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Determining Land Use Land Cover Change and its Effect on Land Surface Temperature in Nainital District

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ABSTRACT

Landscape keeps changing due to modifications in the natural environment. The principal factor that drives the landscape change is the anthropogenic resource utilisation system. Anthropogenic pressure is escalating; as a result, alteration of natural ecosystems into humanised landscapes can be observed globally. Built-up areas, largely the settlements and especially encroachment of urban agglomeration and working areas, extensively alter the natural environmental setting. The current pattern of landscape changes is the result of a modified anthropogenic resource utilisation system. This paper aims to investigate the association between land use land cover types and the corresponding land surface temperatures in Nainital District. Remote sensing, as well as GIS data, provides a reliable outcome. It has been widely used for this purpose as multi-temporal data provides a prospect to study any prevailing phenomena of geographical trends. The paper finds out the changes in the region in the last 25 years, from 1992 to 2017. The area has experienced growth in land surface temperature as land-use changes have taken place. The surge in land surface temperature may further induce changes in the land use patterns directly or indirectly.

Keywords: Landscape changes, land surface temperature (LST), heat spot regions, spatial analysis.

INTRODUCTION

Land use can be described as the organisation, patterns, actions, and various efforts people carry out in a particular land cover category to create, modify or adjust it. In simple terms, the function for which the Land is being exercised is the land use of a region (FAO 1999). Land use is changing rapidly with time to fulfil human needs. The change of land use from porous and saturated surface to impervious and dull surface sharply affects the energy budget of any area that can lead to changes in land surface temperature. Such changes can induce several other changes within a region; therefore, it is important to monitor temporal and spatial changes in land use (Kestens et al. 2011). Land cover can be identified as the real features that occupy the surface of the Earth. The land cover reflects the state of a region. Due to global warming, the air temperature has shown an increase in all the major cities. Also, increased urbanisation has modified the energy budget. Therefore, the inquiry of LULC transformation has become useful in determining the environmental quality (Shanshan et al. 2009). LULC reflects the biophysical status of the Earth's appearance. Interference of energy and matter over the LULC significantly influences biosphere and geosphere and thus has local, regional and global implications (Hu et al. 2004). Advanced remote sensing and GIS know-how can provide rich information and are being used widely in spatial analysis. Modern technologies such as remote sensing and GIS-enabled us to gain accurate and real-time information on the current situation of LULC and used it for monitoring and evaluation**.** LST is among the most important indicators that are used for environmental analysis. The LST displays the interaction between the ground surface and the environment (Rawat and Kumar 2015). LST plays a vital role in an environmental setting, agriculture, meteorology, estimating crop produce, checking the drought, urban environmental analysis hydrology, etc. (Wang et al. 2013). The utmost reliable and efficient way to measure LST is by the use of satellites. The thermal condition of the Earth's

surface and LST can be obtained by thermal infrared remote sensing (Shwetha and Kumar 2015, Yang et al. 2014). The LULC change is a global issue and is a big challenge, particularly in the developing world. Changed land use affects the physical, economic and social characteristics of a region. Global climate change is largely induced by LULC change. For example, the modification of vegetated Land into urbanised Land interrupts carbon and water cycles, and it further causes energy ûuctuations between the surface of the Land and the atmosphere (Hereher 2016). Increasing population and economic development induce LULC change; therefore, the study of LULC change must implement appropriate planning and managing resources. Furthermore, LST changes can be correlated spatially with LULC changes (Ning et al. 2017). The association between the LST and the vegetation density is inverse. The vegetation cover can lower the LST as the higher density of green cover results in a cooling effect on the environment (Gallo and Tarpley 1996, Weng, 2001). The LULC in a region may exist as patches having different shapes, sizes, and spatial arrangements that result in the heterogeneity of the landscape's landscape. The change in the surface features of the Earth can have a dramatic effect on the whole geo-system. The rapid increase in industrialisation and urban population, deforestation of tree cover area, filling and modification of the wetland or other water bodies are critical land-use changes altering the LST globally. The changed landscape causes alteration in the interaction of solar energy with the landscape (Sahanal et al. 2016). Land surface temperatures are determinants of identifying the urban heat island, the magnitude of warmness, spatial coverage and extent of heat movements. Measuring surface temperature within a city is difficult as an urbanised landscape has strong microclimatic contrasts of temperature that varies seasonally (Liu and Weng 2007). Large-scale modifications of natural systems such as deforestation and the variations in vegetation cover from 2000 to 2015 have resulted in an upsurge in LST globally by 0.23-degree Celsius (Duveiller et al. 2018). If the atmospheric considerations and emissivity are known, the LST can be assessed through a single band of radiance data. Multi-spectral satellite data has been used to estimate LST and spectral emissivity over difficult rocky terrain (Srivastava et al. 2010). Effective and accurate use of Geographical Information systems and Remote sensing data for retrieving LST studies is a major concern (Liu 2010). LULC are chief physical environment elements, whereas the LST is a vital parameter that operates physical, chemical, and biological systems on Earth. LST has been a base for studying Earth's environment for many researchers as LULC changes are the primary drivers of environmental aspects (Jicai et al. 2017). Several researches have been performed to recognise the link between LST and variations in the land surface features (Jensen 2000). The extent of human activities has broadened that has further induced changes in Earth's surface features. LULC is an important aspect affecting LST, and thus, LST is the radiative skin temperature of the land surface. Therefore, the extent of the relationship between the LST and LUCC needs to be explored to examine the social, economic, and ecological outcomes (Yuanhong et al. 2017).

METHODOLOGY AND STUDY AREA

The methodology in this paper can be distributed into three different sections, data collection, data processing and data examination. This paper used Several remote sensing data (Landsat satellite data) and techniques such as image processing, image classification and change detection methods. The obtained data were pre-processed using suitable software. Arc GIS, ERDAS imagine, and QGIS software have been used to edit and analyse geospatial data. With the help of Arc GIS, satellite images for two different periods were processed and classified to produce a LULC classification map and records. LST was then retrieved from QGIS using the suitable plugin. Microsoft Excel has been used to represent data graphically. The study area comprises the Nainital district of Kumaun Himalaya, Uttarakhand (Fig. 1).

To determine whether LST shows variations in LULC, the land surface temperature maps were filtered using the Mode filter technique, and then vectorisation was performed. The LULC, as well as LST maps after vectorisation was exported to Arc GIS for different processes. Both the land use map and the LST map was overlaid. The techniques

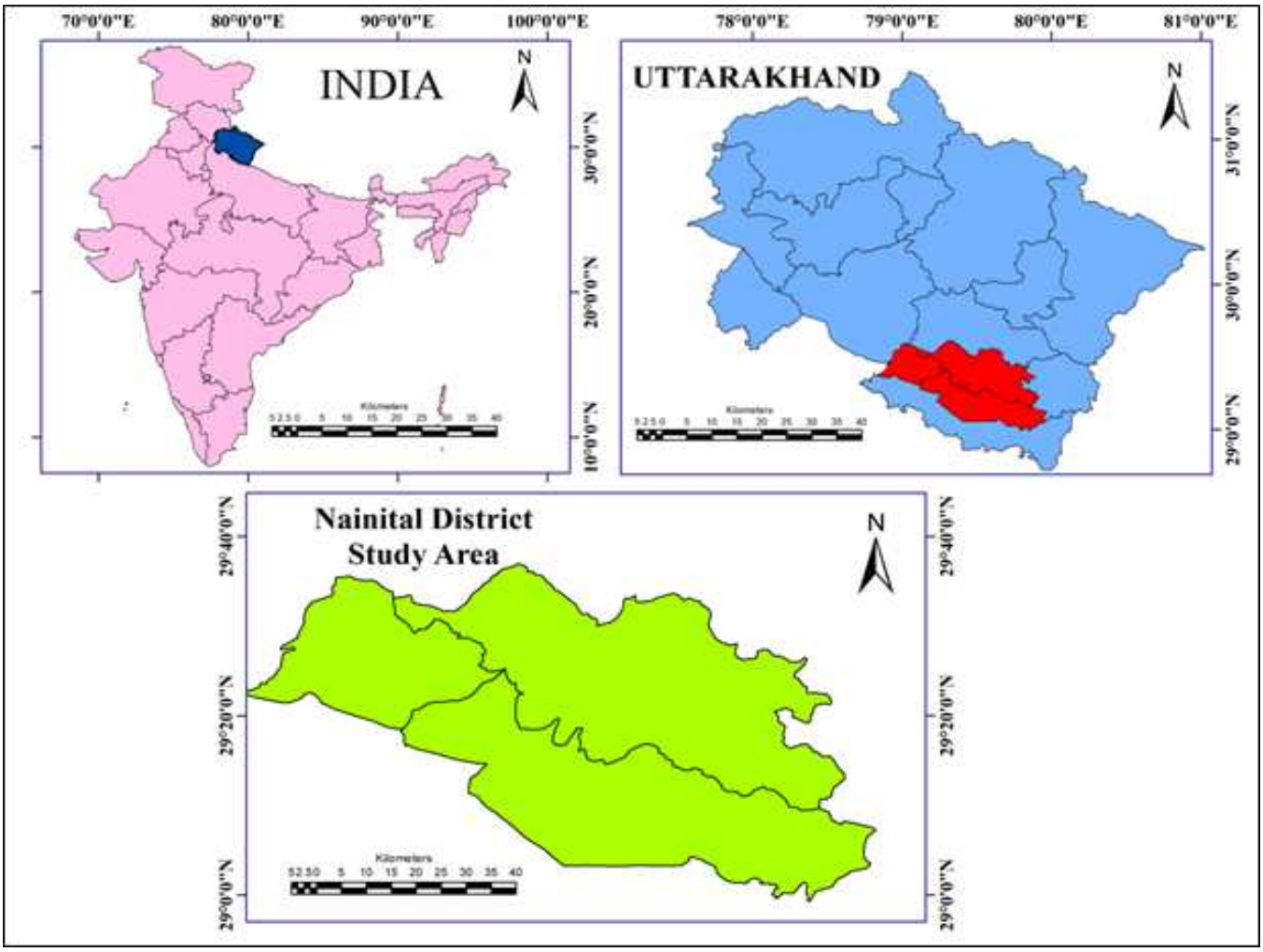

Figure 1. Study area, Nainital District, Uttarakhand.

mentioned above allowed to correlate land-use classification with LST classification. LST and LULC classification maps of areas undertaken for study give a clear visualisation of the changes and corresponding relationship between the two. Standard methodology given in USGS handbooks were used (USGS 2016, 2019). For measuring the LST of the District, 53 major and minor towns (points) were selected. These towns have been chosen from every corner of the District to represent a reliable conclusion.

RESULTS AND DISCUSSION

Land-use type and land cover classification

Nainital District of Uttarakhand is developing rapidly and is becoming an economic Centre. There has been substantial growth in the economy, industrialisation and transportation over the last few decades. The rapid expansion of developmental activities has negatively impacted the environment. We used remote sensing and GIS to quantify LULC changes in the previous 25 years. Based on an interpretation of satellite imagery, the study area has been classified into six different categories: agricultural Land, settlements, rivers, lakes, other Land, and forests. The spatial and temporal changes in LULC can be observed in Figure 2 which illustrates the scenario from 1992 and the changes that occurred till 2003, 2010 and 2017, respectively. By analysing the classified maps of different periods, it can be concluded that the urban area is expanding and occupying the agriculture and forest regions.

The study area covers 4098.50 sq. km, and LULC changes were estimated from 1992 to 2017. Comparison of LULC maps between 1992, 2003,2010 and 2017 indicates a massive increase in built-up area that comprises human habitation and

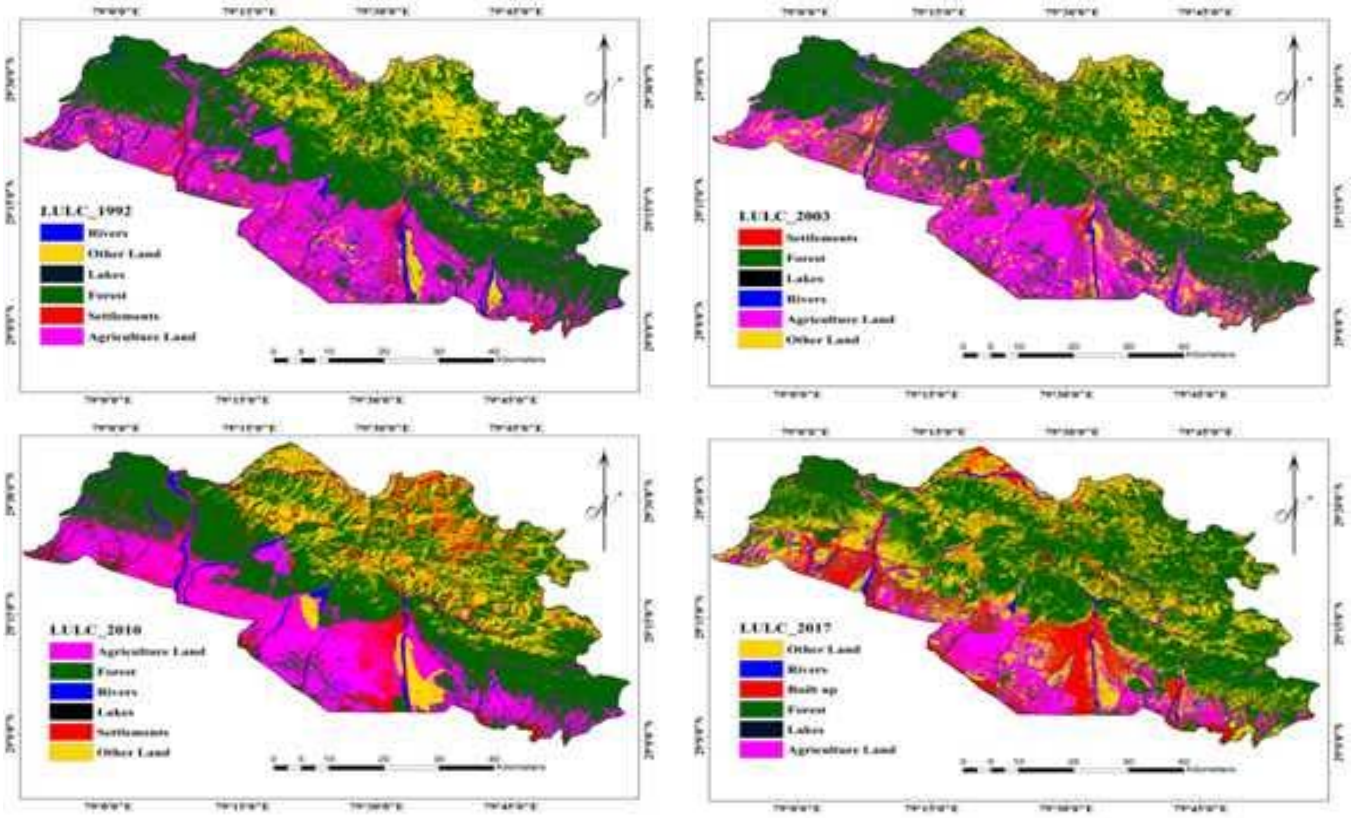

Figure 2. LULC of Nainital District 1992, 2003, 2010 and 2017.

Table 1. Spatial-Temporal Changes over the years from 1992 to 2017

Classes	1992		2003		2010		2017	
	Area (sq. kms)	Area (%)	Area (sq. kms)	Area (%)	Area (sq. kms)	Area (%)	Area (sq. kms)	Area (%)
Agriculture	1075.703	24.7	933.1011	24.2	851.881	20.6	392.1557	9.9
Forest	2306.888	53.1	2201.768	52.8	1933.119	46.9	1865.191	45.2
Rivers	149.9353	3.4	142.5283	3.7	127.8221	3.1	98.83497	2.5
Lakes	1.033425	0.02	1.775565	0.04	1.889448	0.04	1.433025	0.03
Built up	83.10935	1.9	146.9468	3.81	467.762	11.3	525.4461	13.2
Other Land	722.5933	16.6	554.284	14.3	738.3983	17.9	1068.186	27

development of non-agricultural land use. Table 1 clearly shows that the area under agriculture, forests, and rivers has decreased considerably, while the built-up area has shown significant growth. The main reason for such change is the continuous increase of the population in the study area. The area under agriculture was 1075, 933, 851, and 392 sq. km in 1992, 2003, 2010 and 2017, respectively. The area under agriculture used for raising crops, vegetables, orchid farming has primarily decreased from 1992 to 2017. A similar trend can be seen with other lands use categories such as forests and built-up areas. The forest has undergone a decline from 2306.888sq. Km in 1992 to 1865.191 sq. km in 2017. The massive transformation of land-use changes can be attributed due to an increase in built-up areas. The built-up area occupied only 83.10 sq. km in 1997, whereas it rose to 525.44 sq. km till 2017. The Changes can be observed in other classes as well.

Relationship between LULC and LST- Nainital District

Elevation can be considered as one of the critical aspects that affect the surface Temperature of the

Land. There is an inverse relationship between elevation and temperature. Using the DEM/elevation map of the area created on Arc GIS (Fig. 3) and integrating with the LULC map Land Surface Temperature (LST) of the Nainital district was derived.

The changes in LST can be seen with the changing landscape patterns (Fig. 4). It clearly illustrates that there has been a significant increase in the surface temperature of the land over time. These changes are correlated with the temporal change in land use categories. The land surface temperature of the region was low in 1992 as compared to 2003. Further, the LST showed substantial growth from 2010 till 2017. The fundamental cause behind such changes is that the shift of the natural system to the modified system leads to changes in the radiation or energy budget of the region. The higher the part has a green cover, the lower is the LST and vice versa. In 1992, the District had many areas under forest and agriculture, and the human encroachment was more minor in the region. But, till 2017, the built-up area kept on increasing, and the Land under agriculture and forest kept declining. These changes affect the overall interaction between land surface and radiation. The impact of such changes is visible. The continuous growth of built-up environment has created most of the cities in Nainital as 'urban heat islands'. Such a shift in surface temperature will further induce changes in land use patterns. The rise of LST is a significant concern among the environmentalist as the marginal and fragile landscape of the Himalaya

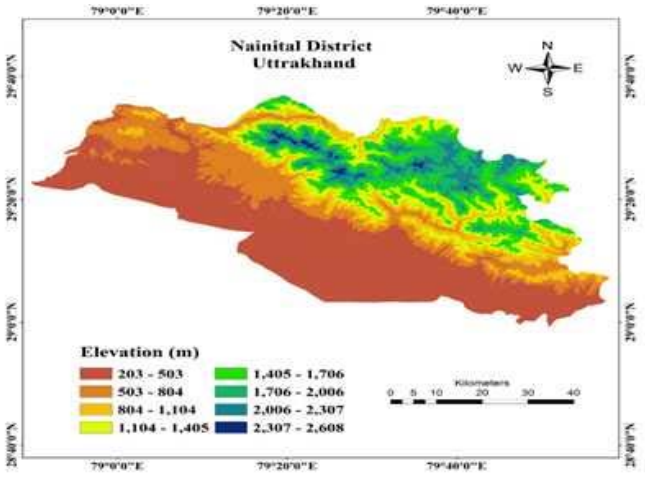

Figure 3. Digital elevation model of the study area

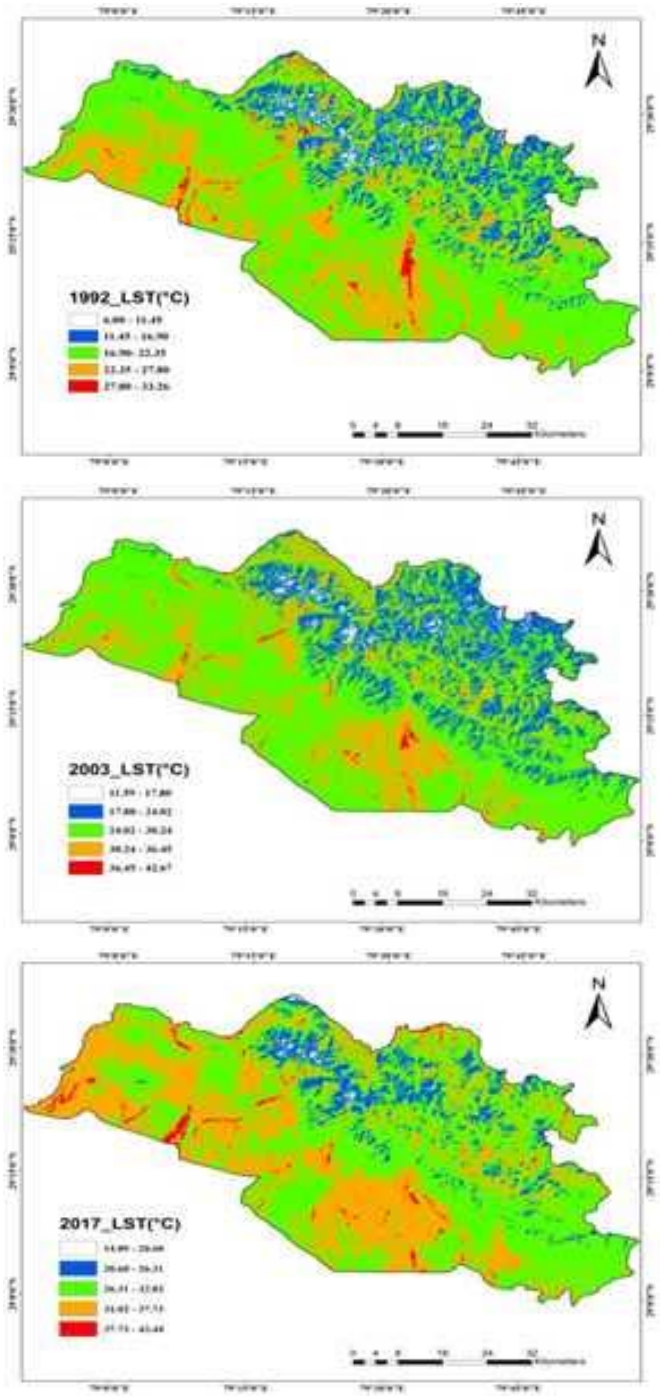

Figure 4. LST map of the study area.

is already vulnerable, and such circumstances are genuine.

The LST isn't only affected by changes in the landscape and the elevation of the region. The elevation factor combined with landscape dynamics affects the LST. The study points out the increase in LST in various periods that can be related to changes in physical characteristics of the Land (Tables 2, 3 and 4). Most of the regions have experienced 10-to-

Table 2. Temporal changes in LST in urban areas

Urban areas	Elevation	1992	2003	2010	2017
Halduchaur	304	39.86	42.01	25.01	35.07
Chorgallia	317	38.80	41.10	26.90	36.20
Shivlalpur Khazanchi	341	37.50	40.10	26.60	39.00
Ramnagar	367	36.90	39.20	25.30	33.89
Phool Chaur	380	36.60	38.20	25.20	37.10
Lapur Nayak	396	36.37	37.96	24.85	34.23
Haldwani	420	35.64	41.35	23.63	40.63
Garjiya	424	33.90	35.30	22.80	35.60
Kusumkhera	435	33.30	34.95	21.59	36.20
Damua Dhunga	500	32.20	34.60	21.30	35.20
Kathgodam	541	29.80	33.60	20.90	34.50
Lalkuan	622	28.54	32.25	20.40	32.56
Jeolikote	1262	23.60	31.30	19.60	29.40
Ramgarh	1470	22.23	30.54	19.50	28.99
Bhatrojkhan	1545	20.18	29.90	18.55	28.79
Ghorakhal	1814	18.40	26.50	15.80	27.60
Nainital	1950	17.92	24.30	10.50	25.79

Table 3. Temporal changes in LST in agricultural areas

Place	Elevation	1992	2003	2010	2017
Mirabara Rana	241	29.30	38.20	25.20	38.20
Mukhani Joga	270	28.99	37.20	24.80	37.20
Hripur Jamansingh	331	28.76	36.56	24.00	36.33
Naripur Lamachaur	335	25.06	35.90	23.90	35.63
Bail Parao	342	23.71	35.10	23.03	34.16
Lal Dhag Bandobasti	345	21.37	34.20	22.90	33.22
Teda	388	20.17	34.10	22.60	32.68
Himmatpur Nakayal	399	22.23	33.20	21.30	32.30
Ringora	427	22.81	32.10	20.20	31.68
Chukam	484	21.94	28.36	17.54	30.64
Naudha	609	21.30	26.30	19.60	29.40
Basani	631	21.06	23.54	18.99	28.79
Patkote	786	19.10	21.30	18.80	28.40
Raukher	1251	13.30	20.65	15.99	27.07
Kweral	1322	12.36	19.24	15.00	26.14
Surang	1660	14.26	18.50	14.85	25.99
Dhanachuli	2184	10.92	18.20	14.15	24.69

Table 4. Temporal variation in mean LST in major land use classes

Land use	Mean Land Surface Temperature			
	1992	2003	2010	2017
Agriculture	20.9788	28.9794	29.1677	31.3247
Urban area	30.6906	33.5735	23.8600	34.8918
Forest	19.6863	25.9632	28.4226	30.8721

12-degree Celsius increase in temperature in last 25 years. The temperatures in urban or built-up areas are higher compared to all classes. Land surface temperature map reflects that the urbanised areas or towns had comparatively less temperature in 2010 than in 2017. A similar pattern can be observed in most cases; the city region shows an increase in temperature compared to its nearby spaces. This trend can be related to anthropogenic influence as well as geographic influence. A similar trend can be seen in other classes as well. Outcomes of the land surface temperatures demonstrate that LST values have a good correlation with land use classes.

The impact of LST is not equally reflected upon the features of LULC (Table 4). It behaves differently in different parts or classes. That is why it was essential to calculate the LST of specific surface features.

CONCLUSIONS

The study found some common trends of LULC and LST, but universal conclusions might be drawn from these findings. Mountains, especially those with huge tourism potential in developing countries, are experiencing continuous growth in urban centers with urban areas encroaching into the agricultural and barren lands. The LULC change can be correlated to LST as both are highly interconnected. Both works as a cause-effect of one another. Summing up, the association between the LULC and LST is direct in this case. To reduce the influence of changing land use on the surface temperature, sustainable development and planning should be adopted with more vegetated areas and less urbanised landscapes. Further research is required to review the potential changes and consequences of LULC changes.

Conflict of Interest: The authors declare no conflict issues.

Authors Contributions: All authors contributed equally.

Availability of Data and Material: Open source and free remote sensing data has been used for this study which is available in public domain.

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