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Urban Heat Island Footprint Mapping of Delhi Using Remote Sensing

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ABSTRACT: Urban centres are increasing in number and size to foster the economic development in India. Increasing population is putting tremendous pressure on the limited resources available with these urban centres. Urban centres have system behaviour where pressure on any part of the system distort the system and the system as whole resist the change. Urban system is composed of various subsystem namely physical, economy, social, environmental, ecology, institutional and infrastructure. In the era of development, our planners are focused towards achieving economic development through physical development, losing on environment and ecological fronts. Urban heat island (UHI) is one of the backwash effect of this urbanization and causes economic, social, environmental and ecological losses. Taking Delhi as a case, this paper aims at capturing the spatial variability and exposer to urban heat island using remote sensing. Image processing techniques using Erdas imagine, ArcGIS are used for capturing the systems growth. Land surface temperature (LST) analysis techniques are used to quantify UHI. The increased urban surface temperature intensity is quantified in relation with rural temperature. Various indices namely normalized difference vegetation index (NDVI), normalized difference bareness index (NDBI), and soil and atmospherically resistant vegetation index (MSARVI) are developed and then utilized to see the spatial variability and their correlation with UHI intensity. UHI derived from the landsat imagery can be utilized to quantify the backwash effect of land cover change over a period of time. The study concludes with the impact of UHI intensity on electricity consumption and estimated savings by mitigating UHI.

I. INTRODUCTION

India, in 21st century, is developing at par with the developed world. Urban settlements with 32% population are contributing 70% of this economic development. This led to increase in number of urban centres, increase in the population density of the existing urban settlements along with the increase in the sprawl. The economic development, infrastructure availability and social life become major attraction for rural to urban migration. UN population projections for India show that 50% of the population will be urbanized by 2041. Rapid urbanization changes the landscape conditions, infrastructural and industrial progress significantly modify the atmospheric properties both within and around these settlements. The phenomenon of temperature rise in settlements with higher human intervention “termed as urban settlements” as compared to neighboring areas is known as urban heat island. The rise in temperature in urban centre as compared to surrounding suburbs is resultant of the intensity of anthropogenic activities in urban settlements. Remote sensing is an UHI observational technique, that provides the continuous spatial information of an area under observation. Arial Photography (Voogt & Oke 1997; Schwarz *et al*. 2012), Landsat (Nichol 2005; Tran *et al.* 2006; Weng *et al.* 2004; Qin *et al*. 2001; Agarwal *et al.* 2014), MODIS (Keramitsoglou *et al.* 2011; Ma *et al.* 2013; Schwarz & Manceur 2014), ASTER (Kato & Yamaguchi 2007; Nichol 2009; Feizizadeh & Blaschke 2013), NOAA, SPOT, LISS III, SEVIRI satellites have been used for analysis of UHI. The limitations of remote sensing observation are spatial and temporal resolution of the satellites used, for capturing the variability of urban system. Retrieval of LST from Landsat TM/ETM/OLI imagery has shown optimal spatial and temporal results because of its 30 M spatial resolution and revisit time of 16 days. While downloading the data from USGS, it has been observed that almost 90% of the imagery are affected by the cloud cover which decreases the temporal resolution of the data in study area.

II. STUDY AREA

Delhi (Union Territory), the capital city of India and metropolitan, has observed enormous development in past century. Population has also grown many fold, increasing the demand for resources with decrease in the land availability for further development. Increasing population require more buildings, spatial and geographical footprint, vehicles, industries etc., generating anthropogenic heat, which then require more resources for meeting human needs. Delhi, with the limited resources, is dependent on the surrounding states for its basic needs. Looking at the complexity of Delhi, authors identified the state for detailed study and modelling the spatial variability of different variables over a time period.

III. METHODOLOGY

Remote sensing imagery captured by Landsat satellites from USGS website with Row 146 and Path 40 and cloud cover less than 4%, covering the study area, have been used. Mono window algorithm proposed by Qin *et al.* (2001) is used for LST computations (Fig. 1).

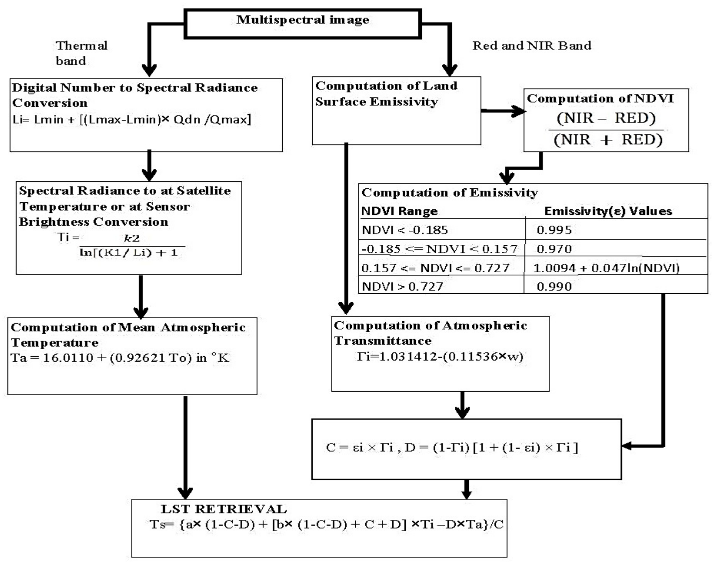


Fig. 1. Detailed methodology for LST retravel.

Single imagery of Row 146 and Path 40 is not able to capture Delhi as a state in complete and intermixing of two paths would have led to merging of two different weather conditions. The mixing would provide imperfect results of UHI intensity. So, authors preferred to use the subsets of Row 146 and Path 40 of the imagery and Delhi state boundary. Different spectral bands of these imagery have been downloaded and stacked using ERDAS Imagine software to develop multispectral .img files of respective imagery for further analysis. The algorithm is specifically designed to derive Land Surface Temperature (LST) from transmittance, emissivity, and effective mean atmospheric temperature from Landsat TM/ETM+/OLI.L and cover change detection using K-Mean algorithm is done for identification of urban cover. Various indices namely Normalized Difference Vegetation Index (NDVI), Normalized difference Bareness Index (NDBI), and Soil and Atmospherically Resistant Vegetation Index (MSARVI) using standard equation are developed. Stacking of the indices developed and LST is done in Erdas Imagine. The .img file is used to see the spatial variability and their correlation with UHI intensity with different indices mentioned above.

IV. RESULTS

The urbanization in Delhi is very much from the results. Correlation of LST with NDVI, NDBI and MSARVI, presented in table 2. The chronological growth of landcover, NDVI, NDBI and MSARVI has been presented in Table 1. The correlation results show that NDVI and MSARVI are negatively correlated whereas NDBI is positively correlated. It can be inferred that NDBI of the image is better representation of LST as compared to other two.

Table 1: Chronological growth of Urban Land Cover, NDVI, NDBI, MSARVI and LST.

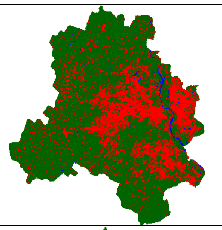
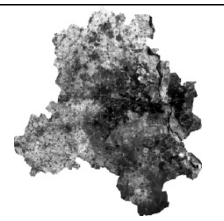
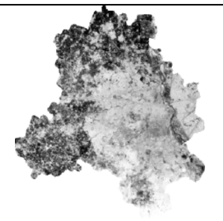
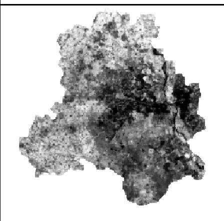
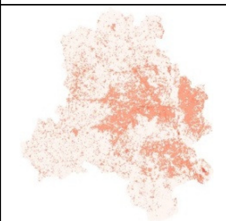
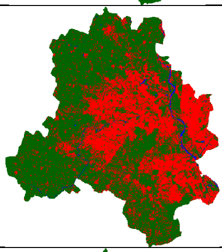
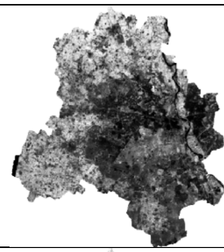
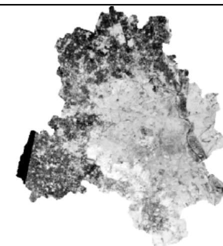
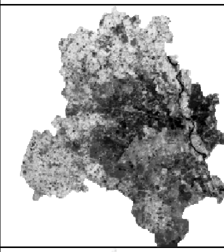
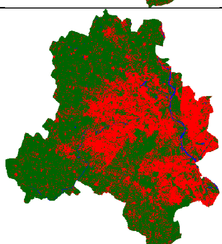
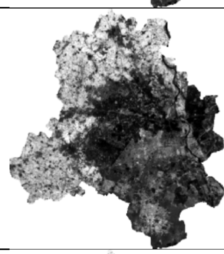
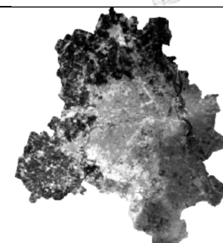
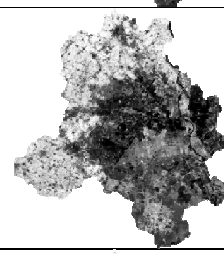
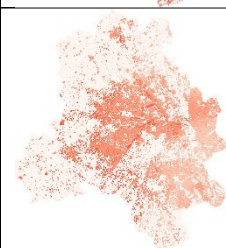
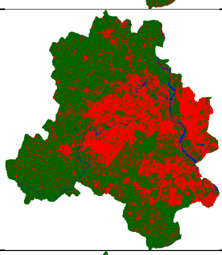
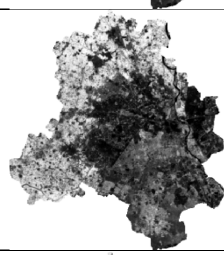
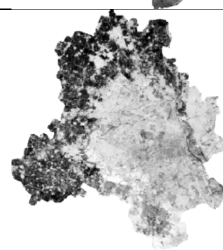
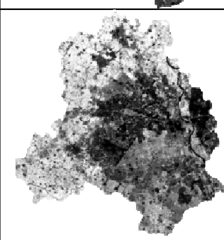
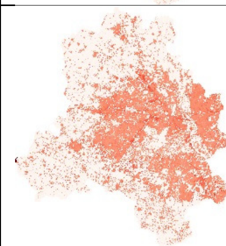
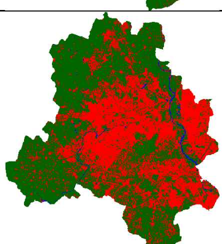
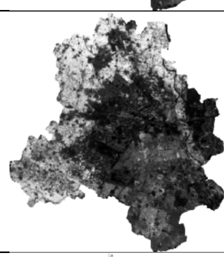
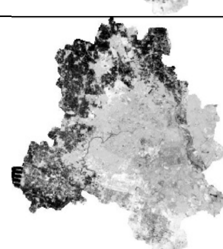
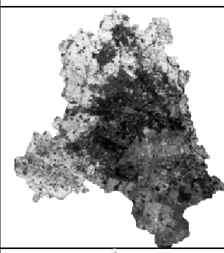
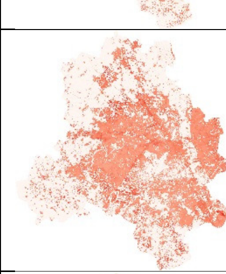
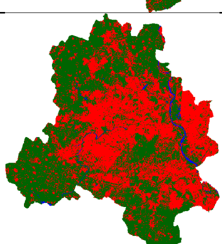
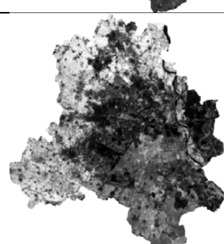
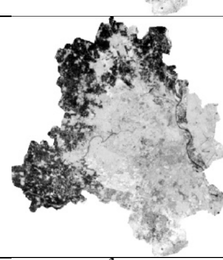
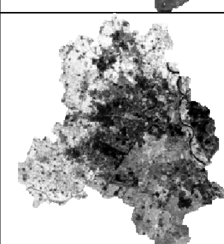
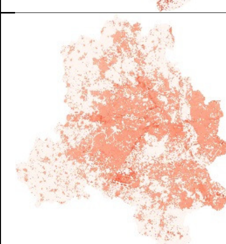
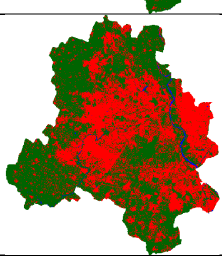
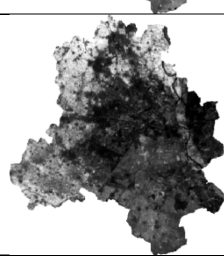
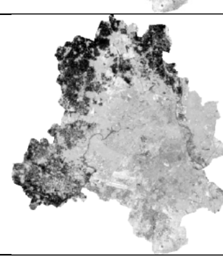
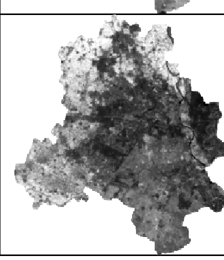
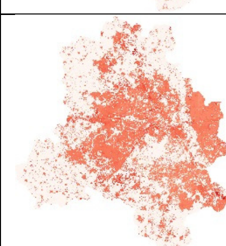
Year (Pop.)	Urban Land Cover	NDVI	NDBI	MSARVI	LST	°C
1991 (9550000)						14
1996 (11610000)						23
2000 (13460000)						25
2003 (14480000)						23
2009 (16296000)						19
2011 (16896000)						16
2016 (18686902)						17

Table 2: Correlation of LST with NDVI, NDBI and MSARVI

Year	1991	1996	2000	2003	2009	2011	2016
NDVI	-0.65973	-0.65714	-0.63459	-0.72383	-0.68327	-0.71033	-0.5978
NDBI	0.794606	0.781529	0.74797	0.842154	0.806031	0.827942	0.785473
MSARVI	-0.63166	-0.61726	-0.62428	-0.66084	-0.64608	-0.67128	-0.57234

V. CONCLUSION

Landcover change detection and LST are highly beneficial in capturing the actual growth of city. It is useful in monitoring the success of development plans envisioned by urban planners. The soil characteristics in the study area highly impact the quantification of land cover classification and SUHI intensity through remote sensing. Land surface temperature intensity has shown increase as well as area of intense LST from 1991 to 2016. NDBI is better depiction of LST as compared to NDVI and MSARVI. Further land use land cover classification result urban areas promise higher degree of correlation with specific land uses, population and building density.

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