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Analytical land temperature analysis with NDVI and NDBI for Buchakewadi watershed using google earth engine and GIS

SP Shinde, VN Barai, AA Atre and BK Gavit

Abstract
The study aims at the surface temperature of urbanization, Non-urban heat island (NUHI) and urban heat island, an important factor for heat changes that affect the surface of the earth. Therefore, due to local and global environmental changes and man-made operations, so many years of Buchakewadi watershed land surface temperatures are rising. The estimation of urban heat island, NDVI, and NDBI indices was calculated using GEE, Machine Learning Algorithm also remote sensing data. In this paper, the relationship and correlation between the LST, NDVI and NDBI indices have been established for the estimation of the surface temperature of the Buchakewadi watershed situated in Junnar block of Pune district of Maharashtra State. The NDVI and NDBI indices have been estimated using the Machine Learning Algorithm and satellite data. The GEE platform has provided easy access to all satellite data with a java script algorithm for analysis and LST relationship between the built-up area and the vegetative land. Various urban thermal islands (UHIs) have demarcated as higher temperatures in urban areas within village borders due to more man-made activities and climate change factors. The UHI value threshold for 2015 was measured at 43.04 °C and in 2019 at 44.68 °C. The relationship between LST–NDVI and LST–NDBI was identified quantitatively by a correlation analysis based on the algorithm and the GEE platform. LST shows a strong negative correlation (−0.41 for 2015 and −0.57 for 2019) with NDVI and a strong positive correlation (0.31 for 2015 and 0.71 for 2019) with NDBI throughout the Buchakewadi watershed. The non-UHI zones (green areas and water bodies) remain almost unchanged if any change is assumed to be very little altered, but the only UHI zones are in severe heat stress due to urban air pollution. The study field results can help to the urban, agricultural and ecological planners to decide on the sustainable practices of ecological and climate change.

Keywords: remote sensing, LST, NDVI, NDBI, GEE and UHI

1. Introduction
LST (Land Surface Temperature) is the world's surface temperature which is straightforwardly in contact with the estimating instrument (typically estimated in Kelvin). LST is the surface temperature of the world's outside layer where the warmth and radiation from the sun are assimilated, reflected and refracted. LST changes with a change in climatic conditions and other human exercises where the definite expectation gets testing. Overall urbanization has altogether expanded in ozone harming substances and reshaped the scene, which has significant climatic ramifications over all scales because of the synchronous change of normal land spread and presentation of urban materials for example anthropogenic surfaces. Ground overviews would allow a profoundly precise Land Use Land Cover (LULC) characterization; however, they are tedious, troublesome and costly, which features remote detecting an apparent and favoured other option. Recognizable proof and portrayal of Urban Heat Island (UHI) is commonly founded on LST that fluctuates spatially, due to the non-homogeneity of land surface spread and other barometrical elements. LST is the key factor for computing most elevated and least temperature of a specific area. Medium spatial goals information, for example, that from the LANDSAT and SPOT are appropriate for land spread or vegetation mapping at local nearby scale. LANDSAT 8 conveys two sensors, i.e., the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). OLI gathers information at a 30m spatial goal with eight groups situated in the noticeable and close infrared and the shortwave infrared districts of the electromagnetic range, and an extra panchromatic band of 15m spatial goals. TIRS faculties the TIR brilliance at a spatial goal of 100m utilizing two groups situated in the air window somewhere in the range of 10 and 12 µm. Unlike twentieth century, about 50% of the population is now living in the city. In recent years, with rapid development of

urbanization, India has gradually become one of the world's fastest countries in land cover changes. China, India and the United States of America had the largest numbers of urban dwellers in the world (United Nations, 2006). The conversions between vegetation, water and other ecological surface and construction land not only make obvious contradiction of water and soil resources supply and demand, but also cause many ecological environment effects including the reduce in evapotranspiration and water quality, flow speeding and the urban heat island effect enhancing. Temperature is an important magnitude for many environmental models. It can be obtaining a synoptic view of this magnitude on local, regional or global scales from thermal data provided by sensors on board satellites (Valor *et al.*, 1996). How to quantitatively monitor, analyse and evaluate the urban heat island effects have become one of the issues in current urban climate and environment research. Multi-temporal and multi-resolution remote sensing images can provide basic data for analysing urban spatial information and thermal environment effectively. Previous studies suggest that there exists a strong negative correlation between normalized difference vegetation index (NDVI) and land surface temperature (LST), whereas NDVI changes greatly with season. (NDBI) is defined as the linear combination of near infrared band (0.76–0.90 μm) and the middle infrared (MIR) band (1.55–1.75 μm), used for extraction of urban built up land. As one of the additional NDVI indices, NDBI can be applied to seasonal changes in surface urban heat island effect. The seasonal LST was estimated using the radiative transfer model. The relationship between urban surface temperature and surface characteristics indices was also analysed, aiming at providing the reference information and scientific basis for urban expansion monitoring an evaluation of ecological environment.

2. Material and Methods

The present study entitled "Analytical Land Temperature Analysis with NDVI and NDBI for Buchakewadi Watershed using Google Earth Engine and GIS." It was undertaken to study the comparison between different indices and impact of land surface temperature on it. The details of different instruments, and methods adopted during the research are described in this section.

2.1 Description of study area

The village Buchakewadi is situated in Junnar block of Pune district of Maharashtra State. It lies between 19°9 ' N to 19° 16' latitude and 73° 47 ' E To 73°64 ' longitude covered by survey of India on 1:50,000 Scale in (Fig. 1). The boundary of Buchakewadi Watershed was marked by utilizing Topo-sheet No. E43B16 of Survey of India (SOI) on a scale of 1:50,000 for delineation of watershed. The study area is covers 1028.21 ha. It has continental type climate classified as sub-tropical and sub humid with average annual rainfall of 741.90 mm. The highest elevation in the village is 1097 m whereas lowest elevation is 738 m from the mean sea level. The area is highly undulating and has moderate slopes ranging from 5 to 40%. Buchakewadi watershed is a part of Sahyadri ranges. The main drainage line is part of Bhima drainage system. Buchakewadi village is prone to high climatic stresses which further compound the problem.

2.2 Materials

2.2.3 Data collection

A. For Extraction of Land Surface Temperature

Landsat 8 is one of the Landsat arrangement of NASA (National Aeronautics and Space Administration). The information of Landsat 8 is accessible in USGS (United States Geological Survey) Earth Explorer site at liberated from cost. Landsat 8 satellite pictures the whole earth once in 16 days. In the present investigation, the TIR group's 10 were utilized to evaluate splendour temperature, the extent of vegetation and groups 4 and 5 were utilized to create NDVI of the examination zone. Satellite information over Buchakewadi watershed for May 2015 and May 2019 have been utilized in this examination. Landsat 8 gives metadata of the groups, for example, warm consistent, rescaling factor esteem and so on., which can be utilized for computation like LST.

B. For Calculation of Indices

Landsat 8 data collected from data catalogue of Google earth engine from Surface reflectance data as image collection for calculation of NDVI and NDBI for 2015 a for 2019 Sentinel 2 data collected from Google earth engine data catalogue used for same indices calculation. Java script used for requesting to the Google earth servers.

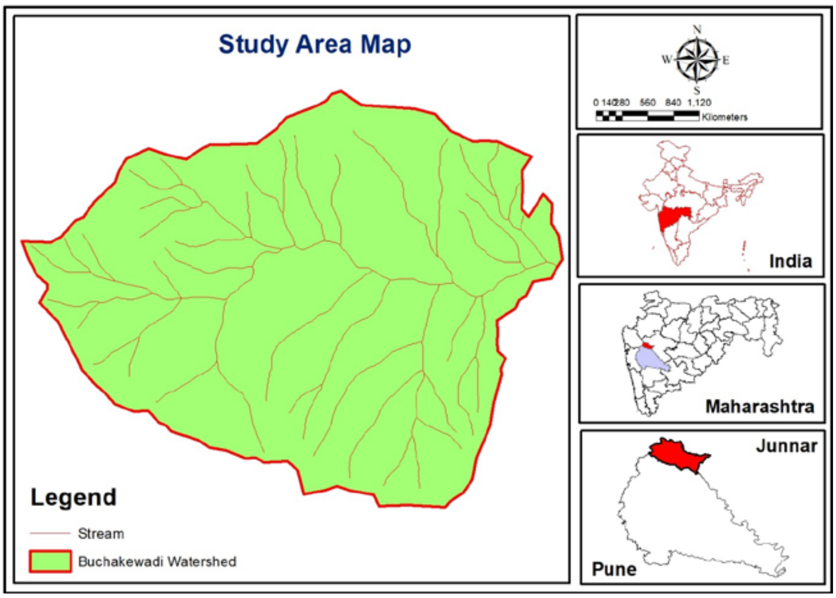

Fig 1. Location map of study area

2.3 Methodology
A. For LST extraction

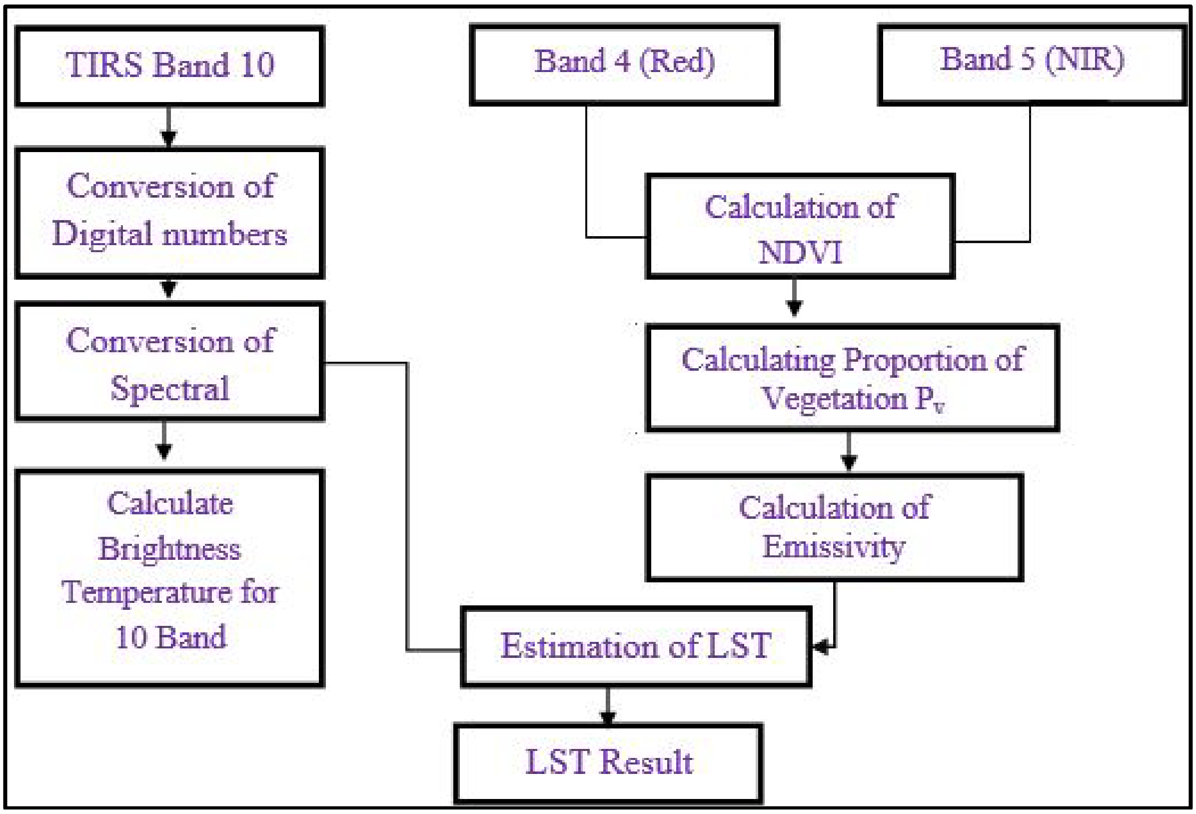

Fig 2: Flow chart of the methodology

B. Process
I. Extraction of Thermal band
The thermal band of Landsat 8 was extracted for extraction of land surface temperature i.e. Band no.10 (shown in plate 1)

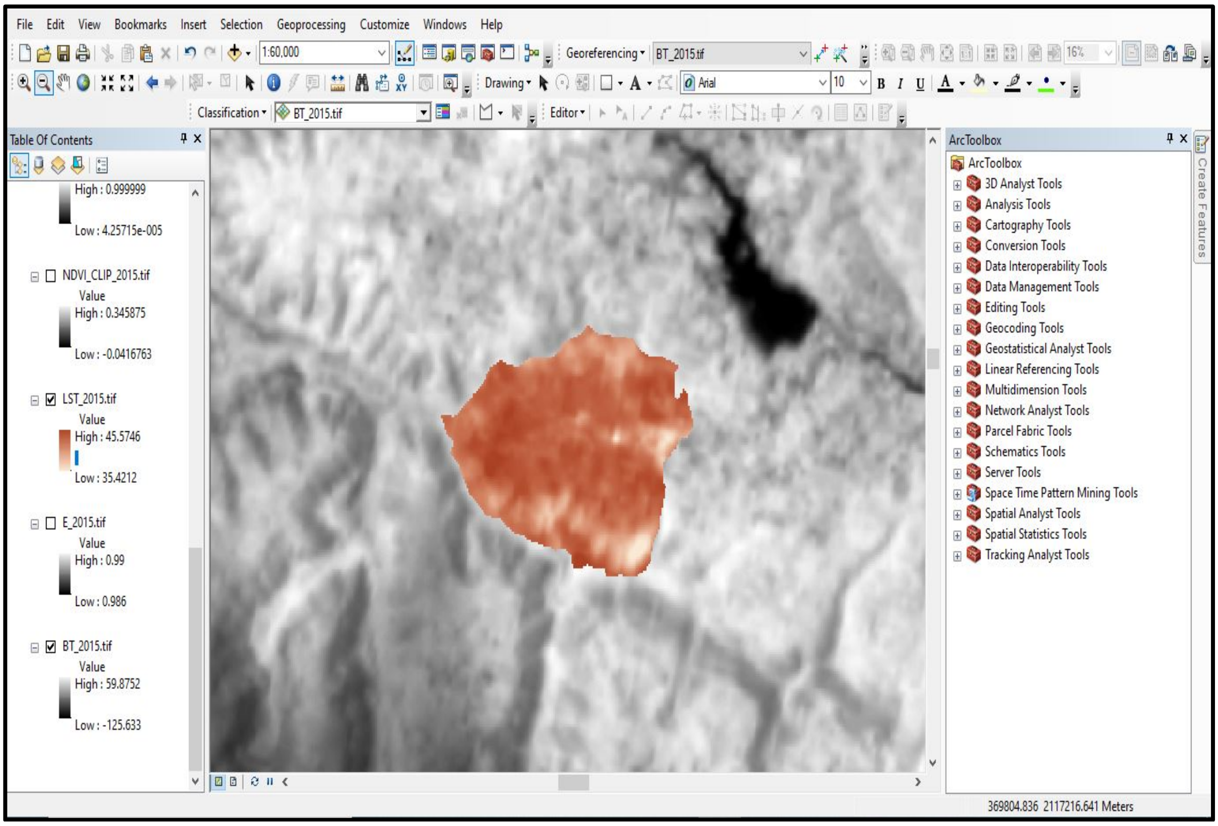

Plate 1: Extraction of Thermal band

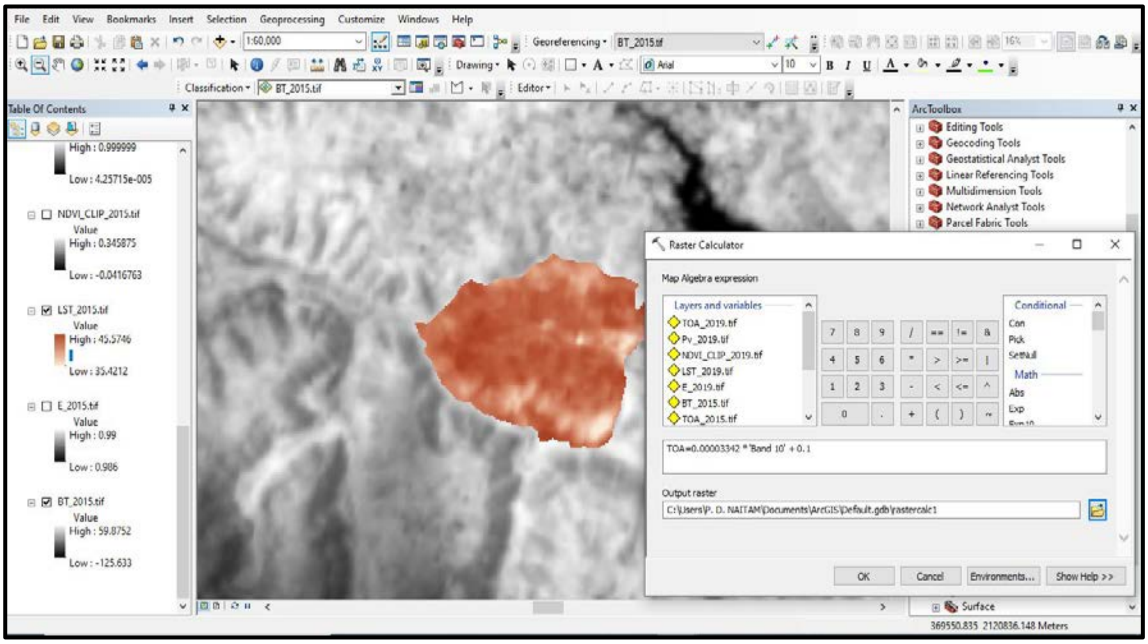

Plate 2: Extraction of Top of Atmosphere

II. Top of Atmosphere (TOA) Radiance

Using the radiance rescaling factor, Thermal Infra-Red Digital Numbers can be converted to TOA spectral radiance. (shown in plate 2)

$L\lambda$ = ML * Qcal + AL

Where,
$L\lambda$ = TOA spectral radiance (Watts/ (m^2 * sr * µm))
ML = Radiance multiplicative Band (No.)
AL = Radiance Add Band (No.)
Qcal = Quantized and calibrated standard product pixel values (DN)

III. Top of Atmosphere (TOA) Brightness Temperature

Spectral radiance data can be converted to top of atmosphere brightness temperature using the thermal constant Values in the Meta data file. (shown in plate 3)

BT = K2 / ln (k1 / $L\lambda$ + 1) - 272.15

Where,
BT = Top of atmosphere brightness temperature (°C)
$L\lambda$ = TOA spectral radiance (Watts/(m^2 * sr * µm))
K1 = K1 Constant Band (No.)
K2 = K2 Constant Band (No.)

IV. Normalized Differential Vegetation Index (NDVI)

The Normalized Differential Vegetation Index (NDVI) is a standardized vegetation index which Calculated using Near Infra-red (Band 5) and Red (Band 4) bands.

NDVI = (NIR – RED) / (NIR + RED)

Where:
RED= DN values from the RED band
NIR= DN values from Near-Infrared band

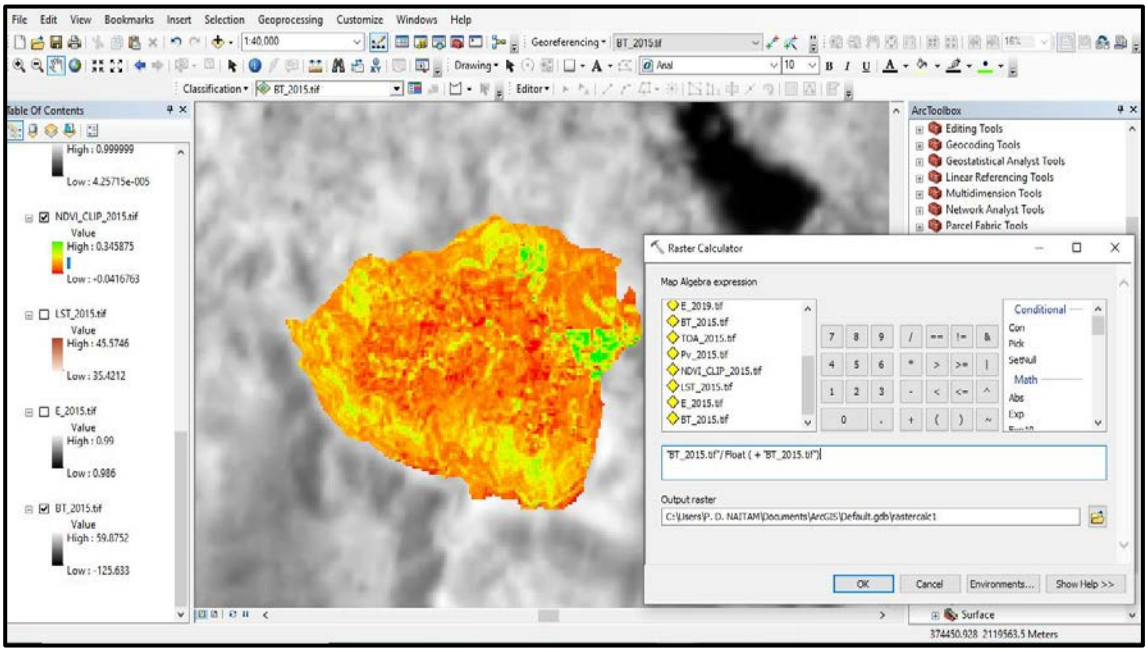

Plate 3: NDVI Calculation

V: Land Surface Emissivity (LSE)
Land surface emissivity (LSE) is the average emissivity of an element of the surface of the Earth calculated from NDVI values

PV = [(NDVI – NDVI min) / (NDVI max + NDVI min)] ^2

Where,
PV = Proportion of Vegetation
NDVI = DN values from NDVI Image
NDVI min = Minimum DN values from NDVI Image
NDVI max = Maximum DN values from NDVI Image

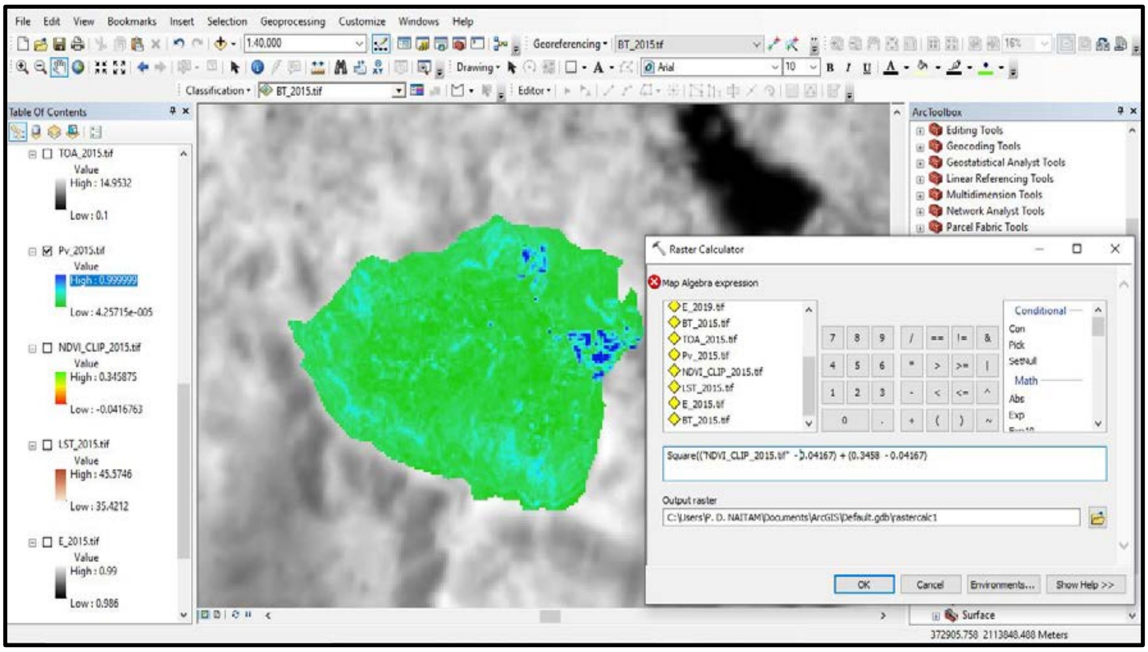

Plate 4: Proportion of Vegetation

E = 0.004 * PV + 0.986
Where

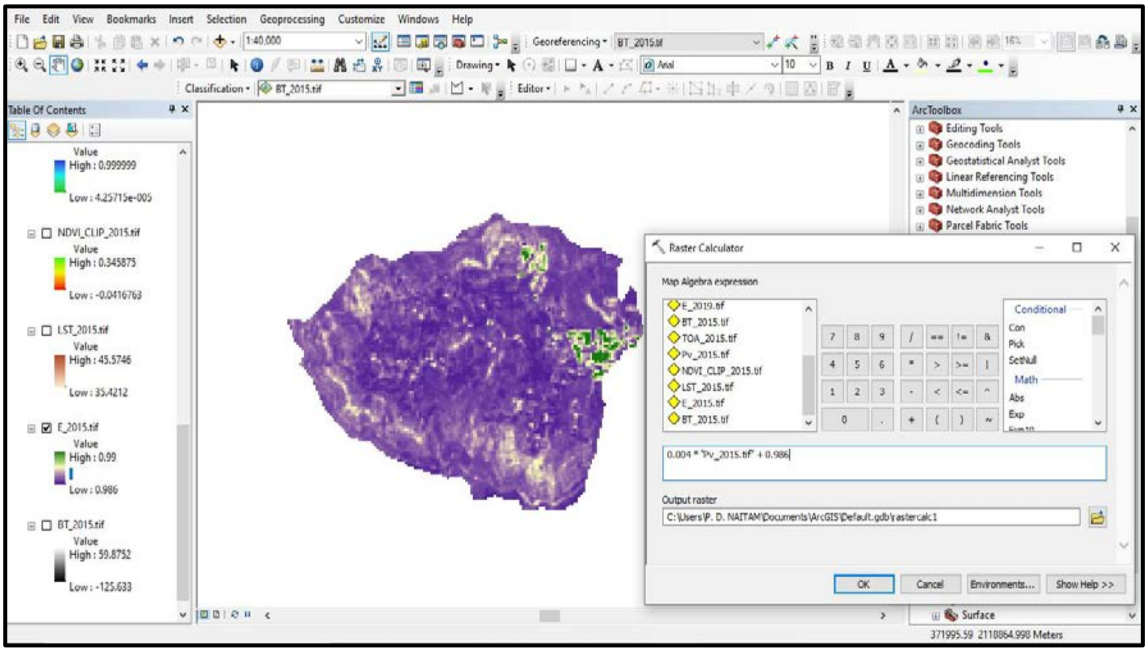

Plate 5: Emissivity estimation

E = Land Surface Emissivity
PV = Proportion of Vegetation

VI. Land surface Temperature (LST)
The Land Surface Temperature (LST) is the radiative temperature calculated using Top of atmosphere brightness temperature, Wavelength of emitted radiance, Land Surface Emissivity.

LST = (BT / 1) + W * (BT / 14380) * ln (E)

Where,
BT = Top of atmosphere brightness temperature (°C)
W = Wavelength of emitted radiance
E = Land Surface Emissivity

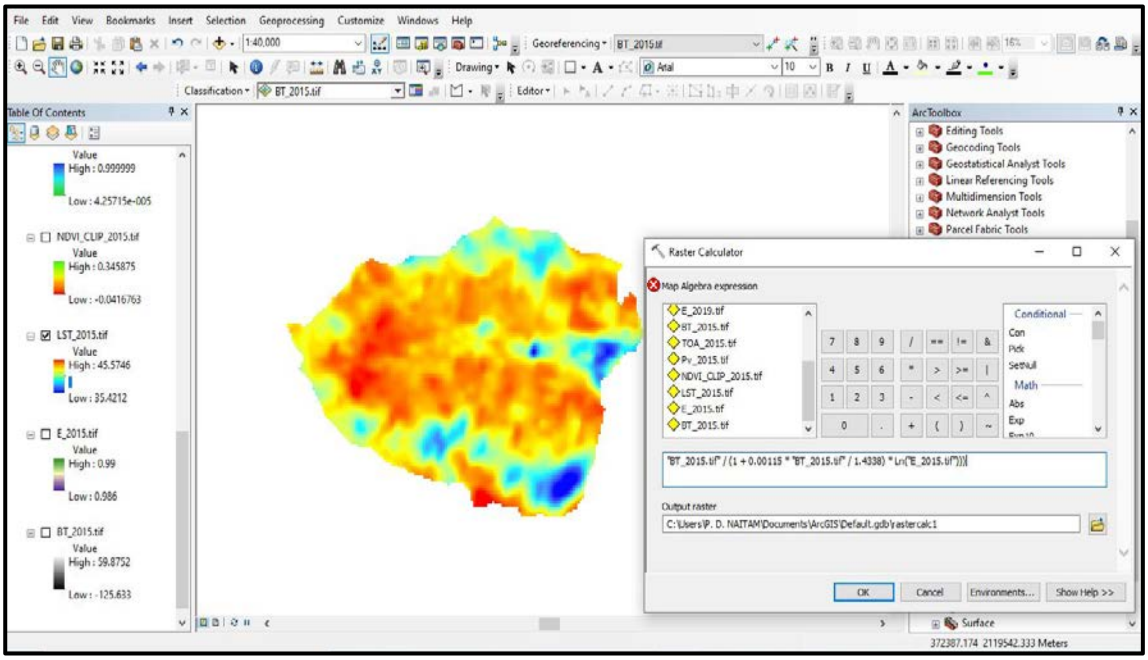

Plate 6: Land Surface Temperature Estimation

C. For calculation of Indices

a. Normalized difference vegetation index

NDVI is a linear combination between the near-infrared band and red band, which is regarded as the basic index for measuring the 'greenness' of the earth's surface. It is calculated by

NDVI = (NIR – RED) / (NIR + RED)

For Landsat 8:
NDVI = (Band 5 – Band 4) / (Band 5 + Band 4)
For Sentinel 2:
NDVI = (Band 8– Band 4) / (Band 8+ Band 4)

b. Normalized difference Built-up index (NDBI)

It is defined as the linear combination of near-infrared band (0.76–0.90 µm) and the short-wave infrared (SWIR) band (1.55–1.75 µm), used for extraction of urban built up land.

NDBI = (SWIR-NIR) / (SWIR+NIR)

D. Procedure in Google Earth engine

Define study area by importing shape file of Buchakewadi watershed and collecting the Landsat images for 2015 and sentinel image for 2019 for particular period which consider for research.
var study Area=ee. Feature Collection ('users/sachinshinde04121992/Buchakewadi_watershed');
var style_1={color:'red'};
Map. add Layer (study Area. style (style_1), {},'studyArea');
Map. center Object (study Area); print(studyArea);

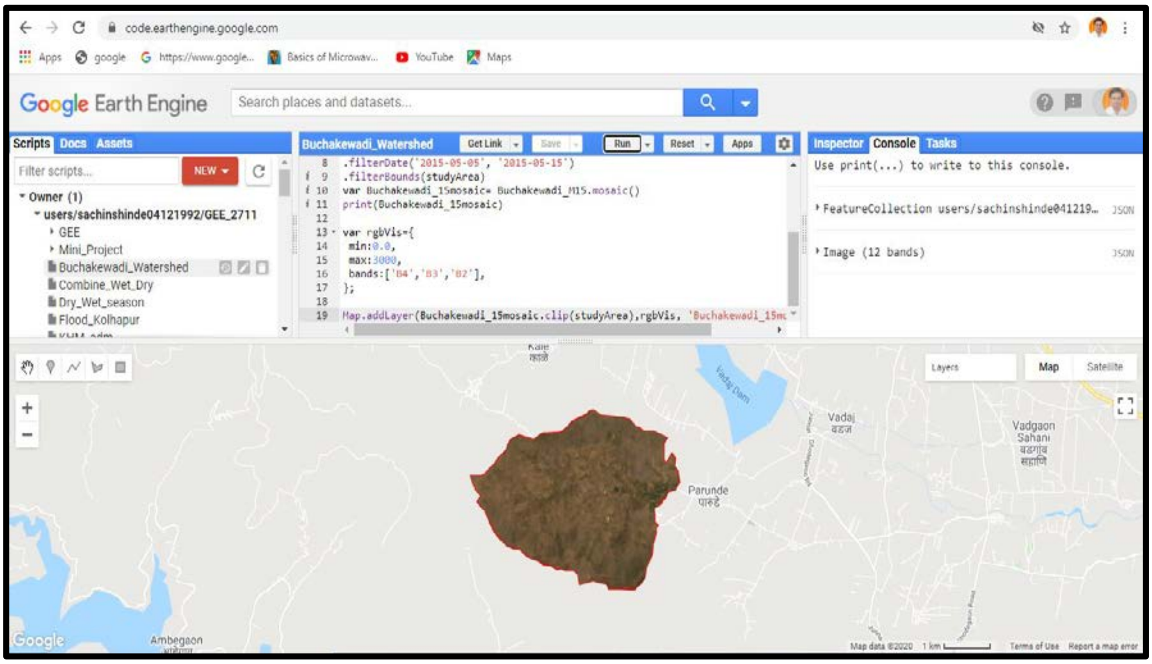

Plate 7: GEE Window with sentinel 2 image of Buchakewadi watershed

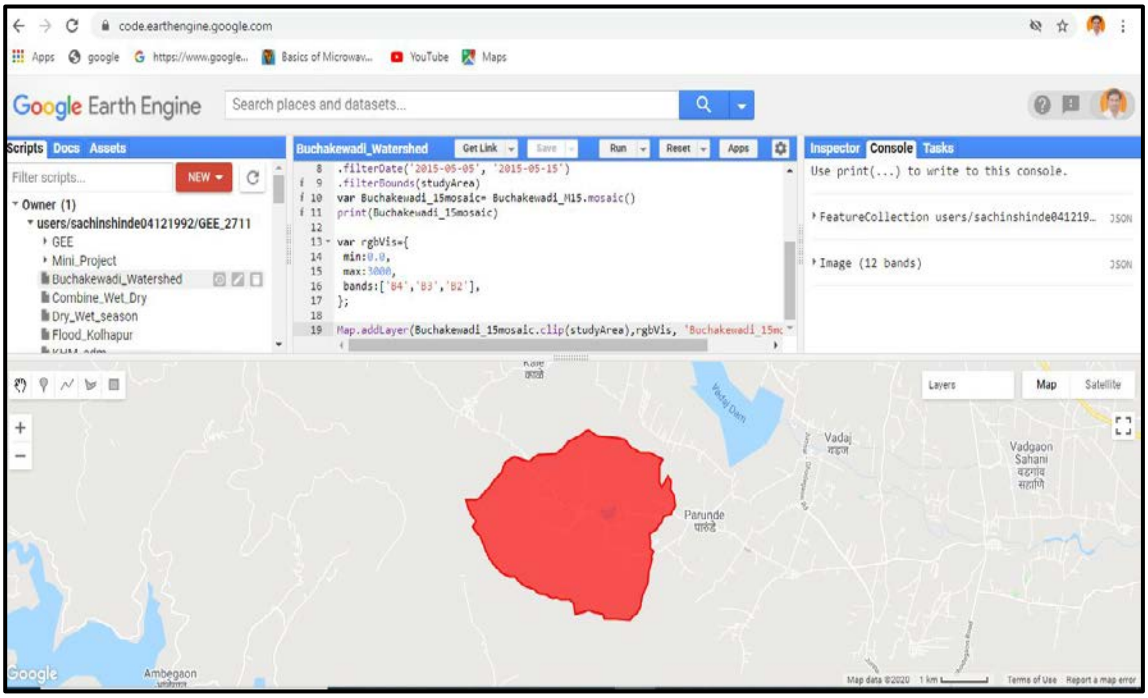

Plate 8: GEE Window with Shape file of Study area

var Buchakewadi M15 = ee. Image Collection("LANDSAT/LC08/C01/T1_SR"). filter Date ('2015-05-05', '2015-05-15'). filter Bounds (study Area)
var Buchakewadi_15mosaic= Buchakewadi_M15.mosaic()
print (Buchakewadi_15mosaic)

var rgb Vis={min:0.0, max:3000, bands: ['B4','B3','B2'],};
Map. add Layer (Buchakewadi_15mosaic.clip (study Area), rgb Vis, 'Buchakewadi_15mosaic');

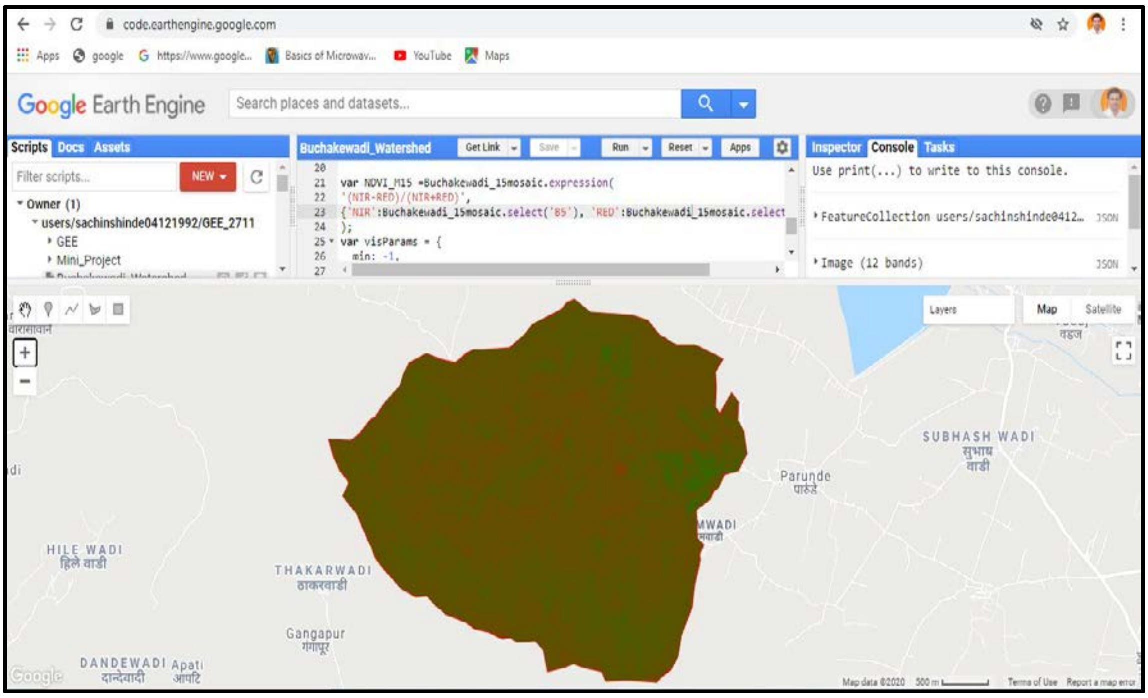

Plate 9: GEE Window with NDVI Calculation

a. Calculation of NDVI

var NDVI_M15 =Buchakewadi_15mosaic.expression ('(NIR-RED)/(NIR+RED)',
{'NIR':Buchakewadi_15mosaic.select('B5'),
'RED':Buchakewadi_15mosaic.select('B4')});
var vis Params = {min: -1, max:1, palette:['red','green'],}; Map.add Layer (NDVI_M15.clip(study Area), vis Params, 'NDVI_M15'); print (NDVI_M15);

b. Calculation of NDBI

var NDBI_M15 =Buchakewadi_15mosaic. expression ('(SWIR-NIR)/(SWIR+NIR)',
{'SWIR':Buchakewadi_15mosaic.select('B6'),
'NIR':Buchakewadi_15mosaic.select('B5')});
var visParams1 = {min: -1, max:1, palette:['orange','blue'],}; Map. Add Layer (NDBI_M15.clip (study Area), vis Params 1, 'NDBI_M15'); Print (NDBI_M15);

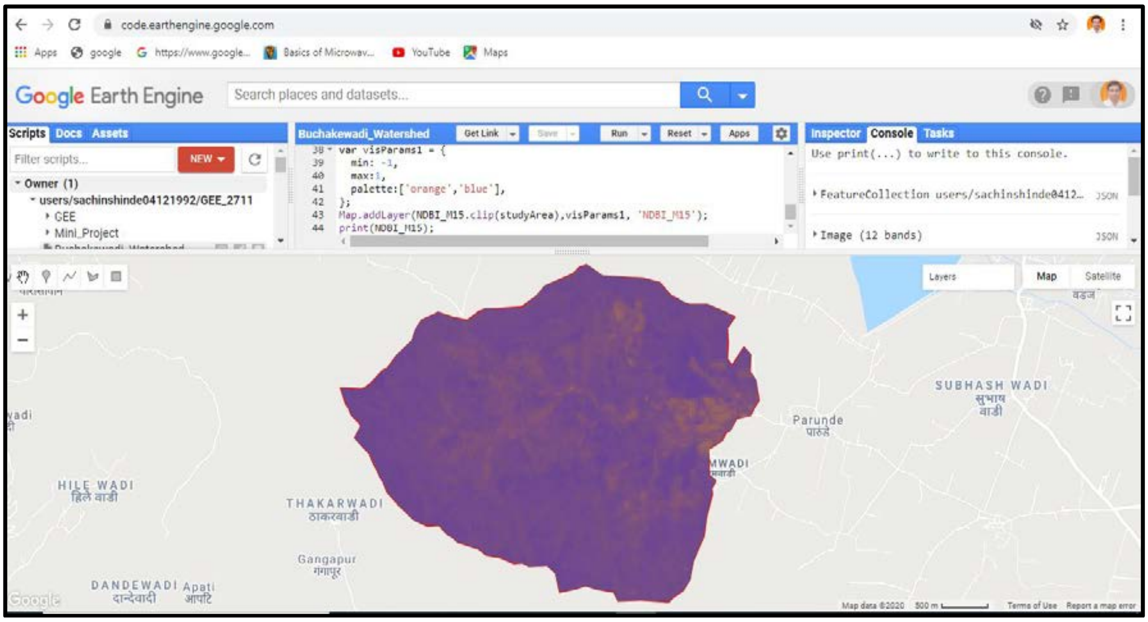

Plate 10: GEE Window with NDBI Calculation

E. Exporting Images to drive

From google drive images downloaded and imported in Arc GIS 10.2 and then further processing and map preparation was done.

Export. image. To Drive ({image:NDVI_M15, description:'NDVI_M15_final', scale:30, region: study Area}); Export. image. to Drive ({image:NDBI_M15, description:'NDBI_M15_final', scale:30, region: study Area});

Similarly, three indices calculated for May 2019 using Sentinel-2 images in Google earth engine code editor with the help of Java scripting.

2.4 Mapping UHI

UHI and non-UHI were identified by the range of LST determined by the following equations (Ma, Kuang, &Huang, 2010; Guha, Govil, & Mukherjee, 2017):

$LST > \mu + 0{:}5*\delta$
$0 < LST < \mu + 0{:}5*\delta$

Where, μ and δ are the mean and standard deviation of LST in the study area, respectively.

2.5 Delineating the UHS

In this study, LST maps were used in delineating the UHS over Florence and Naples to provide special emphasis for continuous monitoring. These small pockets are too hot and unfavourable for human settlement and mostly developed within the UHI. These UHS were delineated by the following equation (Guha, Govil, & Mukherjee, 2017).

$LST > \mu + 2*\delta$

Where, μ and δ are the mean and standard deviation of LST in the study area, respectively.

3. Results and Discussion

NDVI values were calculated for 2015 and 2019 of Buchakewadi watershed. Table 1 shows the statistical results of NDVI values in 2 different years. The maximum values and standard deviations of NDVI in May 2019. Difference between the maximum and minimum NDVI values in two dates was 0.085 and 0.017 respectively.

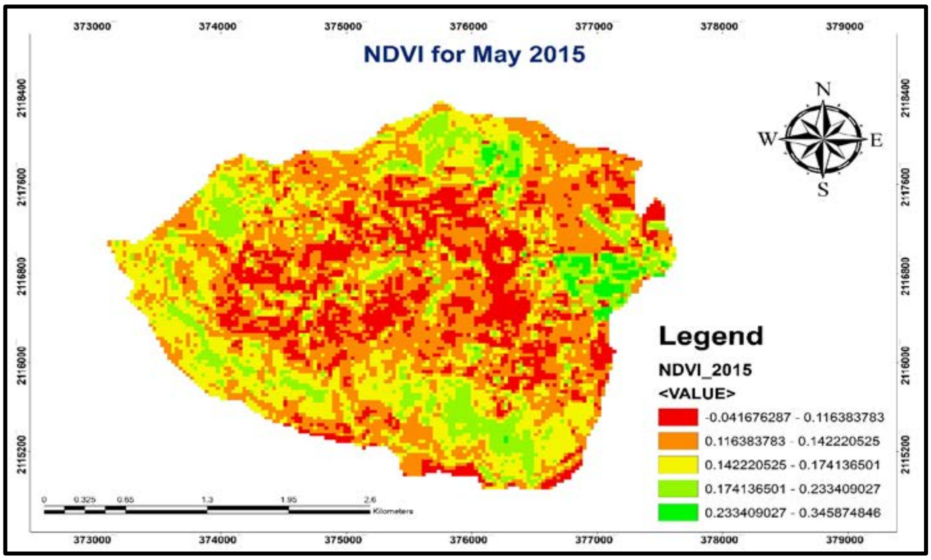

Fig 3: NDVI map of Buchakewadi watershed for May 2015

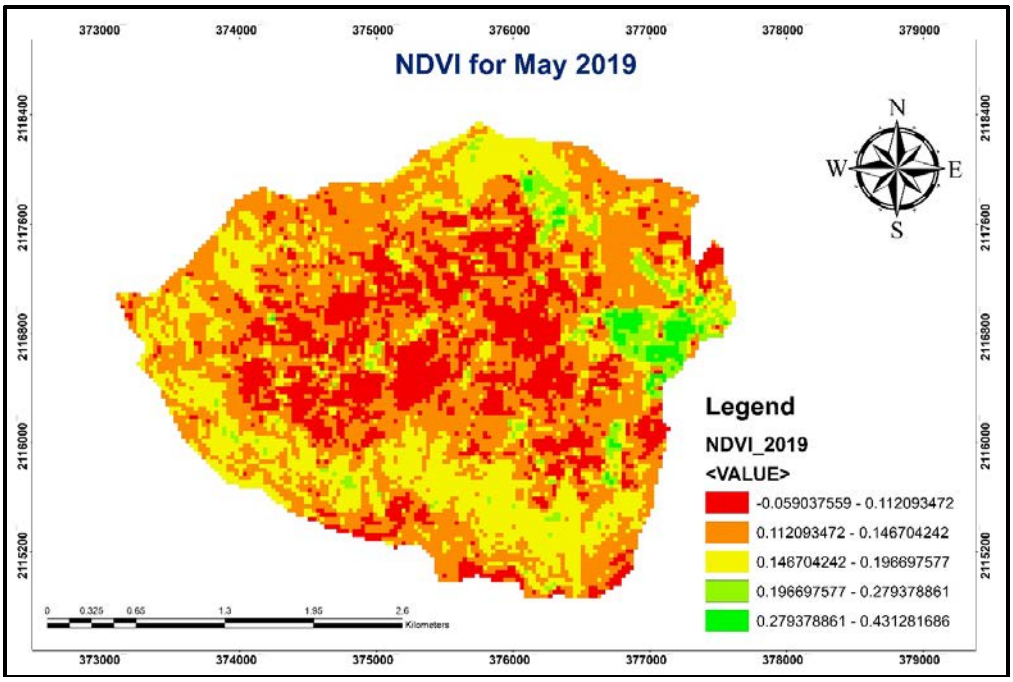

Fig 4: NDVI map of Buchakewadi watershed for May 2019

Table 1: NDVI for Buchakewadi watershed

Year	Statistical Results			
	Max.	Min.	Mean	SD
May 2015	0.3458	-0.04167	0.1413	0.0334
May 2019	0.4312	-0.05903	0.1367	0.0401

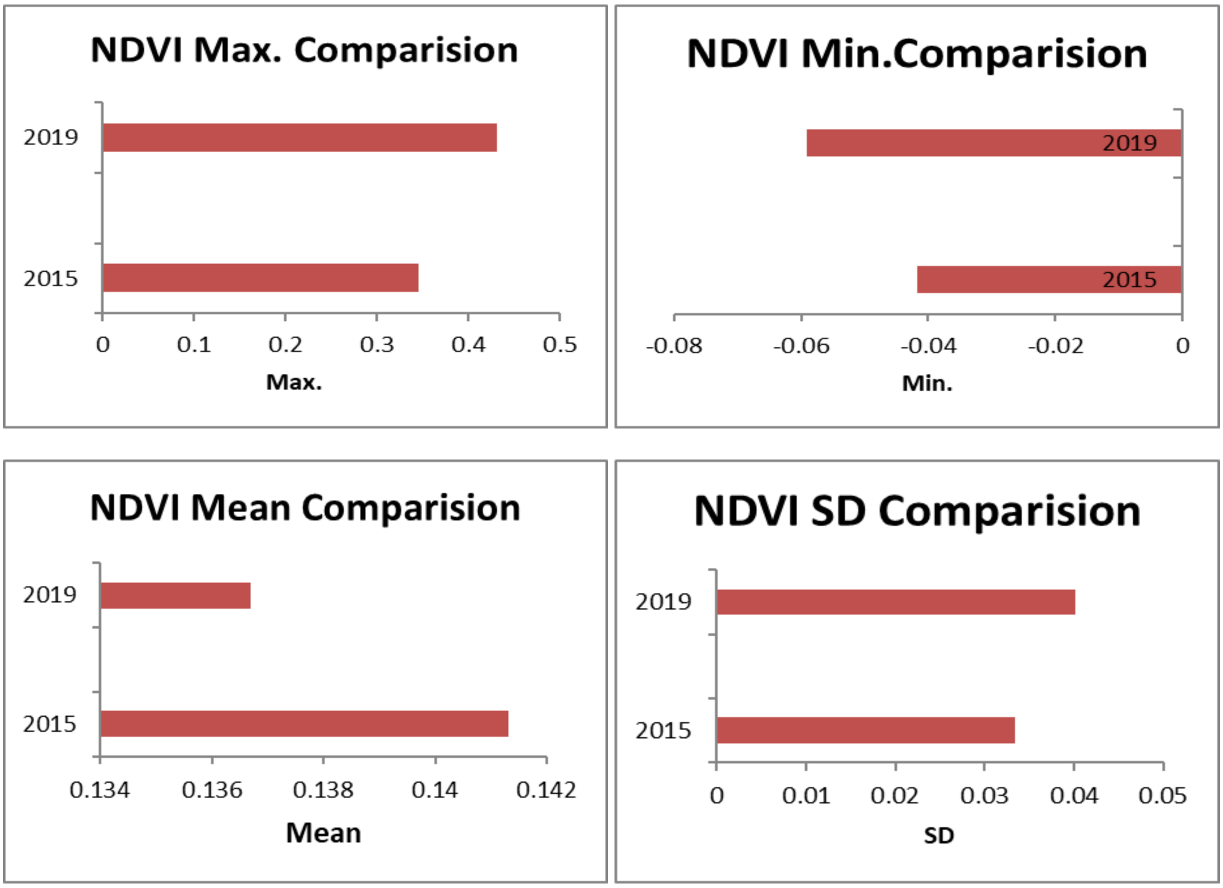

Fig 5: NDVI graph for two year of Buchakewadi watershed

NDBI values were calculated in 2015 and 2019 for Buchakewadi watershed. Table 2 shows the statistical results of NDBI values in 2 different years. Difference between the maximum and minimum NDBI values in two dates was 0.085 and 0.138, respectively (Figures 2–6 and Table 3).

Table 2: NDBI for Buchakewadi watershed

Year	Statistical Results			
	Max.	Min.	Mean	SD
May 2015	0.1952	-0.1310	-0.0365	0.0374
May 2019	0.1102	-0.2689	0.0205	0.0372

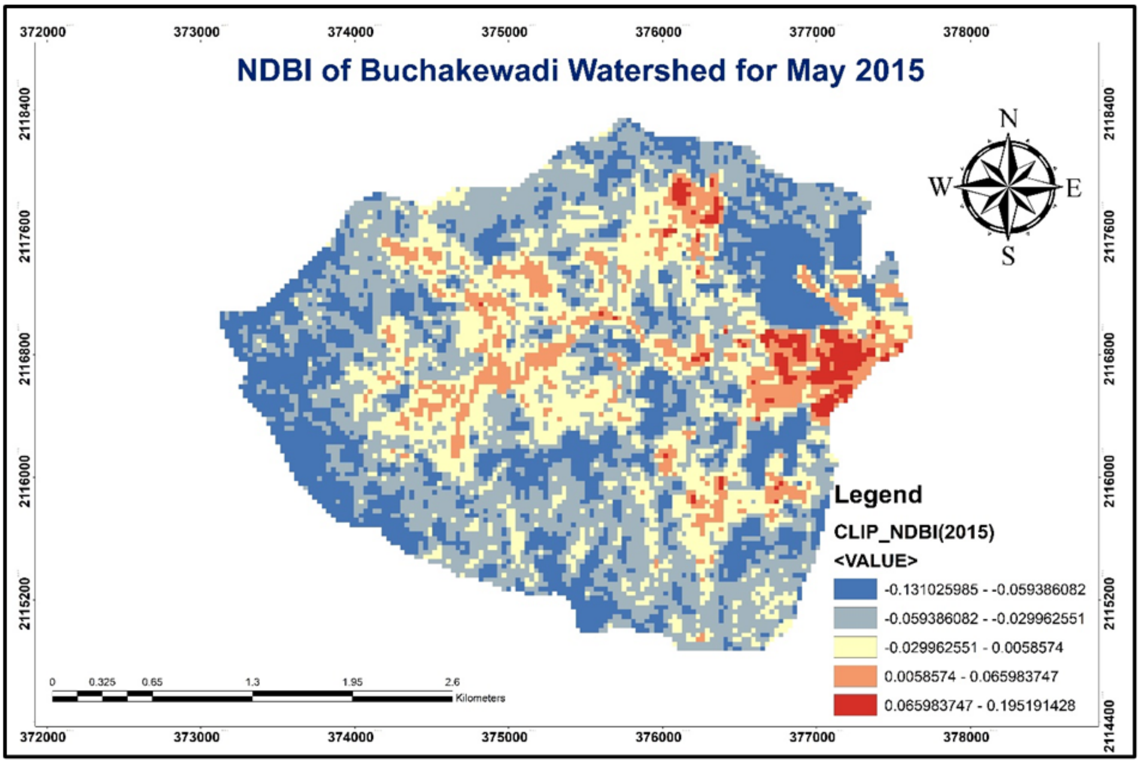

Fig 6: NDBI map of Buchakewadi watershed for May 2015

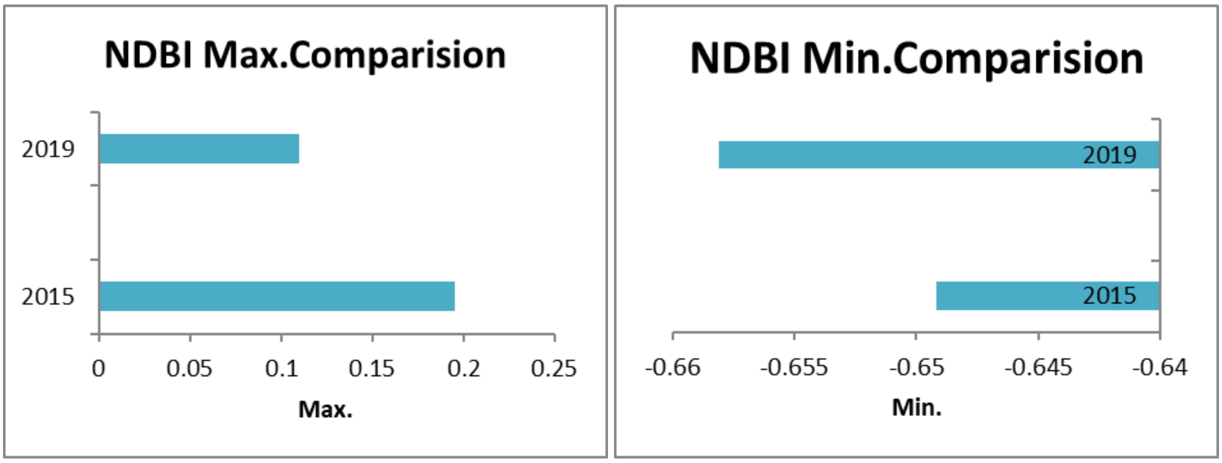

Fig 7: NDBI graph of Buchakewadi watershed

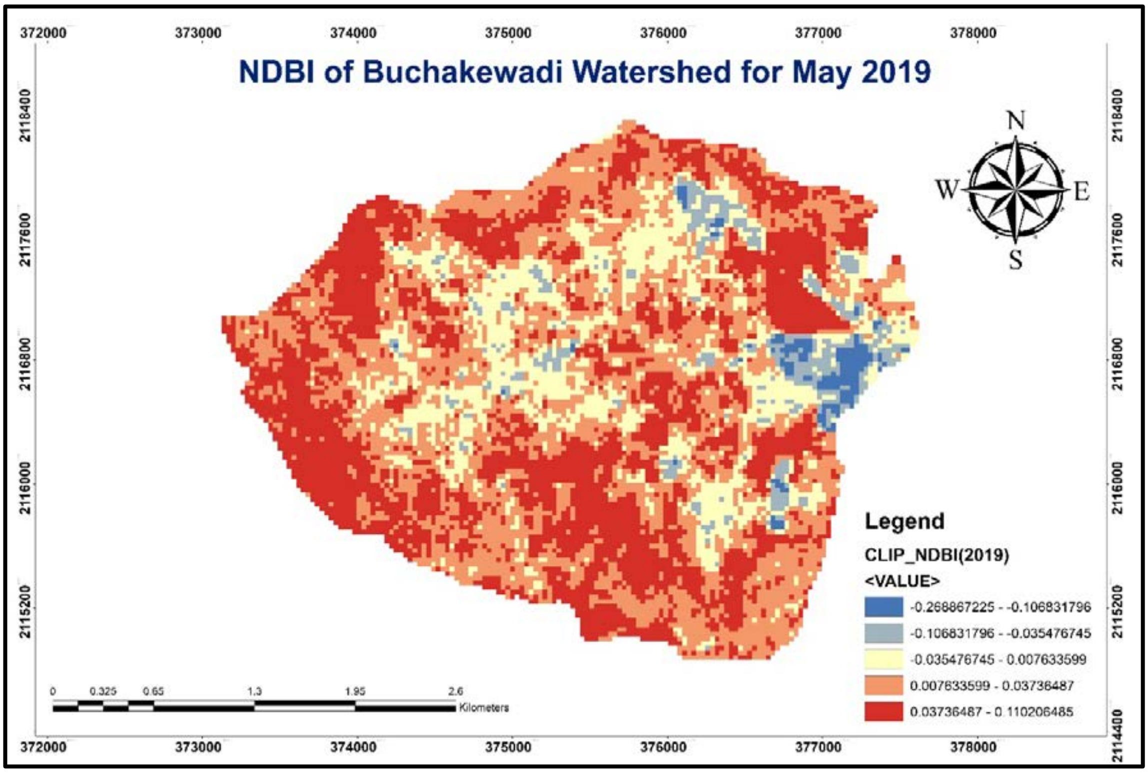

Fig 8: NDBI map of Buchakewadi watershed for May 2019

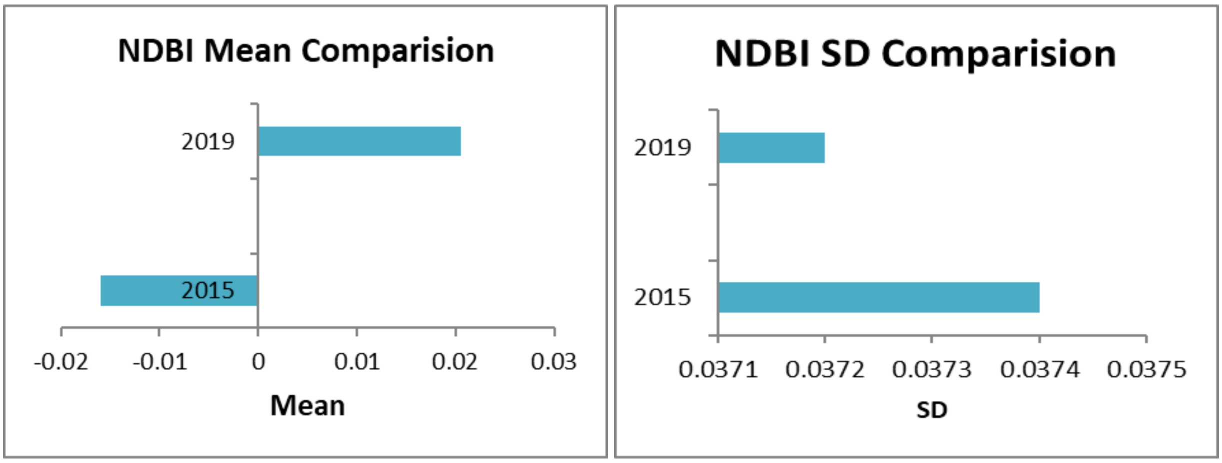

Fig 9: NDBI graph of Buchakewadi watershed

3.1 Relationship of LST–NDVI and LST–NDBI within the UHI and within the non-UHI

LST distribution was classified into appropriate ranges (Figure 4) and color-coded to generate a thermal pattern distribution map of LST over the study area. The mean LST values are 42.21 °C and 43.74 °C for 2015 and 2019, respectively. The threshold values for UHI generation are 41.03 °C and 43.28 °C for 2015 and 2019, respectively.

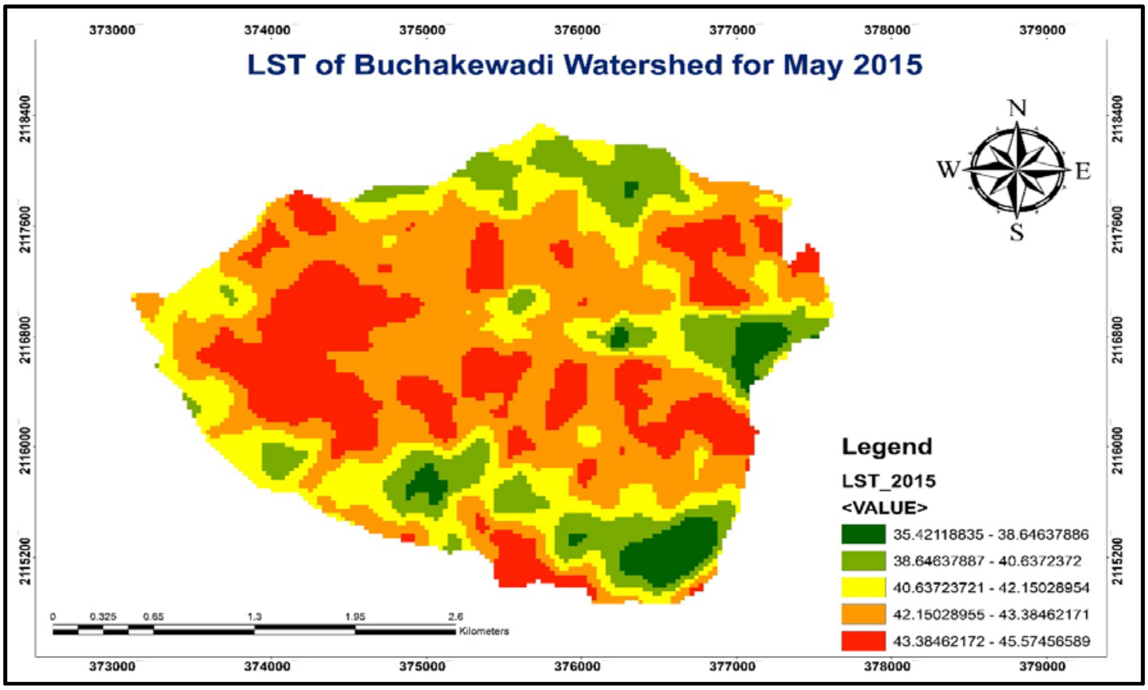

Fig 10: Spatial distribution map of LST for May 2015

In general, LST presents a positive relationship with NDBI and an inverse relationship with NDVI. NDVI shows a strong negative correlation with LST for the whole area (−0.41 for 2015 and −0.56 for 2019). NDBI presents a highly positive correlation with LST for the whole area (0.31 for 2015 and 0.71 for2019).

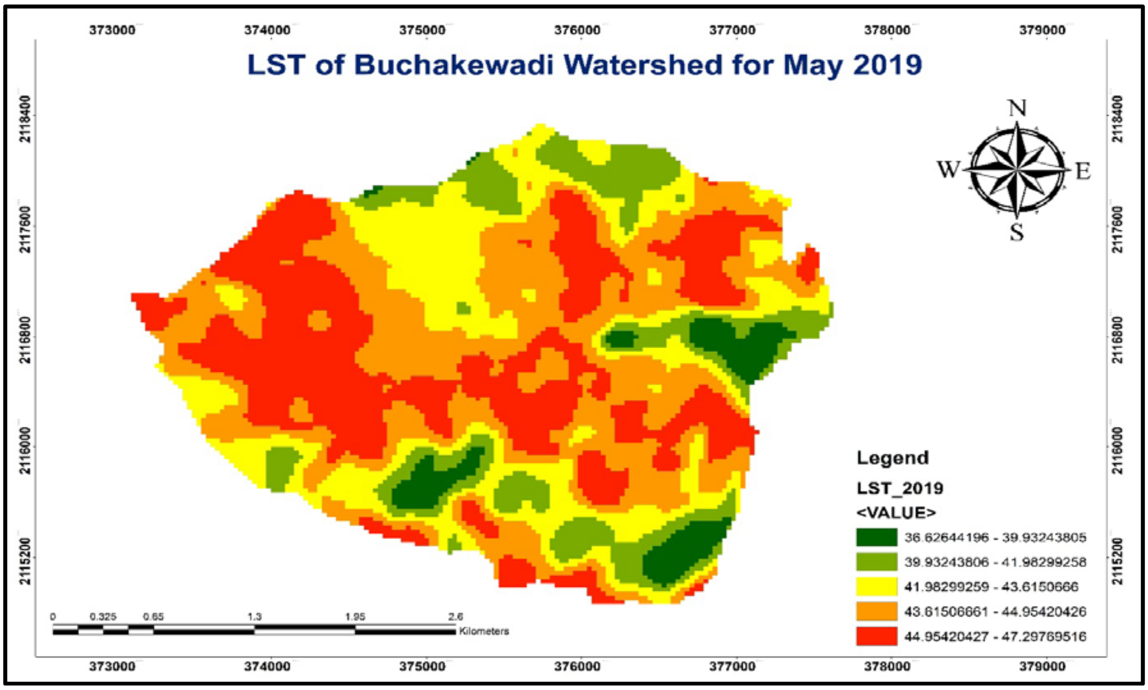

Fig 11: Spatial distribution map of LST for May 2019

Table 3: Statistical results of LST

Year	Statistical Results of LST			
	Max.	Min.	Mean	SD
May 2015	45.57	35.42	42.21	1.6536
May 2019	47.30	36.63	43.74	1.8752

This phenomenon is observed due to the presence of complexity in landscape composition. Thus, LST–NDVI and LST–NDBI both build stronger correlation in large natural landscapes, while it tends to be weaker in small built-up areas.

Table 4: Correlation coefficient between LST, NDVI and NDBI

Year	LST-NDVI	LST-NDBI
2015	-0.41	0.32
2019	-0.56	0.71

3.2 Spatial distribution of UHI and non-UHI

The intensity of UHI may be defined as the difference between the average temperature of UHI and non-UHI (Table 5). The UHI intensity more in summer in watershed area. The threshold value of UHI is estimated at 41.03 °C for 2015 and 43.28 °C for 2019.

Table 5: Variation of LST in UHI and Non-UHI

Year	LST(Max.)		LST (Min.)	
	UHI	NUHI	UHI	NUHI
May 2015	45.57	43.04	43.04	35.42
May 2019	47.30	44.68	44.68	36.63

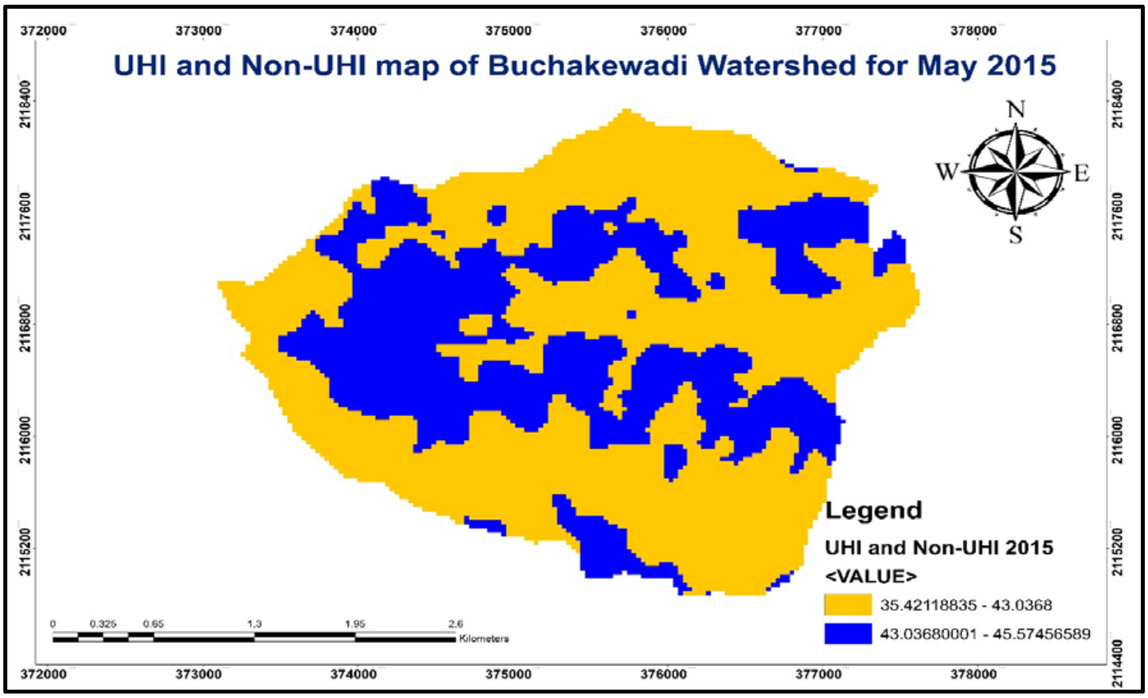

Fig 12: Spatial extent of UHI and Non-UHI 2015

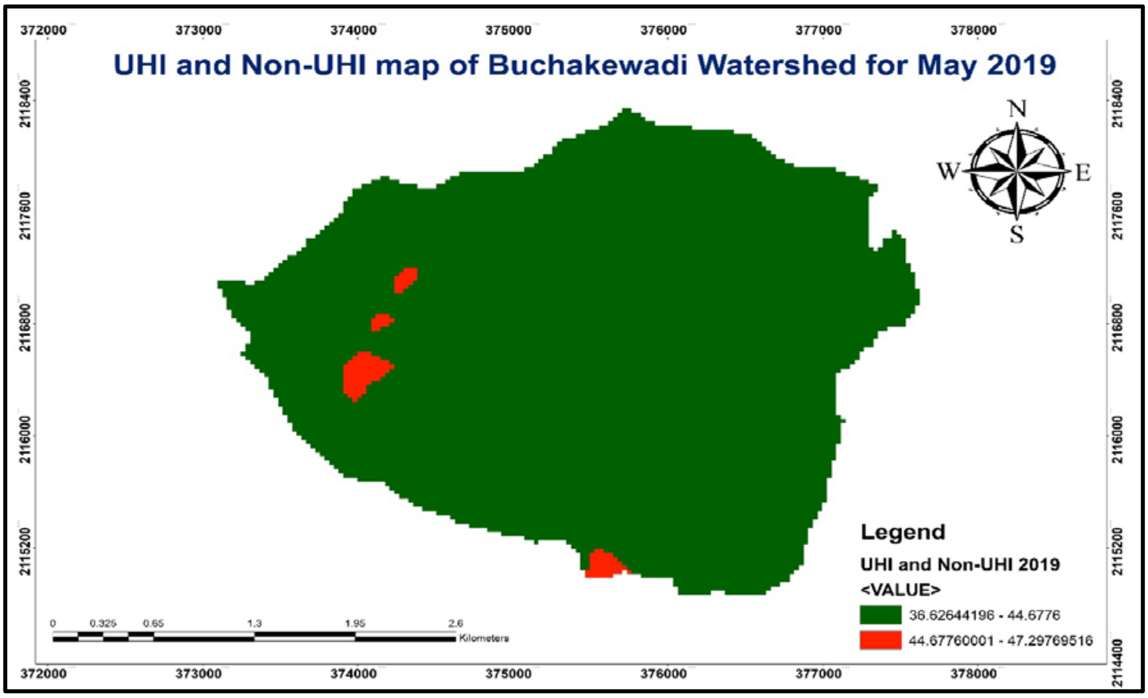

Fig 13: Spatial extent of UHI and Non-UHI 2019

4. Acknowledgments
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5. Conclusions
Landsat 8 OLI and TIRS data were used to investigate the UHI intensity effect on Buchakewadi watershed and to interpret the dynamic relationship between LST with NDVI and NDBI. UHI zones were identified through LST which were distributed. Bare land and built-up area are mostly

responsible for LST generation. The presence of vegetation and water bodies reduces the LST level. Some UHS were also delineated within the UHI zones which are characterized by high concentrated LST.

Furthermore, the relationships between LST–NDVI and LST–NDBI were interpreted quantitatively by correlation analysis. For Buchakewadi watershed, LST shows strong negative correlation (−0.41 for 2015 and −0.57 for 2019) with NDVI; and strong positive correlation (0.31 for 2015 and 0.71 for 2019) with NDBI. It indicates that non-UHI zones (green areas and water bodies) remain almost unchanged or very little changed. Only the UHI zones are under severe heat stress.

6. References

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