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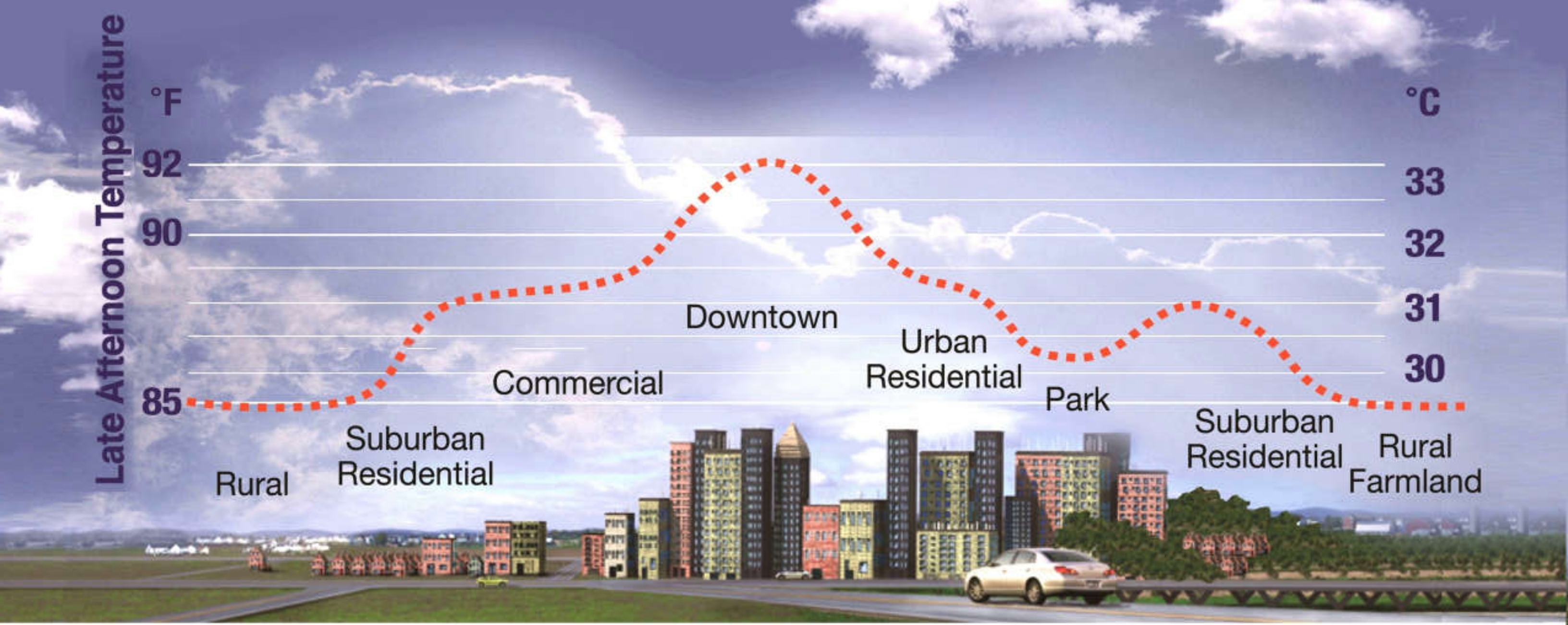

IC2UHI 2019

International Institute of Information Technology Hyderabad
Hyderabad

Editors: Hashem Akbari, Vishal Garg, Jyotirmay Mathur, Vaibhav Rai Khare

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Land surface temperature responses to land use dynamics across the agro-climatic zones of Karnataka

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ABSTRACT

Landscape dynamics has a crucial role in the ecological processes and sustainability of natural resources. Understanding of landscape dynamics aids in planning and prudent management of natural resources. However, unplanned rapid urbanization during the post 1990's consequent to the globalization has driven anthropogenic activities leading to the alterations in the landscape structure, impacting the ecological process evident from the increase in land surface temperatures, alterations in the hydrologic regime, etc. Thus, land surface temperature being sensitive to land use dynamics, has become a vital factor in the regional climate change studies. The current study explores the relationship between biophysical parameters of earth to sub pixel thermal variations based on agro climatic zones of Karnataka. The general trend of temperature of the region with different land use class was established which indicates rise in temperature in the recent period. The study identifies the hotspot zones of higher temperature with the insights of land uses across the agro climatic zones of Karnataka.

Keywords: Landscape dynamics; Land use land cover; Land Surface Temperature; Remote sensing; GIS

Introduction

Landscape patterns plays an important role in ecological processes and the structure of a landscape, shape and configuration are responsible for its functional aspects such as bio-geo chemical cycling and hydrologic regimes (Chen et al. 2014; Ramachandra et al. 2016). The landscape transition can be natural or anthropogenic. The several studies across the globe have proved the anthropogenic activities are altering the global climate (Peng et al. 2011; Newbold et al. 2015; Grizzetti et al. 2017; Szymura et al. 2018). The abrupt environmental changes at local, regional and global scales are threatening the survival of humans and other biota. Land use land cover (LULC) are the important parameters of landscape which reflects its change characteristics (Ganasri et al. 2010). LC refers to the observed physical cover on the earth's surface whereas LU expresses arrangements, activities and inputs people undertake in a certain LC. LULC change is governed by the crucial drivers such as population, urban expansion, agricultural production and land management policies, which alters a landscape into heterogeneous mosaic of patches (Ramachandra et al. 2012). LULC alterations will affect the range of functionalities of landscape such as nutrient cycling, bio-geochemical cycle, hydrologic cycling, carbon sequestration potential, water retention capability, etc. (Ramachandra et al. 2018; Ramachandra and Bharath 2019). The rampant LULC changes of a region will affect the exchanges of energy that take place between the biophysical properties of the Earth with the atmosphere. The comprehensive

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understanding of these changes are necessary to evaluate critical drivers of changes and frame polies for sustainable development (Ramachandra et al. 2017). Land surface temperature (LST) is a prime climate variable to account climate change across the local and global scales and it is also an indicator of the energy balance of the land surface processes (James and Mundia 2014). Changes in LST can be directly linked with associate LULC changes to account adverse effect on environment, energy balance and biogeochemical interactions.

Global warming and consequent changes in the climate has given momentum to the research to understand the causes of LULC. LST is sensitive to vegetation, canopy layer and soil moisture, hence it can be used to detect LULC changes and link to climate alterations (Mallick et al. 2008). The unplanned developmental activities will intensify the environmental degradation, induce disasters, disrupting the sustainable economic growth (Ramachandra et al. 2019). LST changes play an important role in most of the environmental processes and effect microclimate through associated biophysical changes. Increase in surface temperature has been observed due to conversions of pervious or vegetation surfaces to impervious surfaces. These changes in turn affect the absorption of solar radiation, surface temperature, evaporation rates and wind turbulence and alters the conditions of the near-surface atmosphere (Aithal et al. 2014). Thus, understanding linkages between LST and landscape dynamics help in evaluating human-environment interactions, aids in the planning and management of natural resources with persistent knowledge of landscape at temporal scale (Bharath et al. 2013). The advancement of spatial technologies has aided in understanding LULC changes, precise evaluation of LST and its environmental consequences. The temporal satellite remote sensing data of thermal band can capture the variation in energy across various features of landscape. The abundant studies have tried to capture LST using split-window algorithms in Landsat 8 using band 10 and 11 (Li et al. 2013; Bunai et al. 2018). Moderate Resolution Imaging Spectral radiometer (MODIS) data has more advantageous in LST estimation due to its global coverage, high radiometric resolution and dynamic ranges makes it efficient for monitoring and estimation of land surface temperature over a large area (Wan et al. 2002). The satellite derived LST of a larger region will provide information of different types of Earth surface processes, surface-atmosphere interactions and evapotranspiration (Anderson et al. 2011). The Karnataka state of India is experiencing the LULC changes due to increase in anthropogenic pressure from post 1990's. In this regard, the current research tries to understand the LULC changes at a temporal scale from 1985-2018 and tries to explore correlation between biophysical parameters of earth to sub pixel thermal variations based on agro climatic zones of Karnataka. Evaluation of temperature variations across forest and non-forest cover regions.

Materials and Method

Study Area

Karnataka is the eighth largest state in India with varied agro climatic zones (Figure 1) and population density of 319 persons per sq.km as per 2011 census. It lies between 11.5° and 18.50° N and 74° and 78.30° E in the southern plateau with a geographic area of 1,91,791 km^2. It is bordered by Arabian Sea to the west, Goa to the northwest, Maharashtra to the north, Andhra Pradesh to the east, Tamil Nadu to the east and southeast, and Kerala to the southwest. The state comprises of diverse topographical features of high mountains, plateaus, residual hills and coastal plains and is enclosed by chains of mountains to its west, east and south. The region is endowed with the most magnificent forests in the country, from the rich evergreen forests of the Western Ghats to the scrub jungles of the plains, a wide variety of habitats exist and some of them endemic to the region. The weather is very dynamic, changes from place to place owing to its altitude, topography and its distance from the sea. It experiences climatic variations from arid to semi-arid in the plateau region, sub-humid to humid tropical in the Western Ghats and humid tropical monsoon in the coastal plains. The mean rainfall varies from 400 mm in the Eastern parts to more than 4000 mm in the Western Ghats and coastal beach of the State.

Method

The method adopted for the analysis is illustrated in Figure 2. LU analysis involved (i) generation of False Color Composite (FCC) of remote sensing data (bands–green, red and NIR). This composite image helps in locating heterogeneous patches in the landscape, (ii) selection of training polygons by covering 15% of the study area (polygons are uniformly distributed over the entire study area) (iii) 60% of the training data has been used for classification, while the balance is used for validation or accuracy assessment. (iv) LU analysis was done using supervised classification technique based on Gaussian maximum likelihood algorithm through GRASS GIS (Geographical Resources Analysis Support System) a free and open source software accessible at http.//wgbis.ces.iisc.ernet.in/grass/index.php. MODIS Land surface temperature (LST) and emissivity data has retrieved from Land Processes Distributed Active Archive Center (LPDAAC), which has been re-projected from sinusoidal projection to UTM Zone 43 projection with WGS 84 datum using MODIS Re-Projection Tools. To investigate temporal patterns of temperature across the study region 2005, 2012 and 2018 of May month data were used. LST was computed by multiplying DN (Digital numbers) with a scale factor of 0.02 and then converted into degree Celsius. Validation of land surface temperature was done using ground data of 0.5 degree downloaded from Princeton University which gives air temperature above 2m ground level. Finally, statistical analysis has performed to understand the relationship among various LU classes and LST.

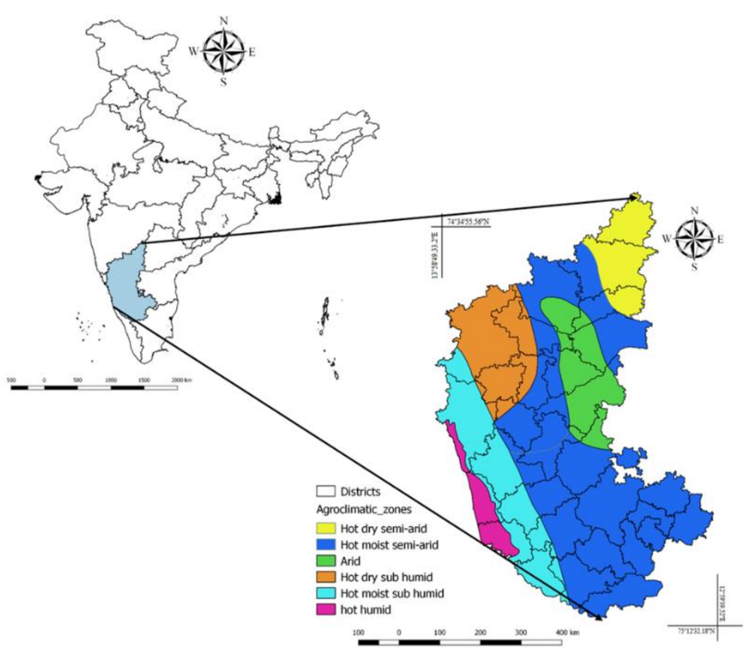


Figure1. Geographic location of the study area.

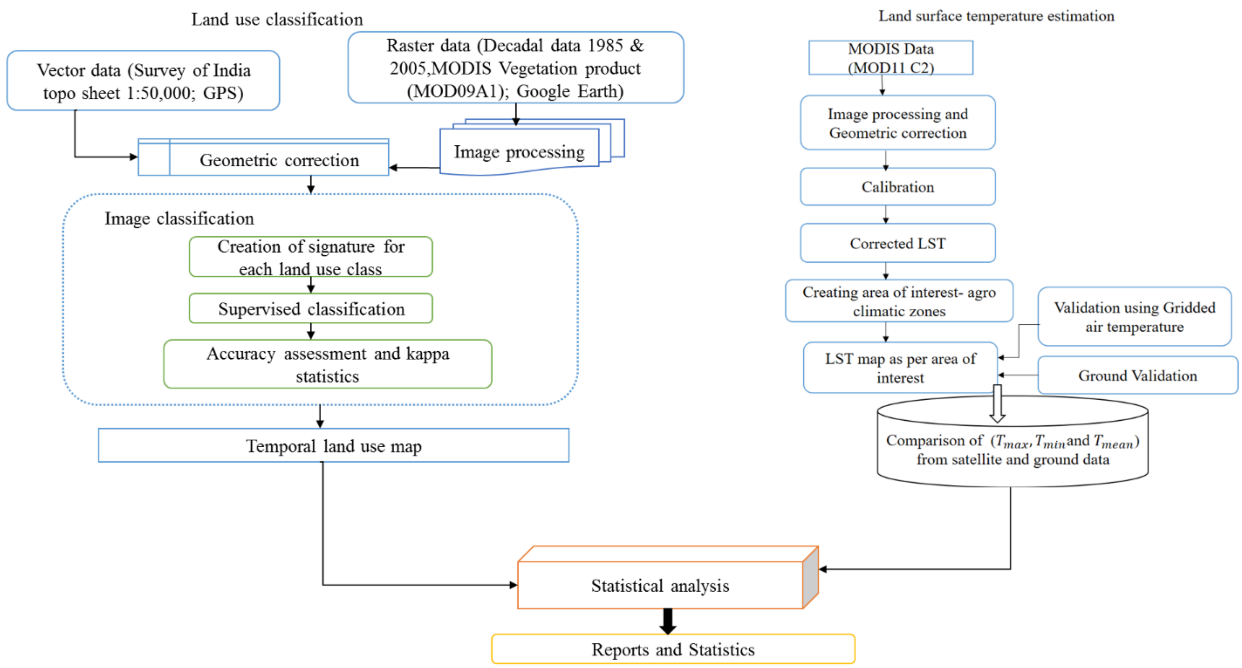


Figure 2. Method adopted

Results and Discussions

Analyses of spatio temporal LU changes for Karnataka highlights the loss of forest cover and conversion of agriculture to other use due to anthropogenic pressures. The evergreen forest cover has reduced from 4.2% (1985) to 3% (2018) with the increase in plantations, built-up areas. The new urban agglomerations were noticed across the cities and major towns such as Bengaluru, Mangalore, Hubli, Hassan, Mysore etc. The total forest cover loss was accounted to be 6.2%, where as non-forest over has increased by 5.7%. The major tracts of deciduous forests were replaced by anthropogenic as evident from 1985 to 2018. Due to large scale plantations of Eucalyptus, Rubber, Acacia, teak and Arecanut have increased from 1985 to 2018 covering 19.45% of the state. Due to increase in horticulture plantations and increase in paved surfaces croplands have decreased from 68% (1985) to 64.09% (2018). These changes are abrupt and resulting in imbalance of ecosystem services, hydrology, and natural resources availability. The temporal LST results further highlights the loss of forest cover has resulted in increase in temperature gradient across the state. The higher temperature can be seen especially in non-forest areas due to intensified built-up activities. The rise in temperature can be attributed to high deforestation with unplanned urbanisation and industrialisation. Table 1 illustrates temperature gradient across the agro climatic zones. Urban areas show increase in temperature (maximum) as population explosion exerts pressure on the local resources such as open lands and forest cover. Temporal analysis of LST indicates rise in mean temperature over the periods. The highest temperature of 48.46˚C was found in the hot dry semi-arid region and the lowest was found in hot humid of 32.46 ˚C.

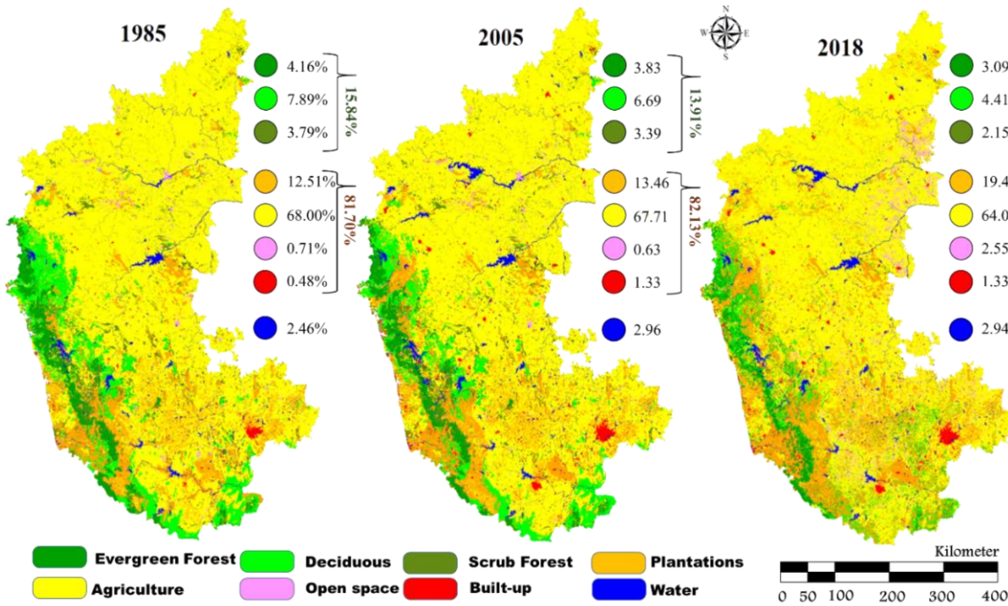


Figure 3. LU analysis of Karnataka from 1985 to 2018

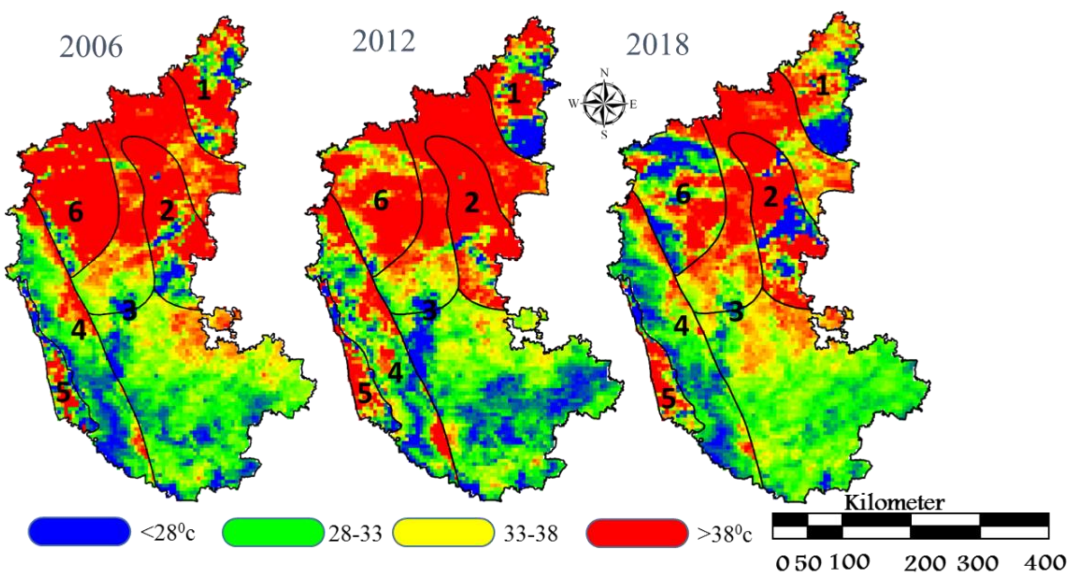
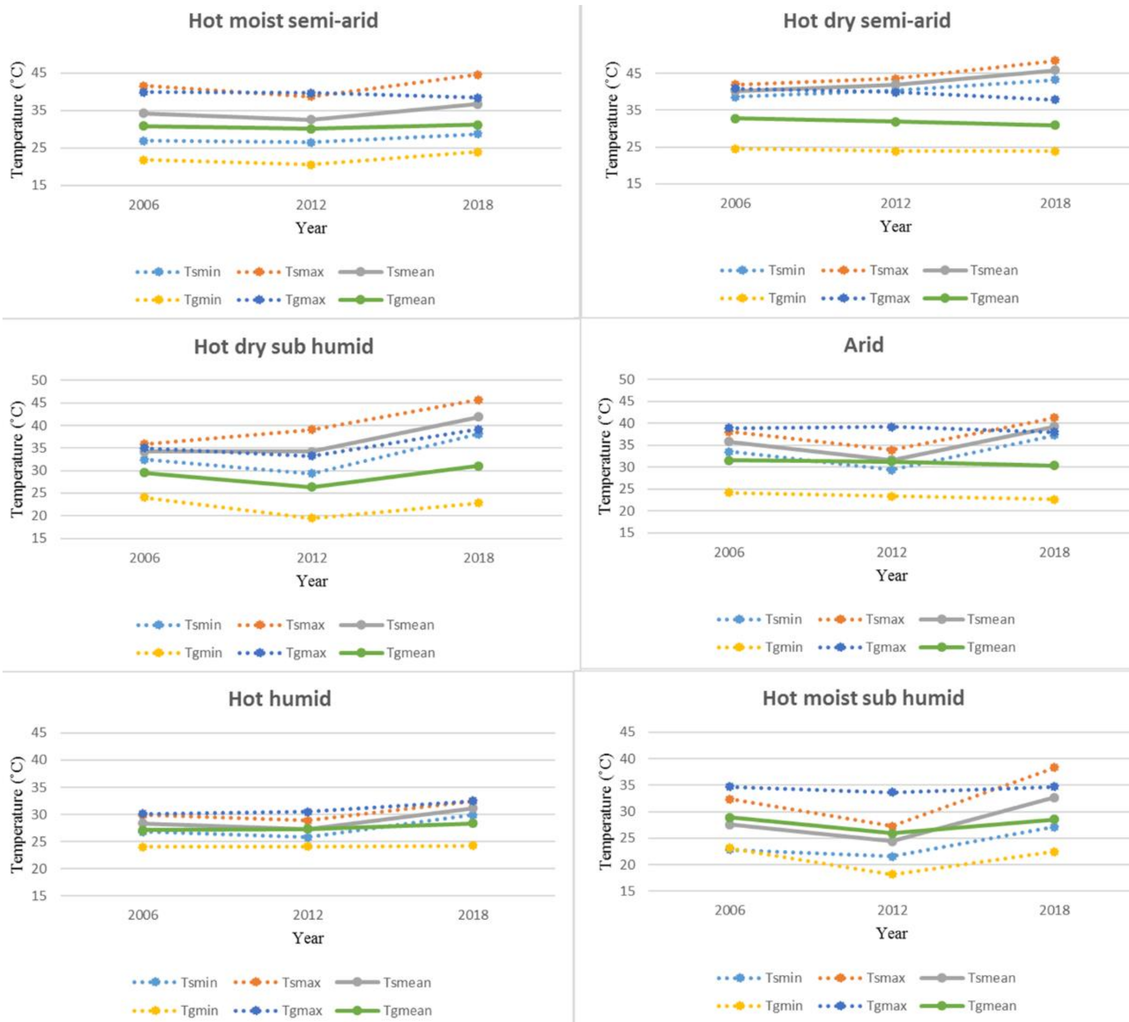


Figure 4. LST dynamics of Karnataka from 2006 to 2018

Table 1. LST across the agro climatic zones

Regions	2006		2012		2018	
	Min (˚C)	Max (˚C)	Min (˚C)	Max (˚C)	Min (˚C)	Max (˚C)
Hot dry semi-arid (1)	38.55	41.92	40.35	43.5	43.27	48.46
Arid (2)	33.57	38.08	29.39	33.88	37.21	41.25

Hot moist semi-arid (3)	26.91	41.58	26.49	38.7	28.78	44.57
Hot moist sub humid (4)	22.85	32.38	21.53	27.3	27.11	38.31
Hot humid (5)	26.83	29.9	25.77	28.9	29.89	32.46
Hot dry sub humid (6)	32.49	35.92	29.33	39.08	38.11	45.68



Where Tsmin = Satellite minimum temperature, Tsmax = Satellite maximum temperature, Tsmean = Satellite mean temperature, Tgmin = Ground minimum temperature, Tgmax = Ground maximum temperature Tgmean = Ground mean temperature

Figure 5. LST across agro climatic zones from 2006-2018.

Figure 5 confirms that LST (satellite temperature) are comparable to ground measurement across the agro climatic zones. Ground air temperature was measured at a distance of 2 m above ground while satellite gives temperature of land surface which may be 2-3 ˚C higher. The 1km gradient has been used for sampling across the agro climatic zones from forest and non-forest categories to assess the temperature variations across the LU. The two samples were taken for each agro climatic zone except Hot Moist semi-arid (4 samples) due to larger coverage. The correlation analysis shows (Figure 6) forest decreases on increase in temperature indicating indirect relationship. This indicates forest holds strong co-relationship of 0.8 (r=0.94) with temperature. Whereas, it was observed that on increase built-up areas, temperature goes up which shows direct relationship. Also, non-forest cover holds a strong co-relationship of 0.5 (r=0.74) with temperature. The gradients depict as non-forest cover has increased in the region depicted rise in temperature. The results highlight the role of bio-physical variables in maintaining regional climate. The increase in temperature can induce higher loss of species, imbalance in ecosystem, vegetation die-off. It is suggested to curb the unplanned developments and increase in forest cover with native species through stakeholder's active involvement would help in the conservation and prevent further degradation of landscape. The effective forest management with forest regeneration activities would help in reducing LST and its ill effects.

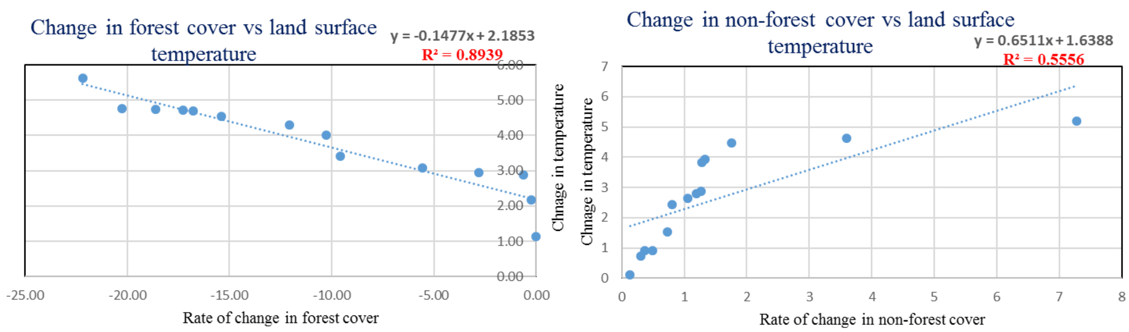


Figure 6. Correlation among forest, non-forest LU with LST

Conclusion

Spatial temporal LU analysis reveals increase in built-up area at the cost of forest cover, signifies anthropogenic pressure. The temporal analysis of forest and non-forest cover with temperature indicates a strong relationship among LU and bio-physical variables. The results revealed forest cover has reduced from 15.84% (1985) to 9.65% (2018) whereas non-forest cover has increased from 81.70% (1985) to 87.41% (2018). However, the temporal analysis of land surface temperature shows increase in temperature over the periods. Therefore, it can be understood that large scale deforestation will lead to increase in temperature. The investigation across agro-climatic zones of Karnataka, depicts increase in temperature in hot dry semi-arid regions which are devoid of forest cover. However, there is not much increase in hot humid region as the region has healthy vegetation. However, escalations in anthropogenic activities leading to degradation of forests. Will enhance the regional temperature. Statistical analysis of LST and LU indicates a negative correlation between vegetation with an increase in LST. The general trend in the ambient temperature of Karnataka further clarifies that there was a fundamental drift of temperature rise in recent years, especially during the last decade. Therefore, there is an urgent need to mitigate these issues and possible drought conditions. Proper land use planning and restoration of degraded land through the afforestation with native species would help in mitigating the increase in temperature.

Acknowledgement

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