vegetation or forest cover. The NDVI images are shown in the figure.3.

LST (Land Surface Temperature) result shows a clear boundary between the isolated heat centre in the core settlement area and non forest of the study area. LST 16^0C-25^0C observes over the urban area and the non forest surfaces. Croplands and vegetated areas have the temperature from 10^0C -16^0C .LST image obtained from the raster model is shown in figure.4.

Table.1 LST for different landuse / landcover type

Land Use Class	LUC Classification 2005 (Area %)	LST Classification (Temp.^{0}C)
Very Dense Forest	15.93	8^0C -14^0C
Mod. Dense Forest	21.56	
Open forest	13.74	14^0C -15^0C
Scrub	0.94	16^0C -18^0C
Cultivated Land	38.74	14^0C -16^0C
Built up	4.25	16^0C -18^0C
Water Body	0.76	8^0C -10^0C
Non Forest	4.08	20^0C -25^0C

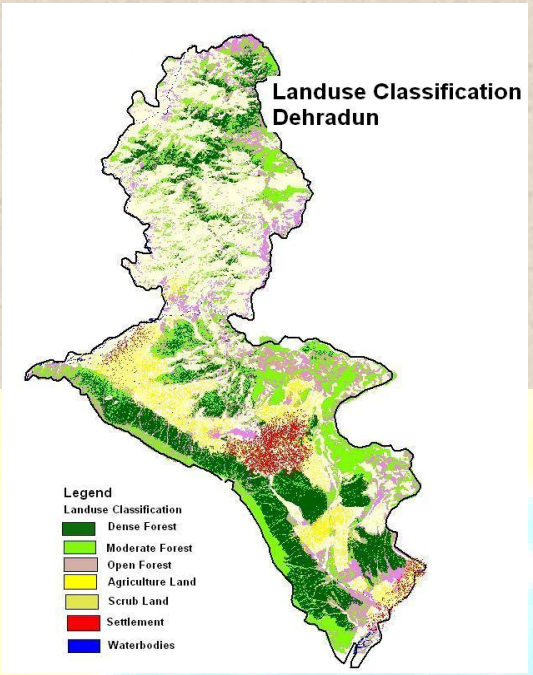


Figure.2 Landuse Classification

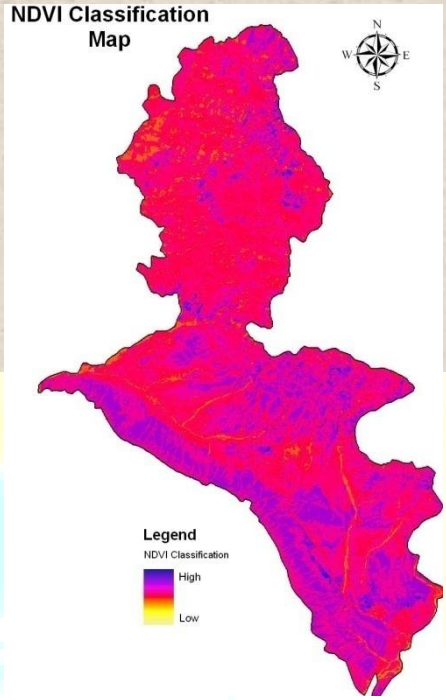


Figure.3 NDVI Classification

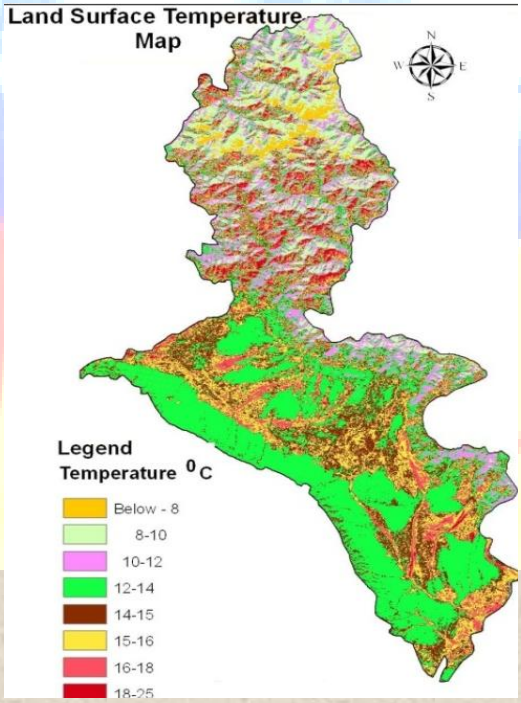


Figure.4 LST Classification of Dehradun District

Conclusion:

Landsat TM and ETM+ images are used for this study to calculate LST, Landuse and NDVI raster model. Thermal signatures of different landuse/landcover types in the study areas help to throw light on their roles in contributing to the increasing surface temperature phenomenon. The maximum temperature is found in built up areas and non forest areas with negative NDVI values where plantation\ forest cover is needed to reduce the land surface temperature and prevents from heat condition in built up areas. This study is more useful for urban and rural planning strategies, water balance computation, surface modeling (climatologically aspects), mapping hot spots and hydro electrical projects or dams.

Acknowledgement:

Authors are thankful to Prof. Kamlesh Kumar (Rtd.), HNBGU, Dpt. of Geography, Srinagar for his suggestion and guideline. We are also thankful to Dr. L.P.Lakhera, (Assit. Prof., Dpt. Geography, HNBG University) has rendered helpful support and guideline.

References:

- Jegankumar R., Umamathi S.,(2009),GIS and Remote Sensing for Urban Heat Island Analysis – A Case Study of Salem City and its Environ, *GIS for Natural Resources and Disaster Management*, pg.203-215.
- Ifatimehin, O. O, Ishaya, S and Fanan, U,(*2010),* An Analysis of Temperature Variations Using Remote Sensing Approach in Lokoja Area, Nigeria, *Nasarawa State University, Keffi, 6 (2): 35-44.*
- Sultan Alsultan, Mohd. Zubir Matjafri , Hwee-San LIM and Khiruddin Abdullah,(2005), An Algorithm for Land Surface Temperature Analysis of Remote Sensing Image Coverage Over AlQassim, Saudi Arabia, Pharaohs to Geoinformatics FIG Working Week 2005 and GSDI-8,Cairo, Egypt April 16-21, 2005.

- Lilly Rose A, Monsingh D. Devadas,(2009), Analysis of land surface temperature and land use / land cover types using remote sensing imagery - a case in Chennai City, India, *Anna University Chennai, India.*
- Javed Mallick, India, Atiqur Rahman, India, Pham Viet Hoa, Vietnam and P.K.Joshi, (2009), Assessment of Night-Time Urban Surface Temperature -Land Use/Cover Relationship for Thermal Urban Environment Studies Using Optical and Thermal Satellite Data, *7th FIG Regional Conference, Hanoi, Vietnam.*
- Boegh. E, Soegaard.H, Hannan.N, Kabat. P, Lesch.L,(1998), A remote sensing study of the NDVI – Ts relationship and the transpiration from sparse vegetation in the Sahel based on high resolution satellite data, *Remote Sensing of Environment, 69, 224 – 240.*
- Weng. Q, Lu . D, Schubring. J, (2004), Estimation of land surface temperature – vegetation abundance relationship for urban heat island studies, *Remote Sensing of Environment, 89 (4), 467 – 483.*
- Voogt. J. A, Oke. T. R, 2003, Thermal remote sensing of urban climates, *Remote Sensing of Environment, 86,370 – 384.*
- Lo, C.P. and D.A. Quattrochi, (2003), Land- use and land-cover change, urban heat island phenomenon, and health implications: A remote sensing approach. Photogrammetric Engineering and Remote Sensing 69(9), 1053-1063.
- Owen, T.W., Carlson, T.N., Gillies, R.R., (1998), Remotely sensed surface parameters governing urban climate change: *Internal Journal of Remote Sensing*. v.19, p.1663–1681.