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Satellite Imagery Based Observation of Land Surface Temperature of Kathmandu Valley

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Abstract- Kathmandu valley one of the rapidly urbanizing city for a period of exactly twenty years. Cities are the new reformation of fertile land over the years to carry the volume of five million people from every corner of the country. The number of built-up areas is increasing exponentially at the gap of 5 years, which is gifting adverse effect on the environmental aspect. Recently, Kathmandu has been listed on the list of the worst case of climate change with the highlight of urban warming. As urban growth is known as one of the most contributing factors for urban warming so it is necessary to unveil the pattern of urban warming and degradation of land vegetation which is a direct relationship with an increment of the built-up area. Urban planners in urban planning and management team can use this pattern for prediction as well as to raise public awareness regarding urban warming effect. Remote Sensing, GIS, and statistical procedure have enabled monitoring land surface temperature and its correlation to land use. To analyze such relationship, we calculated NDVI and land surface temperature and change detection of temperature over a period of 21 years have been determined and it has shown that land surface temperature is in the increasing rate with the decrement of NDVI.

Keywords- *Kathmandu Valley, Satellite Imagery, GIS, NDVI, LST*

I. Introduction

Kathmandu valley is the capital of Nepal with 50 lakh people. After the period of 2000 AD people, all parts of Nepal are being migrated to here for various purposes and so to accompany them the building is built in an exponential rate. Urbanization has changed the existing natural land surfaces with the modern land use and land covers such as buildings, roads and other artificial area of human which indicates vegetation loss. Human population in the form of settlements and industrial area has a negative impact on the environment. Therefore, it is mandatory to have a detailed information about temporal land use changes and their rate. Land use should be matched with the land capability and at the same time, it should respect the environment, and global climate systems (UNEP, 1996).

The land surface temperature (LST) is the temperature of the land surface of a land which can be derived from the satellite information on the height of 1m. LST is the surface radiometric temperature emitted by the land surfaces and observed by a sensor at instant viewing angles (Prata et al., 1995).

Some studies have estimated the relationship between the land surface temperature and built up area, different built-up indices such as a normalized difference built-up index (NDBI) and the relation of NDBI is inverse with NDVI. Statistical analysis method was used to observe the relationship between NDVI and LST. The reason for changes in Land surface temperature is incorporated into many factors such as changes in land use, climatic condition, seasonal variation land surface parameters, seasonal variation, and economic development, etc. This paper considers only normalized difference vegetation index (NDVI) as a main cause of change in land surface temperature (LST). To study the effect of NDVI we should choose the Landsat collection level -1 image dated on roughly the same season. In this study, we investigate the effects of land use change on the land surface temperature in the Kathmandu valley based on the remote sensing analysis and zonal statistic methods. This paper focuses on the relation of NDVI with LST and pattern of temperature change and forecasts the future temperature of the valley for certain NDVI.

II. MATERIALS AND METHODS

A. Study area

Kathmandu valley is bowl-shaped. Its central lower part stands at 1,425 meters (4,675 ft) above sea level. Kathmandu valley is surrounded by four mountain ranges: Shivapuri (at an elevation of 2,800 meters or 9,200 feet), Phulchowki (2,795 meters or 9,170 feet), Nagarjun (2,825 meters or 9,268 feet and Chandragiri (2,551 meters or 8,369 feet). The major river flowing through the Kathmandu Valley is the Bagmati. The valley is made up of the Kathmandu District, Lalitpur District and Bhaktapur District covers an area of 220 square miles (570 km2). It carries 5 million people.

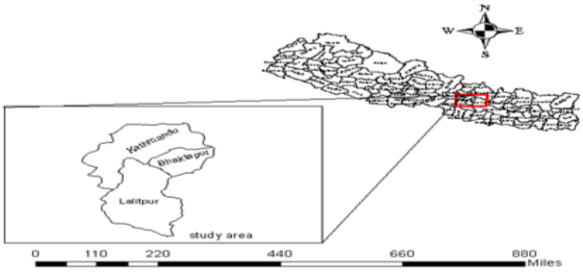


Figure 1. study area

B. *Data collection*

Satellite data that encompassed of 5 years interval multi-temporal satellite imageries. The path and row of data are 141 and 142.some data have a cloud percentage of less than 10% and some have greater than 10%.

TABLE I. SATELLITE IMAGE INFORMATION

SN	SPACECRAFT ID	SENSOR ID	DATE ACQUIRED
1	LANDSAT_5	TM	1996-10-05
2	LANDSAT_7	ETM	2002-10-27
4	LANDSAT_7	ETM	2012-10-22
5	LANDSAT_8	OLI_TIRS	2017-10-12

C. *Image pre-processing*

The file format and data type of the Landsat imagery were tagged image file format (TIFF) and integer respectively. All bands of the satellite imagery of Kathmandu valley (band 2-8 and 10-11) were clipped to the study area boundary. Since the imagery used was not cloud-free, similar to the situation mentioned by Deng and Wu (2013) in their study, so atmospheric corrections were performed using ENVI. Digital numbers (DNs) of bands 2-8 were converted to top of atmosphere (ToA) reflectance and surface reflectance using ENVI 5.1 and necessary information for ENVI were obtained from the metadata.

III. METHODOLOGY

A. *landsat7 TM*

The Surface temperature was derived from atmospherically corrected Landsat 5 TM (band 6). The Spectral radiance model was used to retrieve the surface temperature from the Landsat 5 TM and split window method was used to retrieve the surface temperature from LANDSAT 8 TIRS. A three-step process was followed to derive surface temperature from Landsat TM 5 Image. Spectral radiance was calculated using the following equation:

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

Where L = spectral Radiance, LMIN = 1.238, LMAX = 15.600, DN = Digital Number

Spectral Radiance (L) to the temperature in Kelvin may be expressed as:

$TB = K2/Ln\ (K1/L+1)$

Where K1= calibration constant 1 (607.76), K2= calibration constant 1 (1260.56), TB= surface temperature. Then land surface temperature is calculated in correlation with NDVI and is expressed as to convert the At-Satellite Brightness Temperature to Land Surface Temperature, using the equation $T = TB/[1+(\lambda * TB/c2) * \ln(e)]$.

s = Boltzmann constant = $1.38 * 10^{-23}$J

λ = wavelength of emitted radiance

$c2 = h * c/s = 1.4388 * 10^{-2}$ m K = 14388 μm K

B. *Landsat 8*

To calculate the LST, we use the USGS formulas (more information in the article Algorithm for Automated Mapping of Land Surface Temperature Using LANDSAT 8 Satellite Data),

Calculation of TOA (Top of Atmospheric) spectral radiance:

TOA (L) = ML * Qcal + AL, where:

ML = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number).

Qcal = corresponds to band 10.

AL = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number)

TOA to Brightness Temperature conversion:

BT = (K2 / (ln (K1 / L) + 1)) − 273.15

Where: K1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the thermal band number). K2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number).

Calculate the NDVI:

NDVI = (Band 5 – Band 4) / (Band 5 + Band 4)

Note that the calculation of the NDVI is important because, subsequently, the proportion of vegetation (Pv), which is highly related to the NDVI, and emissivity (ε), which is related to the Pv, must be calculated.

Calculate the proportion of vegetation Pv:

Pv = Square ((NDVI – NDVImin) / (NDVImax – NDVImin))

Calculate Emissivity ε:

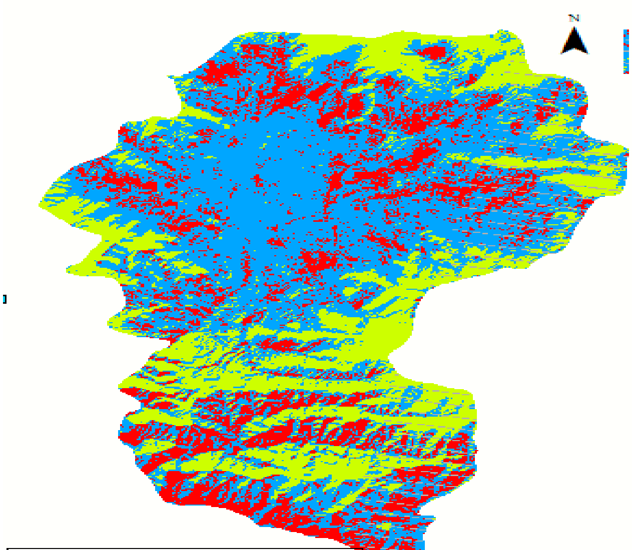
ε = 0.004 * Pv + 0.986

Calculate the Land Surface Temperature:

LST = (BT / (1 + (0.00115 * BT / 1.4388) * Ln(ε)))

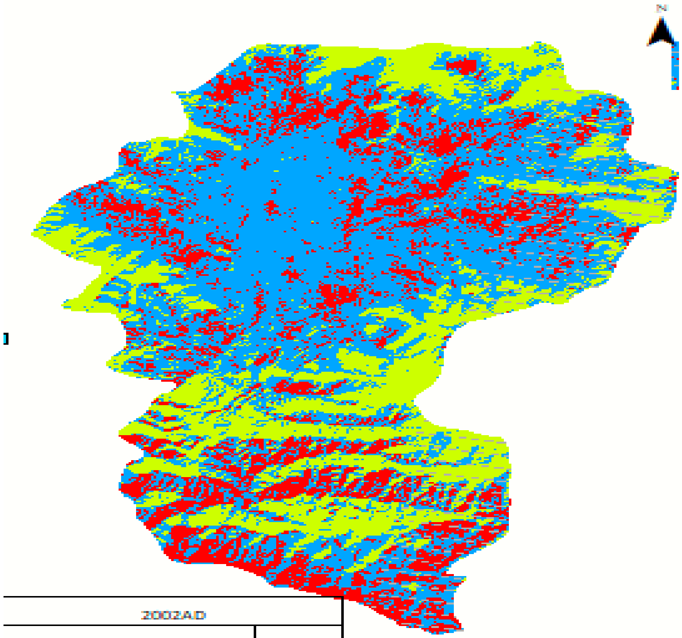
IV. OBSERVATION AND RESULTS

All the NDVI and LST model are shown by respective year are shown with their statistics.



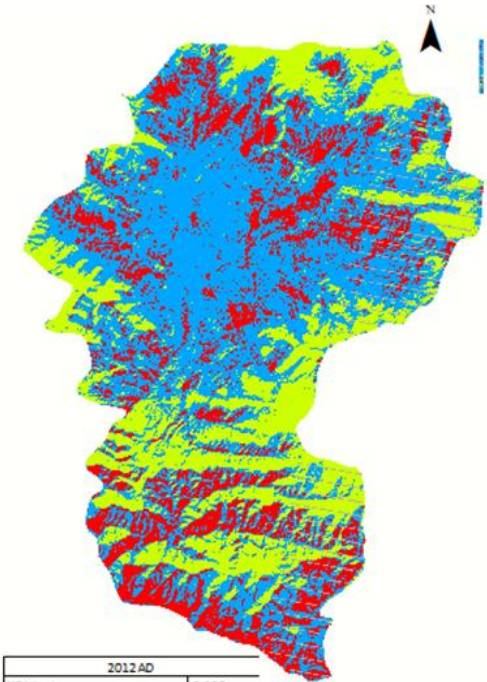
2017AD	
NDVI min	-0.225
NDVI max	0.811
NDVI mean	0.403
standard deviation NDVI	0.157

Figure 2. NDVI 2017



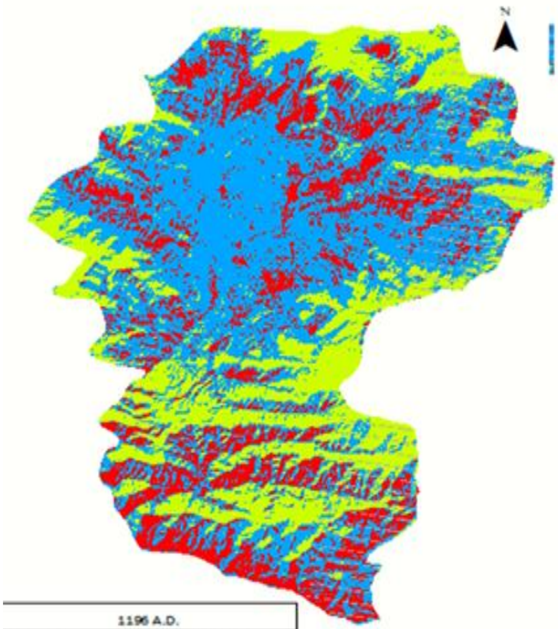
2002AD	
NDVI min	-0.135
NDVI max	0.854
NDVI mean	0.532
Standard Deviation NDVI	0.163

Figure 4. NDVI 2002



2012AD	
NDVI min	-0.129
NDVI max	1
Ndvi mean	0.411
standard deviation NDVI	0.171

Figure 3. Figure 3: NDVI 2012



1196 A.D.	
NDVI min	-0.2123
NDVI max	0.822
NdVI mean	0.552
standard deviation NDVI	0.137

Figure 5. NDVI 6

TABLE II. NDVI RESULT

NDVI result196 A.D.		2002AD		2012AD		2017AD	
NDVI min	-0.2123	NDVI min	-0.135	NDVI min	-0.129	NDVI min	-0.225
NDVI max	0.822	NDVI max	0.854	NDVI max	1	NDVI max	0.811
NDVI mean	0.552	NDVI mean	0.532	NDVI mean	0.411	NDVI mean	0.403
S.d NDVI	0.137	S.d NDVI	0.163	S. d NDVI	0.171	S. d NDVI	0.157

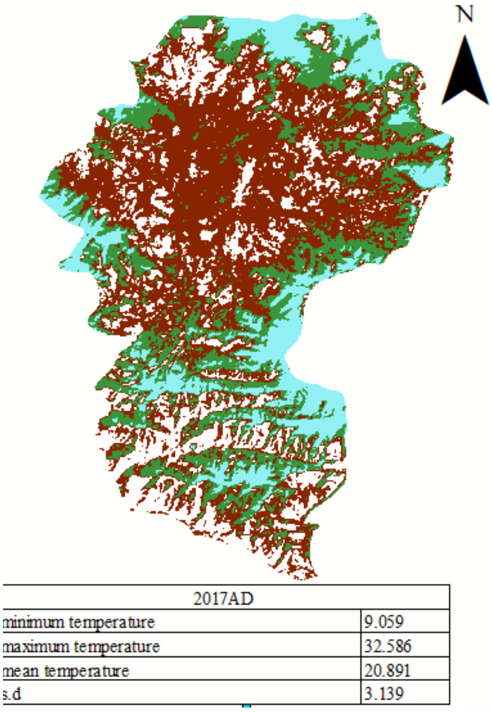


Figure 6. LST 2017

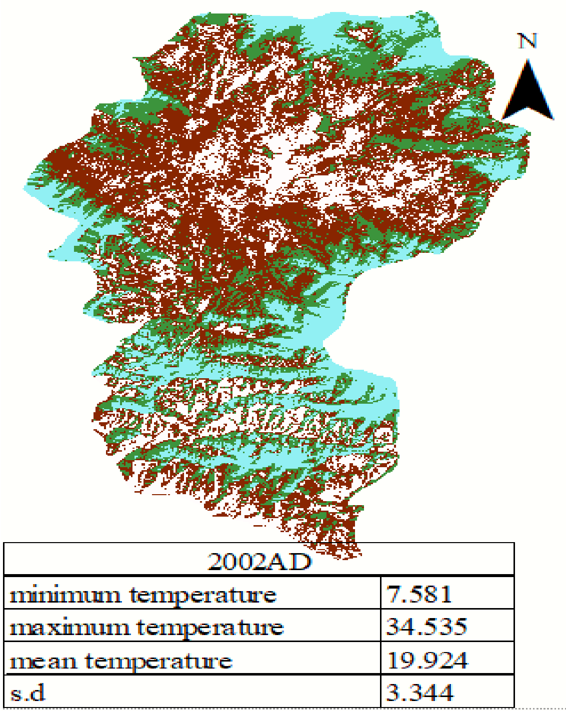


Figure 8. LST 2012

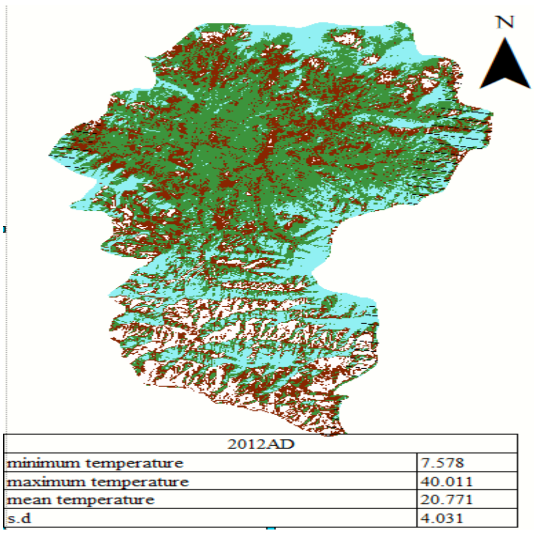


Figure 7. LST 2012

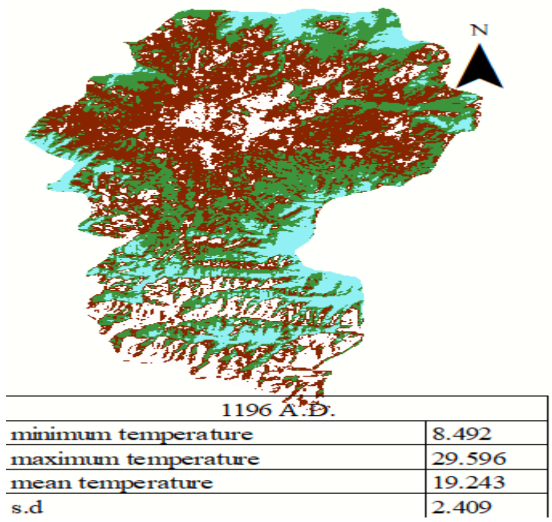


Figure 9. LST 1196

TABLE III. LST OF YEARS

1196 A.D.		2002AD		2012AD		2017AD	
Min. temp.	8.492	Min. temp.	7.581	Min. temp.	7.578	Min. temp.	9.059
Max. temp.	29.596	Max. temp.	34.535	Max. temp.	40.011	Max. temp.	32.586
mean temp.(°C)	19.243	mean temp.	19.924	mean temp.	20.771	mean temp.	20.891
S. d	2.409	S. d	3.344	S. d	4.031	S. d	3.139

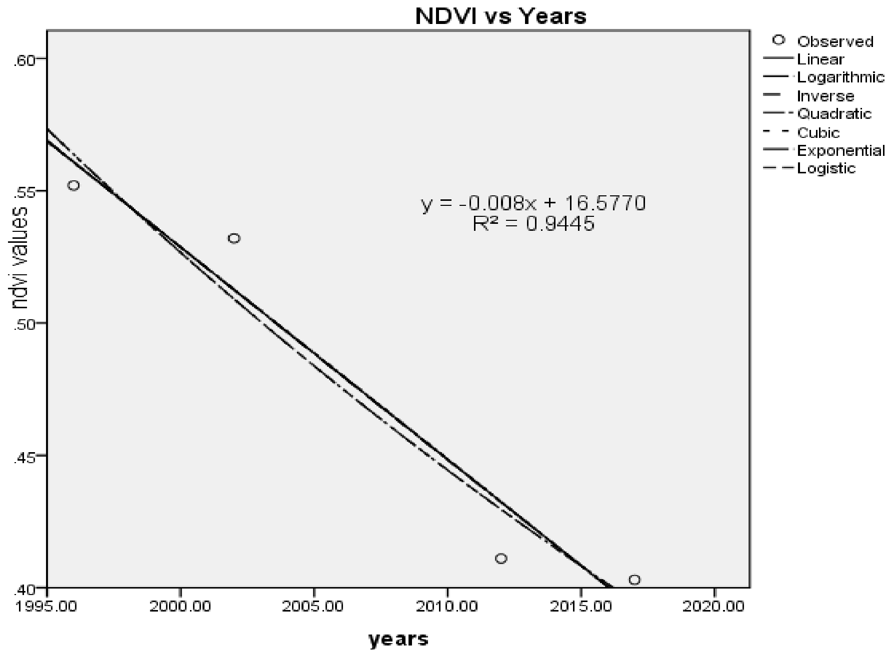


Figure 10. NDVI VS years

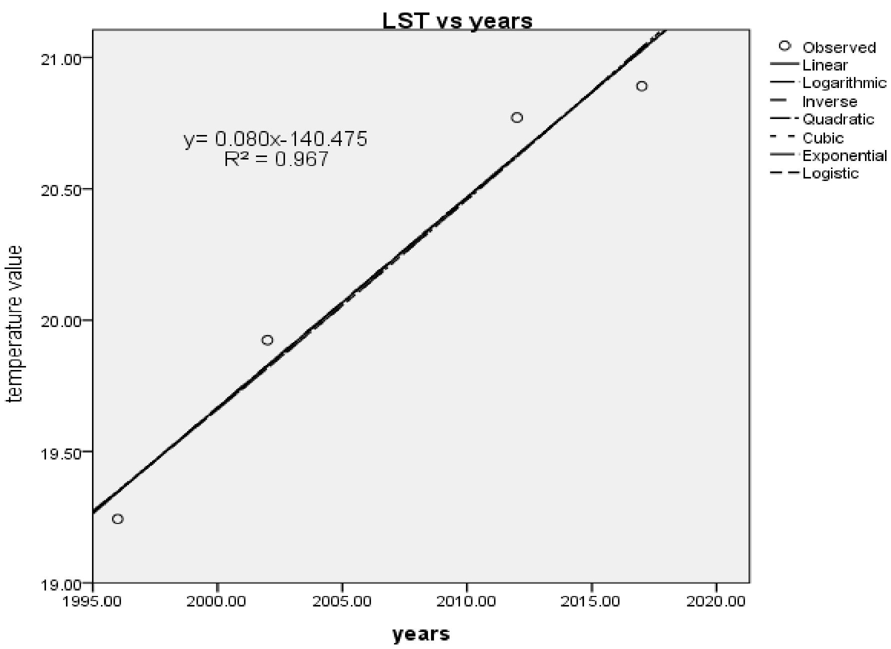


Figure 11. LST VS years

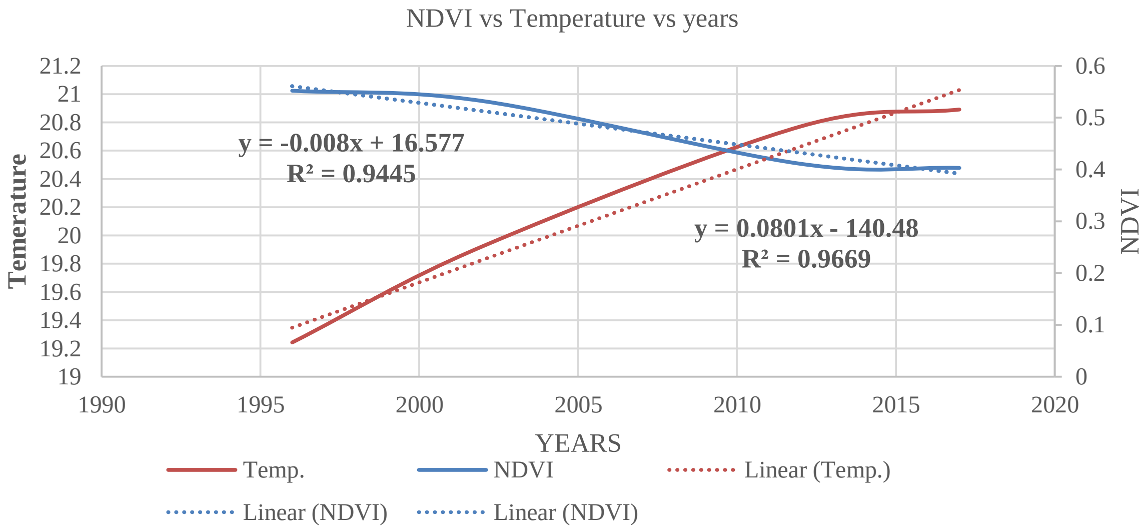
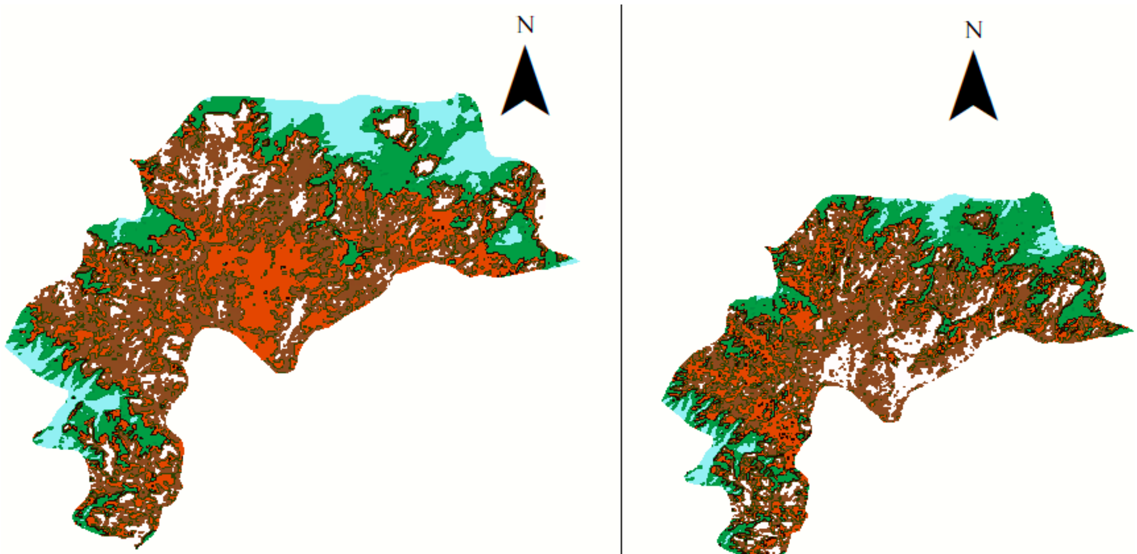


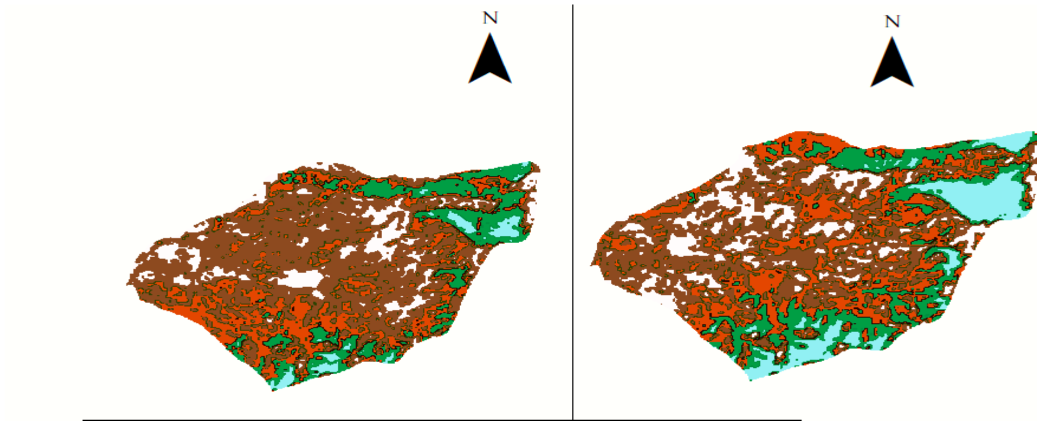
Figure 12. LST vs NDVI vs years

Mean temperature values of three districts of valley are listed below with their map:



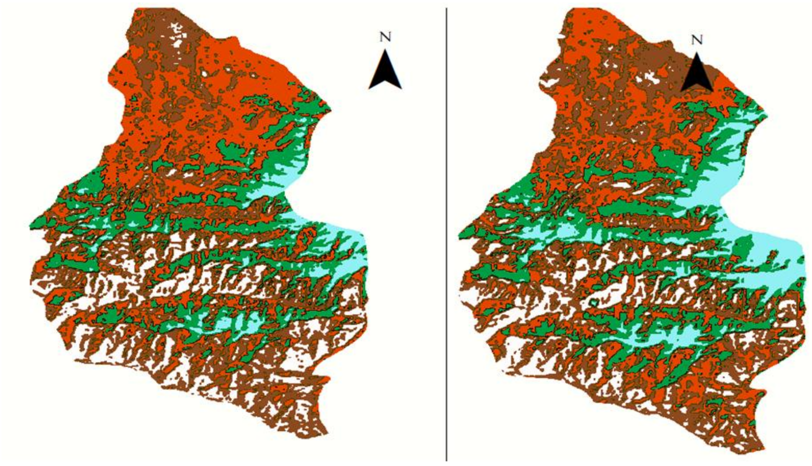
item	ktm	
years	1996	2017
minimum temperature	9.472	11.138
maximum temperature	27.516	30.837
mean temperature	19.401	20.908

Figure 13. LST of kathmandu valley of 1996 and 2017



item	bhaktapur	
years	1996	2017
minimum temperature	10.443	13.868
maximum temperature	24.974	28.052
mean temperature	19.218	20.898

Figure 14. LST of Bhaktapur of 1996 and 2017



item	lalitpur	
years	1996	2017
minimum temperature	8.495	9.059
maximum temperature	29.597	32.586
mean temperature	19.104	20.884

Figure 15. LST of Lalitpur of 1996 and 2017

TABLE IV. LST OF THREE DISTRICT

Item	Kathmandu		Bhaktapur		Lalitpur	
Years	1996	2017	1996	2017	1996	2017
Minimum temperature	9.472	11.138	10.443	13.868	8.495	9.059
Maximum temperature	27.516	30.837	24.974	28.052	29.597	32.586
Mean temperature (°C)	19.401	20.908	19.218	20.898	19.104	20.884

V. DISCUSSION

After 2000 AD people from number of district people were attracted towards Kathmandu valley due to suitable weather of valley, loads of facilities and centralization system so to provide accommodation to them number of ropani lands was converted to residential area as shown in figure as curve of NDVI and curve of LST of years from 1996 to the 2017 year are reverse in nature and which is supported by decreasing of NDVI from 0.552 to 0.403 over a period of 21 years which is about 27% decrement of vegetation area into urban area. With this decrement, it has made a rise of land surface temperature of 1.648 degree Celsius over 21 years, taking as NDVI as a parameter and satellite image of 30m resolution with more than 10% cloud. Among three districts of Kathmandu valley Lalitpur has been affected by urbanization with the rise of land surface temperature of 1.78degree Celsius and Bhaktapur is second and Kathmandu is third with 1.501degree Celsius. If the urbanization continues at the same rate then continue the rise of LST and decrement of vegetated area will make the urban heat island over the core area of Kathmandu valley.

VI. CONCLUSION

The study shows that high rate of urban area increments due to high the population influx and improper land use plan. As a result, productive agricultural land, open area is being replaced by the concrete structures. Based on the result of analysis of the thermal pattern of the study area over the given period of time, we found a gradual increase in temperature in the core area of the valley with the gradual decrease in NDVI. Regarding the determination of the appropriate approach for LST prediction, we use NDVI. However, there were some limitations to the study. The resolution of the images has been just moderate and change detection purpose and only NDVI were considered, however, other factors also play an effective role in LST. Despite the massive repository of Landsat imagery, sometimes it is difficult to get suitable images as per our requirement. In addition, due to the spectral mixing of different land cover within the pixels and complex landscape of the study area did not give us higher accuracy. Hence, we recommend that as urban growth in the Kathmandu valley is in critical condition it is high time that concerned authorities take necessary initiatives and urban residents develop resilience to urban growth and UHI effect.

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