Analysis of Relative Importance of Parameters Representing Vegetation, Urbanization and Elevation with Land Surface Temperature using ANN

Goyal, Rohit¹, Khandelwal, Sumit² and Kaul, Nivedita²

ABSTRACT

Land surface temperature (LST) is a very important physical parameter of the Earth’s surface, which depends on a number of parameters including vegetation cover, vegetation type, land use, land cover, percent impervious surface area, elevation, road density (RD) etc. (Yuan & Bauer, 2007; Khandelwal & Goyal, 2010). However the influence of various parameters on LST has not been studied quantitatively, which is very important as maximum studies on LST dynamics have compared the relationship of LST with individual parameters and simultaneous effect of number of parameters on LST variations has not been studied. This paper studies the relative importance of parameters representing vegetation (Normalized Difference Vegetation Index, NDVI), urbanization (RD) and surface feature (elevation). Artificial neural network (ANN) technique has been used for the analysis. Analysis has been carried out for three seasons of summer, monsoon and winter seasons for area surrounding Jaipur city study area. Aqua/MODIS and ASTER data for the year 2008 has been used for the study. It is found that of all the parameters studied, NDVI has maximum significance on LST, followed by RD and elevation.

1. Introduction

High paced development has taken place during last few decades which has resulted into movement of population from rural to urban areas. This movement has caused large scale urbanization all around the world. Most common visible aspect of urbanization is that the natural landscape having predominantly vegetation cover and pervious areas is converted into built up and impervious area. The impervious area is largely contributed by use of materials like concrete, bricks, tiles etc for buildings and bitumen etc. for roads and parking lots. The introduction of new surface materials coupled with emission of heat, moisture and pollutants change radiative, thermal, moisture, roughness and emission properties of the surface and the atmosphere above (Roth, 2002). In addition, urbanization also causes generation of large amount of heat by vehicular traffic, industries and domestic buildings which also cause increase in local air and surface temperatures. Surface and atmospheric modifications due to urbanization generally lead to a modified thermal climate that causes local air and surface temperatures to rise several degrees higher than the simultaneous temperatures of the surrounding rural areas and this phenomenon is referred as Urban Heat Island, UHI. (Streutker 2003). Heat islands have been

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defined as canopy layer urban heat island (CLUHI) when variations in air temperatures are studied and surface urban heat island (SUHI) for variations in surface temperatures (Voogt and Oke, 2003). The study of SUHI has been largely dependent on remote sensing data and land surface temperature (LST) derived from the satellite data is used for that purpose. Satellite derived LST has been used in many studies and one of the important advantages of remote sensing data is higher spatial resolution of such data thus enabling study of very large area (Zhangyan et. al., 2006, Jusuf et. al., 2007, Yuan and Bauer, 2007, Liang and Weng, 2008, Parida et. al., 2008, Cheval and Dumitrescu, 2009).

Land surface temperature (LST) is defined as the skin temperature of ground. It indicates soil surface temperature for bare soil. LST can be viewed as the canopy surface temperature of the vegetation for dense vegetated ground and for sparse vegetated ground, it is determined by the temperature of the vegetation canopy, vegetation body and soil surface (Qin and Karnieli, 1999). Due to modifications of the land use and land cover due to urbanization there is change in the surface of ground as well as vegetation which are replaced by buildings of varying heights and surfaces of varying properties and consequently there will be changes in the contributors of the surface temperatures as defined above. A number of studies have been conducted to study the LST dynamics with one or more of the land surface characteristics or parameter measuring extent of urbanization. In various studies vegetation cover has been expressed either as NDVI or as vegetation patches or as vegetation fraction. Similarly parameters such as percent impervious surface area (%ISA) or land use or normalized difference built-up index (NDBI) have been used to quantify the extent of urbanization. In most of the studies negative correlation has been reported between LST and vegetation (Yuan and Bauer, 2007; Liang and Qihao, 2008; Weng at al., 2004; Zhang et al., 2009; Pu et al., 2006). Quality of vegetation cover is dependent on availability of water and the density of vegetation cover is typically found, in increasing order, for agriculture in desert areas, rainfed agriculture, irrigated agriculture and forest. The land surface temperature of these categories of vegetation has been reported to be in falling order from agriculture in desert area to forest (Parida et al., 2008). Khandelwal and Goyal (2010) studied the variations in LST due to the change in elevation derived from ASTER global digital elevation model (GDEM) and concluded inverse relationship between LST and elevation for study area surrounding Jaipur city.

The effect of urbanization has long been studied and its effects have been reported on stream habitat, temperature and environment, soils, groundwater and even dietary habits (Wang et al., 2001; Baker et al., 2002; Marcotullio et al., 2008; Naik et al., 2008; Lazarou & Kalavana, 2009). A number of studies have reported positive relationship between LST and indicators representing urbanization such as %ISA, NDBI, land use. While these indicators incorporate the surface property only, Khandelwal and Goyal (2010) suggested road density (RD) as a parameter which incorporates the primary effect of the changes in surface properties as well as the secondary effects due to vehicular, industrial and other pollution and concluded that a strong positive relationship exists between RD and LST for all the study seasons.

Most of the studies conducted on LST dynamics have studied the variations in LST over variation of one or other parameters and the correlations thus found have been compared to
suggest the suitability of various indicators. However the relative weightage of these parameters on LST is not reported. The objective of the present research are to analyse the relative weightages of elevation, NDVI and RD for LST variations over study area surrounding Jaipur city. These can be utilized for developing model for predicting the surface temperature of a particular area for given values of other parameters.

2. Methods and Results

2.1 Study Area

The study area chosen is Jaipur city, the capital of the state of Rajasthan, India. The city is located on a predominantly flat plain and is surrounded by hills on the north, north-east and east sides. Due to the hills, the development of the city has been more along south and west. The part of city closer to the hills is characterized by mostly built-up and paved areas having very less vegetation cover. Rest of the city has a mixture of barren land, low to medium height vegetation and built-up areas in form of buildings, roads, industries etc. The climate of the city is arid with high temperatures during summers and low temperatures during winter nights. Figure 1 shows the study area for the present study in which MODIS yearly land cover dynamics of 2008 was used to extract the urban boundary of Jaipur city. The Jaipur urban area polygon from land cover dynamics image was automatically converted by using Raster to Polygon conversion tool. A preliminary analysis indicated that a buffer of 12 km is sufficient to include rural belt outside the city area and therefore Buffer tool with 12 km distance outside the urban boundary was used to mark the boundary of study area as shown in fig. 1.
2.2 Remote Sensing Data

In addition to the land cover dynamics product of MODIS, several other remote sensing data products, as given in table 1, were used. The study area has mainly three seasons and the study has been carried out for all three seasons namely summer, monsoon and winter season.
Table 1: Remote Sensing Data products used for the present study

<table>
<thead>
<tr>
<th>MODIS Product</th>
<th>Platform (Sensor)</th>
<th>Short Name</th>
<th>Cell Size</th>
<th>Season</th>
<th>Day No. (Period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land cover Dynamics</td>
<td>Combined Aqua &amp; Terra (MODIS)</td>
<td>MCD12Q2</td>
<td>App. 926 m</td>
<td>All</td>
<td>Yearly</td>
</tr>
<tr>
<td>Land Surface Temperature and Emissivity</td>
<td>Aqua (MODIS)</td>
<td>MYD11A2</td>
<td>App. 926 m</td>
<td>Winter</td>
<td>001 (00:00:00 hrs on 1 Jan to 23:59:59 on 8 Jan)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Winter 121 (00:00:00 hrs on 1 May to 23:59:59 on 8 May)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Monsoon</td>
<td>265 (00:00:00 hrs on 22 Sep to 23:59:59 on 29 Sep)</td>
</tr>
<tr>
<td>Vegetation Indices</td>
<td>Aqua (MODIS)</td>
<td>MYD13Q1</td>
<td>App. 423 m</td>
<td>Winter</td>
<td>121 (00:00:00 hrs on 1 May to 23:59:59 on 16 May)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Summer</td>
<td>265 (00:00:00 hrs on 22 Sep to 23:59:59 on 7 Oct)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Monsoon</td>
<td>361 (00:00:00 hrs on 27 Dec to 23:59:59 on 11 Jan)</td>
</tr>
<tr>
<td>Global Digital Elevation Model (GDEM)</td>
<td>Terra (ASTER)</td>
<td>AST14DEM</td>
<td>App. 25 m</td>
<td>All</td>
<td>-</td>
</tr>
</tbody>
</table>

These products were downloaded from Land Processes Distributed Active Archive Center (LP DAAC) website using NASA Warehouse Inventory Search Tool (WIST). Data for year 2008 has been used for the present study. The data from MODIS sensor is in HDF-EOS format and in Sinusoidal Projection System. MYD11A2 & MYD13Q1 products have 12 Science Data Sets (SDS) layers each and MCD12Q2 has 16 SDS layers. The data was sub-set to the study area and also simultaneously reprojected from Sinusoidal projection to UTM projection system with WGS84 datum (Zone 43N) and was reformatted from HDF-EOS to GeoTIFF format using Modis Reprojection Tools (MRT). AST14DEM is available in GeoTIFF format. Single image of ASTER data covers approx. 60km x 60km area and multiple images covering the entire study area were downloaded and mosaic together. The various data layers in GeoTIFF format were then analyzed using ArcGIS software. QC_Night (quality flag for night image) and LST_Night_1km (Night LST) layers of MYD11A2, 250m_16_days_NDVI and 250m_16_days_VI_Quality (quality flag for vegetation indices) layers of MYD13Q1 and Land_Cover_Type_4_Assesment layer of MCD12Q2 product have been used for the present study.

2.3 Image Processing

The MODIS and ASTER products have different spatial resolution and in order to compare them it is necessary to have all of them at same resolution and hence all the products were aggregated to the same resolution as of LST layer. The study area has 1612 pixels of approximately 926 m cell size. The quality flags of MYD11A2 and MYD13Q1 were checked to include only the good quality pixels in the analysis. Those data pixels in which error of the
computed LST is less than 1 K have been considered as good quality pixels for LST. Use of quality flag of MYD13Q1 (also known as quality assurance) enables user to remove pixels on the basis of adjacent clouds detected or for which atmosphere bidirectional reflectance distribution function (BRDF) correction was not performed, as these may cause error in calculation of NDVI values.

The road map of Jaipur city and its surrounding area was prepared by on-screen digitization. The roads were divided into three categories namely, highways and major roads; main roads; secondary roads and streets. These three categories are distinctly visible on Google Earth at different zoom levels. The roads were digitized on screen over the roads visible on Google Earth. The digitized roads were then thoroughly checked for duplication/omission/errors. Total length of roads in the study area is 4578.6 km. The road map has been used to calculate RD value for every cell of the study area. RD has been calculated as line density, which is magnitude per unit area of the road features that fall within a fixed radius around each cell. For the present study this radius has been taken as 655 m, which is the radius of a circle inscribing one complete cell and hence the cell size of RD map has been kept same as that of other parameters. Figure 2 shows the road density map of the study area. The value of RD varies from zero to 27.8 km per square km.

![Road Density Map of Study Area](image)

**Fig. 2: Road Density Map of Study Area**

### 2.4 Artificial Neural Network

A neural network, also called a multilayer perceptron, is a simplified model that works by simulating a large number of interconnected neurons. There are typically three parts in a neural network: an input layer, with units representing the input fields; one or more hidden layers; and
an output layer, with a unit(s) representing the output field(s). Fig. 3 shows the structure of the neural network. The units are connected with varying connection weights. Input data are presented to the first layer, and values are propagated from each neuron to every neuron in the next layer. Eventually, a result is delivered from the output layer. The network learns by examining individual records, generating a prediction for each record, and making adjustments to the weights whenever it makes an incorrect prediction. This process is repeated many times, and the network continues to improve its predictions until one or more of the stopping criteria have been met. Initially, all weights are random, and the answers that come out of the net are probably nonsensical. The network learns through training. Examples for which the output is known are repeatedly presented to the network, and the answers it gives are compared to the known outcomes. Information from this comparison is passed back through the network, gradually changing the weights. As training progresses, the network becomes increasingly accurate in replicating the known outcomes. Once trained, the network can be applied to future cases where the outcome is unknown.

![Fig. 3: Structure of Neural Network](image)

In the present work a three layered neural network is developed with one input layer containing three neurons, on each for NDVI, road density and elevation values; one hidden layer of three neurons and one output layer of single neuron representing LST. 50% of the sample was used for training of the neuron network, based on which connection weights are determined. The model determines relative importance of the three input parameters and the same has been given in table 2.

**Table 2: Relative importance of input parameters**

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Relative Importance Value as per ANN Model</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDVI</td>
<td>0.49</td>
<td>Highest</td>
</tr>
<tr>
<td>RD</td>
<td>0.33</td>
<td>-</td>
</tr>
<tr>
<td>Elevation</td>
<td>0.31</td>
<td>Lowest</td>
</tr>
</tbody>
</table>
This can be seen from table 2 that NDVI, which is an indicator of vegetation, is the most significant parameter affecting LST dynamics and as negative relationship exists between LST and NDVI. Though the relative significance of NDVI is high, significance of RD and Elevation is also high. Elevation is slightly less significant as compared to RD.

3. Conclusions

This paper studies the relative importance of three different parameters namely NDVI (representing vegetation), RD (representing urbanization) and Elevation (surface physical property) for LST dynamics. NDVI is found to be most significant among the three parameters thus establishing that the variations in LST can be attributed to change in vegetation level. However the significance of other parameters is also comparable thus suggesting that any study of LST dynamics should be carried out using multi parametric approach.

4. References


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Prof. Goyal completed his Doctoral Research from University of Roorkee, India in 1994. He has also done Post Graduate Diploma in Remote Sensing Applications in Water Resources from IIRS, Dehradun. He has undertaken five research projects from MHRD, AICTE and DST. He is member of a number of international and national societies including Indian Society of Geomatics, The Institution of Engineers, Indian Society of Remote Sensing etc. He has published 12 papers in Refereed Journals, about 50 papers in Conferences/Seminars. He has also authored 2 Technical Reports, 1 Edited Book and five Chapter of edited Books. He has organized a number of national conferences, short term training programmes including HYDRO 2008.