Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2016, Volume 5, Issue 6, pp. 1755-1767
ISSN 2320 - 0243, Crossref: 10.23953/cloud.ijarsg.58

Research Article **Open Access**

A Geospatial Approach to Analyze the Impact of Population Growth on Bundelkhand Landscape, Central India

Lavkush Kumar Patel[1,2] and Shashikant Tripathi[2]

[1]ESSO-National Centre for Antarctic and Ocean Research, Vasco-da-Gama, Goa, India
[2]Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Satna, Madhya Pradesh, India

Publication Date: 10 June 2016

DOI: https://doi.org/10.23953/cloud.ijarsg.58

Abstract Population growth drives the process of urbanization and associated landscape changes. The conversion of natural landscape to anthropogenic landscape represents the most visible and pervasive form of human impact on the environment. The impact of population growth on Bundelkhand Landscape, Central India was analyzed using Landsat series satellite and MODIS Terra products. Population growth (total, urban and rural), landscape changes and variability in land surface temperature were analyzed for the last decades. The population has been increased manifold since 1901 and urbanization has also increased with the rate of $1.4 km^2 a^{-1}$ during last 24 years. This increase was rapid in current years (2000-2013) as compared to previous years (1989 - 2000). Due to rapid population growth, forest cover has been reduced by ~54% while agricultural land has been increased by ~76%. The mean land surface temperature has also increased by ~0.5 ^{o}C during last 14 years (2001-2014). It is observed that the population growth was proportional to the growth of agriculture land ($r = 0.91$, $p < 0.05$, $n = 4$) and the built up area ($r = 0.94$, $p < 0.05$, $n = 4$) while inversely proportional to the forest resources ($r = -0.99$, $p < 0.001$, $n = 4$). The study indicates the phenomena “human environment interaction” where rapid population growth has lead LULC changes. This study also reveals that population growth is imposing an increasing burden on the limited and continually degrading natural resources thus altering the local environment.
Keywords *Geospatial Techniques; Urbanization; Landscape Changes; Bundelkhand; North Central India*

1. Introduction

Rapid population growth and accelerated demographic shift has made urbanization a significant increasingly global phenomenon [1]. Between one-third and one-half of the land surface has been transformed by human action [2]. The use of land to yield goods and services represents the most substantial human alteration of the earth system. Human use of land alters the structure and functioning of ecosystems, interacts with the atmosphere, with aquatic systems and with surrounding land. Moreover, land transformation interacts strongly with the components of global environment change [2]. With their speed, fragile ecologies and limited natural resources the impact of environmental change are more visible in developing regions [3].

Insights into human drivers of landscape change are crucial to understand the effect of human pressures on the structure and function of ecosystems [4]. Similarly, understanding the impact of anthropogenic activities on natural landscape is crucial for developing effective management plan [5]. The increasing variability, especially in the developing countries calls for the use of monitoring systems like Geospatial modelling. Geospatial techniques with integration of temporal satellite data sets and statistical analysis, it has become more efficient to observe the landscape changes [6], [7], [8]. Geospatial techniques have already shown their value in mapping urban areas, and as data sources for the analysis and modelling of urban growth and land use change [9], [10]. Studies were carried out to analyze the population growth and its impacts on environment using geospatial techniques [10], [11], [12]. The impact of disorganized urbanization on agriculture, ground water resources and on regional climate has been analyzed through geospatial technique [13], [14].

Bundelkhand region having an area of 7.1 million hectares comprises of seven districts of Uttar Pradesh (UP) and six districts of the Madhya Pradesh (MP) is among the least developed regions of Central India [15]. It has several historical places and tourist attractions. The region, with current human population ~21 × 10^6, is lagging behind in terms of social and economic development and also affected by several drought years. The frequency of droughts has increased dramatically during recent years in this region, from one in 16 years during 18th and 19th centuries to virtually per year in recent times [16]. Banda, the largest and highly populated district of this region is influenced by several environmental problems such as rainfall uncertainty, ground water depletion, drought and global warming [16]. In the Bundelkhand region, very few studies have been done using geospatial techniques to analyse the urbanization growth and its impact on natural resources as well in local climate and are limited to explore the basal topography and water resources management [16], [17], [18]. Hence the study were undertaken to analyze the population growth, urbanization trend, landscape changes with respect to land surface temperature changes for the sustainability of the Bundelkhand region, Central India.

2. Study Area

Banda district (80°07'-81°34' E and 24°53'-25°55' N) is the eastern most district of Bundelkhand region, Central India (Figure 1). It covers an area of ~4460 km^2 and total human population of 1.8 × 10^6 (Census of India, 2011). The elevation in the area ranges from 400 to 600 m above mean sea level. It is drained by the Yamuna River and its tributaries (Ken and Baghein rivers). Over ~80% of population is dependent on agriculture and on an average ~96% of the farmer’s income is being earned from the crop and livestock (agriculture economy). Its most of the area is irrigated by Ken canal network and groundwater through shallow and moderately deep tube wells. It is mostly covered by massive sandstone and limestone (high ground water yield) along with basement crystalline, impermeable or hard igneous and metamorphic rocks (poor aquifer and high runoff) exposed in the south-eastern part of the region. The region forms northern fringe of the peninsular India coming in contact with the Gangetic alluvium. Its major area is covered by Bundelkhand Granite Complex (Archean to Proterozoic) exposed in the south-eastern part of the region and overlain by alluvium soils; it is divided into two parts unconsolidated older (Pleistocene) and consolidated newer (Holocene) Alluvium. The general slope of the district is from southwest to north-east [19]. Climate of the district is characterized by hot summer, pleasant monsoon and cold seasons. The climate of the area is dry. The area lies in the semi-arid zone of Bundelkhand region. The annual rainfall is around ~950 mm, with maximum precipitation (80%) received between July and September from the south-east monsoon (20). It has an average temperature of 13-36 ^{o}C, minimum average temperature of 5.6-12 ^{o}C in winters (January-February) and maximum average temperature 32-44 ^{o}C in summers (March-May).

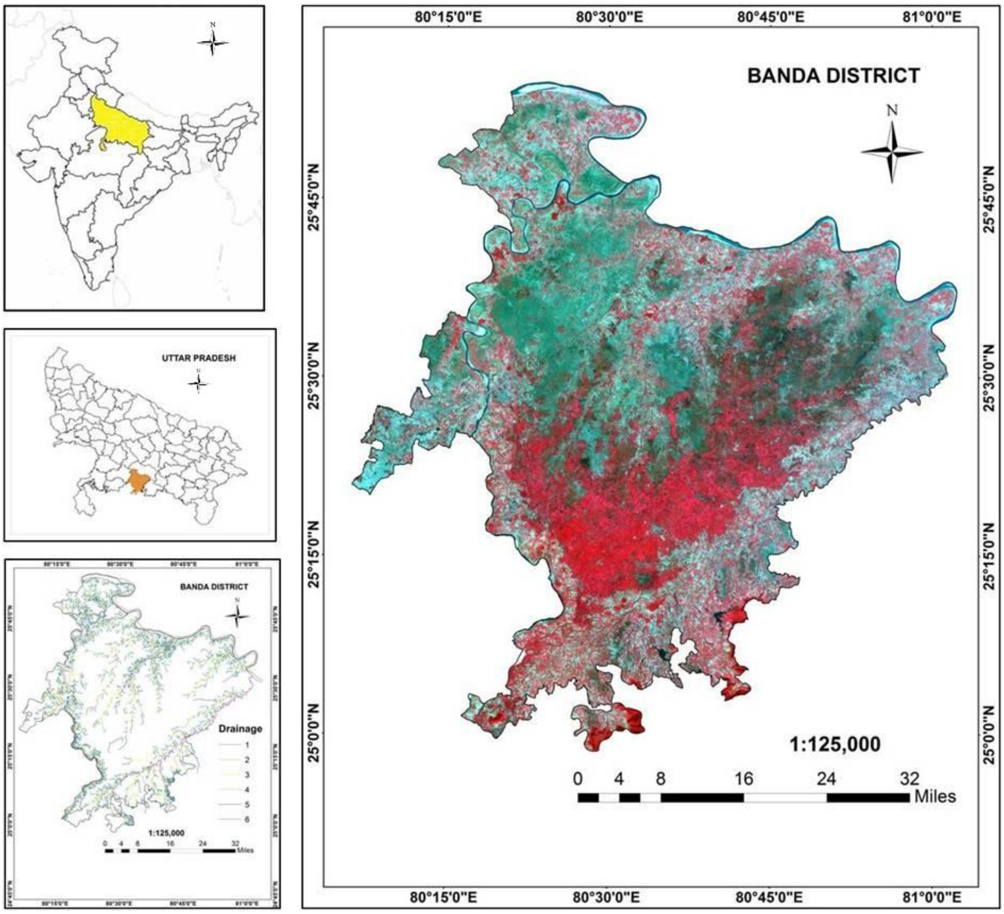


Figure 1: *Location map of Banda district, Bundelkhand landscape, Central India, drainage network and synoptic view by Landsat 8 (PAN merged) operational land imager sensor data*

3. Data and Methods

The census data of the district were collected from the Census survey of India for period of 1901-2011. The population growth and decadal variation were analysed for the urban, rural and total population of the district. Images from Landsat **s**atellites series of different resolutions were used for the spatio-temporal data generation. Multispectral images of Landsat thematic mapper (TM) from 1989, enhanced thematic mapper (ETM^+) from 200 and Landsat 8 Operational Land Imager (OLI) image from 2013 were acquired from United States Geological Survey (USGS, http://earthexplorer.usgs.gov/). Additionally, the topographic maps of 1961 (1:50000) and administrative map of Banda district obtained from Survey of India were used as secondary data for the location identification and interpretation in satellite data. Landsat OLI satellite image was pansharped by using its band 8 (Panchromatic band) and Brovery transform algorithm with bilinear interpolation re-sampling method. Pansharped Landsat OLI satellite image (2014) was used as a reference to co registered satellite images of different time period to UTM Zone 44 North projection with WGS-84 datum within 0.5 pixel error. The built up area was manually extracted from the satellite data for different years (1989, 2000 and 2013) for the nine major populated regions of the district (Banda, Atarra, Baberu, Tindwaree, Badausa, Bisanda, Oran, Narainee, and Kamasin). In the selected populated regions, Banda, Atarra, Narainee and Baberu are the main towns and rest spots are the main villages of the district. The urbanization for last four decades (1989 to 2013) of the district was analysed. Annual expansion rate for the different time periods (1989-2000, 2000-13 and 1989-2013) were calculated and urbanization index were prepared for district and selected towns using following equation [21]:

$$Ire = \frac{\Delta U \times 100}{TLA \times \Delta t}$$

Where I is intensity index, ΔU is expansion area of urban land during a certain period, TLA is the total area of the research area, and Δt is time span of certain duration.

Satellite images were studied thoroughly to ascertain the probable land use classes and their range of reflectance values (DN). Six land use and land cover types were identified and used in this study, including: (1) urban or built-up land, (2) Open land and rocks, (3) Agriculture, (4) Forest (5) Grass land and shrubs, and (6) water. Supervised classification using maximum likelihood classification algorithm was performed for the classification of satellite data of different years in the Erdas Imagine 2015 environment. Accuracy (80-86 %) of the classified images was assessed, by comparing the classified data with ground truth GPS data. The land Use land cover changes (LULCC) were analysed by comparing the classified land use land cover maps of each year. Linear regression analysis was carried out in between variables like population growth, built up area, forest cover, and agriculture land to understand the impact of population growth on environment.

MODIS Land surface temperature (LST) product 8 day L3 Global 1 km (MOD11A2) was used to analyze the land surface temperature of the region. These data have been downloaded from the Land Processes Distributed Active Archive Centre: (https://lpdaac.usgs.gov/). The orbit of Terra around the Earth is scheduled to pass from north to south across the equator at about 10:30 a.m. and p.m. local solar time. The MODIS land surface temperature (LST) is derived from two thermal infrared band channels, i.e. 31 (10.78–11.28 μm) and 32 (11.77–12.27 μm) using the split-window algorithm [22] which corrects for atmospheric effects and emissivity using a look-up table based on global land surface emissivity in the thermal infrared [23].

4. Results and Discussions

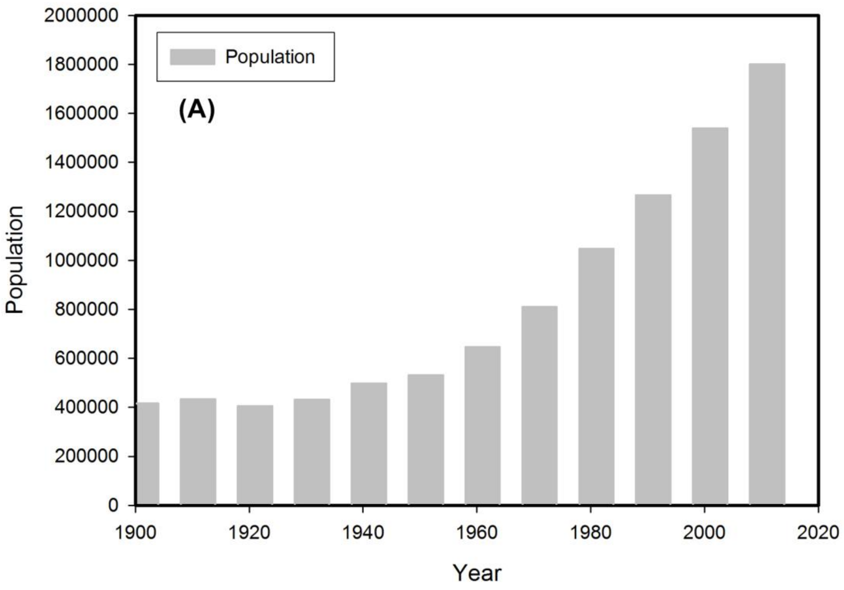
The Banda district, one of the main landscapes of the Bundelkhand, covers major areas and is the major contributor of its economy. As per the analysis of district census data, the population of the district has been increased manifold since 1901 (Figure 2). The results for the population growth indicated increasing trend since 1901. The changes in population for each decade were calculated and it was observed that there was an increment in the population by approximately three times in last six decades (1961-2011). The growth in the urban population is comparatively high as compared to the rural population in the same time period. The decadal variation of the urban population (13-97%) was higher as compared to rural population (18-24%) during last six decades (1961-2011) (Figure 2). In the year 1961, decadal urban population decreased significantly as compared to rural population, the reason of this drift has remained unclear. In the following years (1971 and 1981), the decadal population of urban areas has increased dramatically. Most of the population tend to migrate towards urban areas for the better facilities which could be the reason of this higher population in urban. Increasing urban population could be also due to the natural growth of population in urban areas, rural to urban migration and reclassification of rural areas as urban in course of time [1]. The results of urbanization analysis of the district showed an annual expansion rate of 1.4 km^2a^{-1} during 1989-2013, noticeably, 2000-2013 had higher annual expansion rate (3.4 km^2a^{-1}) as compared to 1989-2000 (1 km^2a^{-1}). Similar results were observed for urbanization index which was higher during 2000-2013 (0.1) as compared to that during 1989-2000 (0.02). The annual expansion in the major towns of the district was higher as compared to the villages. Banda, Atarra, Narainee and Baberu showed high annual expansion rate as (0.2, 0.04, 0.03, and 0.02 km^2a^{-1} respectively) while villages showed a constant expansion rate 0.01 km^2a^{-1} (Table 1). The increased urbanization is indicating increased land consumption and land excessive rate. Considering the built up expansion rate for selected urban towns of the district (Table 1), Banda city is the main town of the district and showed maximum changes (expansion) in built up area (~8 km^2) and had highest expansion rate 0.2 km^2a^{-1} and urbanization index of 1.1. Atarra and Baberu are the second and third highest developed town of district, which also had high annual expansion rate (0.04 km^2a^{-1}, 0.03 km^2a^{-1} respectively) and urbanization index (0.2 and 0.1 respectively) (Table 1). Major development like construction of institutions, hospitals, government buildings etc. was done during 2000-2013 in the district. Increase in built up area with population growth indicates that land was being used for urbanization at faster rate.

Table 1: *Changes in the built up area, annual expansion rate and urbanization index of the selected nine urban towns of the Banda district during 1975-2013*

	Changes in Area (1989-2013) km^2	Annual rate (1989-2013) km^2a^{-1}	Built up Index
Banda	8.0	0.2	1.0
Atarra	1.4	0.04	0.2
Baberu	0.9	0.02	0.1
Tindwari	0.4	0.01	0.1
Badausa	0.3	0.01	0.03
Bisanda	0.2	0.00	0.02
Oran	0.2	0.00	0.02
Narainee	0.7	0.02	0.1
Kamasin	0.2	0.01	0.03

As per the results of LULCC, the agriculture land comprised 73.9% of the area while forest cover comprised 8.1% area of district in 1989. From 1989 to 2013, the area of agriculture was found to increase while forest cover decreased (Table 2). In India and other developing countries, large areas had been partially cleared for agriculture. The degradation of forest cover was high in the period 1989-2000 (2.2%) as compared to 2000-2013 (2.1%) while agriculture land showed increment of 0.01% during the same period (Table 2 and Figure 3). The major LULC changes during 1880-2010 in India, which includes loss of forests, expansion of cropland and urbanization was studied by Tian et al. 2014 [24]. They have proposed that the greater deforestation occurred during 1880–1950 due to British rule policies to increase income from the timber products and cropland, however, deforestation decreased after the 1980s due to formulation of government policies to protect forests. Booth et al. (2002) [25] have reported the changing rates for the Southeast Asia forests (0.8 to −0.9%), Latin America (0.4 to 0.5%) and for the humid forests of Africa (0.4 to 0.5% per year). Richards and Flint (1994) [26] have reported that total forest area decreased from 100 million ha to 81 million ha while cropland area increased from 100 million ha to 120 ha during 1880–1950. New cultivation, population increase and poverty were found as the major cause of this deforestation. Built-up area showed increasing trend, however it had higher growth in 2000-2013 (1%) as compared to 1989-2000 (0.2%). There was increment in built up area (0.3% - 1.6%) since 1989-2013 especially along the roads. Although not significant, agriculture land and built up area were inversely correlated to the deforestation.

A continuous decrease in open land, rocks, grass and shrubs were observed in between 1989-2000 (0.7% and 2.1%) and 2000-2013 (0.04% and 2.8%). The area of surface water bodies of the district were seen fluctuating. It could be due to several drought years in between 1975-2013. Similar observations were reported for the Bundelkhand region [16]. The results showed agricultural expansion and intensification were the major drivers of LULCC. Reduction in the forest cover, grass and shrub land and increment in agriculture and built up land indicate unplanned development and anthropogenic activities in the district.



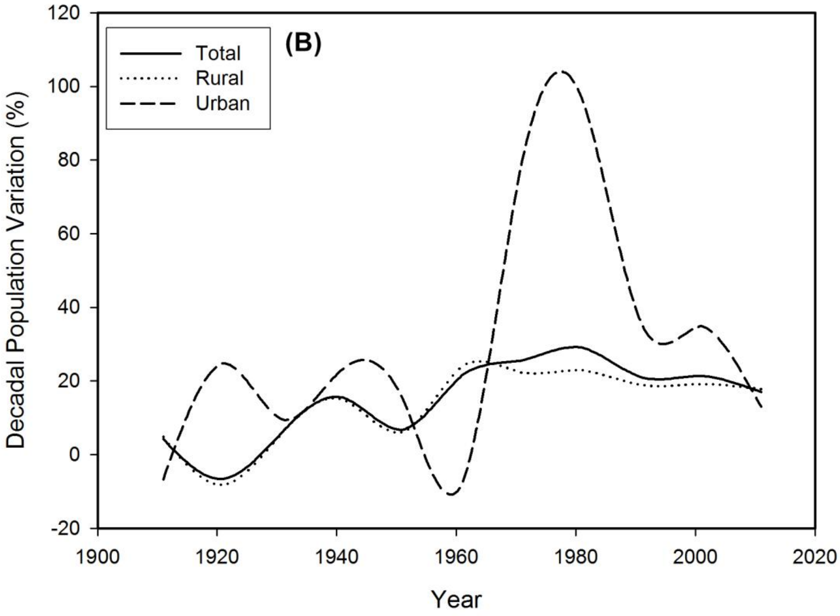


Figure 2: *A) Population of the Banda district during each census since 1901-2011. (B) Decadal population variation for rural, urban and total (rural and urban) population of the Banda district*

Table 2: *Changes in the land use and land cover of the district for the period 1989-2013*

	1989		2000		2013	
LULC	% Area	Area	% Area	Area	% Area	Area
Water bodies	0.9	40.2	1.0	44.4	1.6	70.9
Forest cover	8.1	361.5	5.8	259.8	3.7	166.7
Agriculture	73.9	3296.1	77.2	3442.2	80.4	3587.8
Open land and rocks	3.9	177.1	4.7	209.8	4.8	211.8
Grass and Shrubs	12.8	569.9	10.7	477.7	7.9	353.1
Built-up	0.3	15.2	0.6	26.1	1.6	69.8

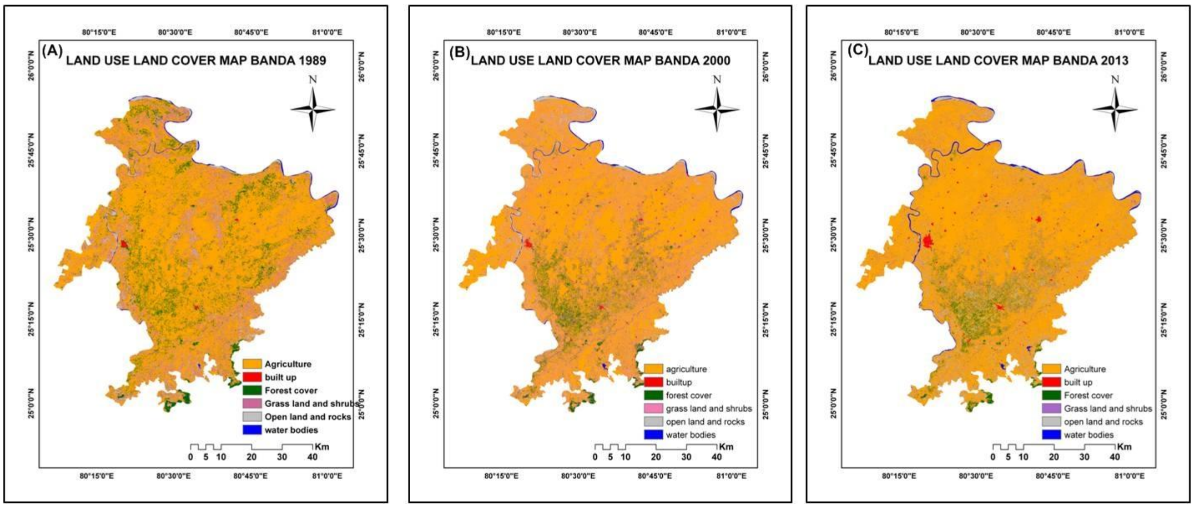


Figure 3: *Landscape changes in the Banda District, (A) LULC map of 1989, (B) LULC map of 2000, and (C) LULC map of 2013*

To understand the impact of increasing population and disorganized urbanization on landscape, a linear regression analysis was carried out. The analysis of population growth and others indicates decrement in the forest resources and substantial increment in the built up and agriculture land (Figure 4). Increase in population growth was significantly correlated to increasing agriculture land ($r = 0.91$, $p < 0.05$, $n = 4$) and built up area ($r = 0.94$, $p < 0.05$, $n = 4$). However, increasing populations significantly affected the forest cover ($r = -0.99$, $p < 0.001$, $n = 4$). The Figure 4 indicates the negative correlation of population and forest cover. With the growing population the forest cover showed a continuous decrease while population growth has positive correlation with agriculture and built up land. The changes of landscapes indicate the social and economic needs of growing population. Deforestation has been associated with increases in population density [5]. It indicates negative effect of population pressure on natural landscape of the district. Increasing human population and climate variability is affecting not only the district but also the other parts. Similarly, Badreldin and Goossens, (2014) [27] have also analyzed the LULC changes in the Egypt, where climate and human activities were the main causes for landscape change.

To analyze impact of human induced changes in LST, the MOD11A2 data for the period 2001 to 2014 were analysed and significant increment in the LST were observed (Figure 5). In 2001, ~59% of the district area represented 24°C to 26°C LST range, ~26% area represented 22°C to 24°C LST range, ~13% area represented 26°C to 28°C LST range and ~1% area represented 28°C to 30°C LST range. As compared to 2001, increment in LST was observed in 2007. In 2007, ~50% area represented 24°C to 26°C LST range; ~48% area represented 26°C to 28°C LST range, ~2% area represented 28°C to 30°C LST range, and ~1% area represented 23°C to 24°C LST range. Similarly for 2014, ~70% area represented 26°C to 28°C LST range, ~22% area represented 24°C to 26°C LST range, and ~8% area represented 28°C to 30°C LST range. The lowest land surface temperature range for the district increased 2°C and highest land surface temperature range increased 1°C (Figure 6). The overall mean land surface temperature of the district has been increased by 0.5°C (Figure 5). Mohan and Kandya, (2015) [28] have analyzed the diurnal temperature range (DTR) of the Delhi city for period 2001 to 2014 and reported that the converging trend of DTR which is primarily due to the increase in the minimum temperatures as a consequence of built structures in the cities. Similarly, Zhang et al., (2009) [29] had analyzed the effect of human induced changes and land surface temperature rise in the non-urban areas, and reported that the LULC changes has altered the land surface temperature of the Fuzhou city China. Chen et al., (2006) [30] had also reported changes in the temperature of the Pearl River Delta, caused by the LULC changes. So, the impact of rapid urbanization is not limited to urban areas but it has impact on non-urban areas (rural) also. So, it indicated the impact of rapid population growth and disorganized urbanization on the LULC changes, which has altered the local climate.

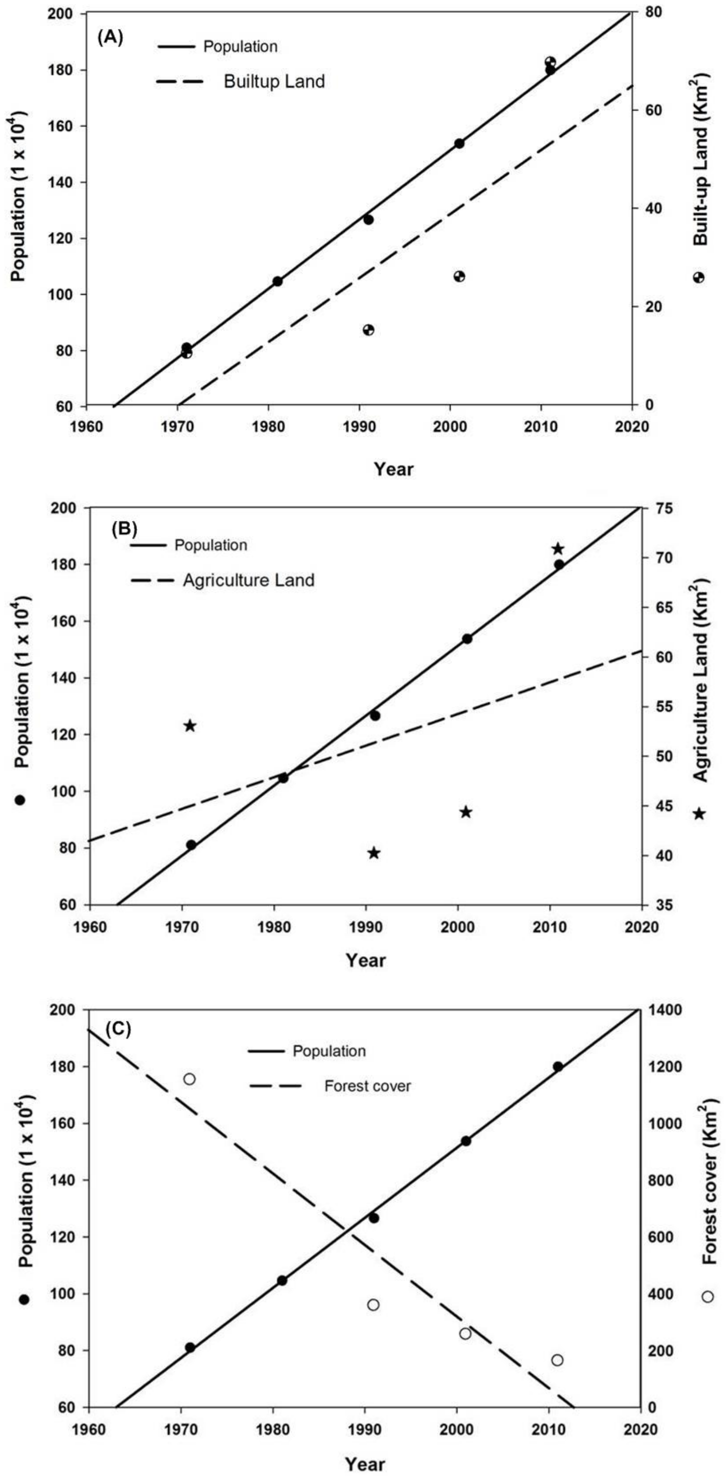


Figure 4: *Population growth and its correlation with landscape changes (A) with built-up land, (B) with agriculture, and (C) with forest cover*

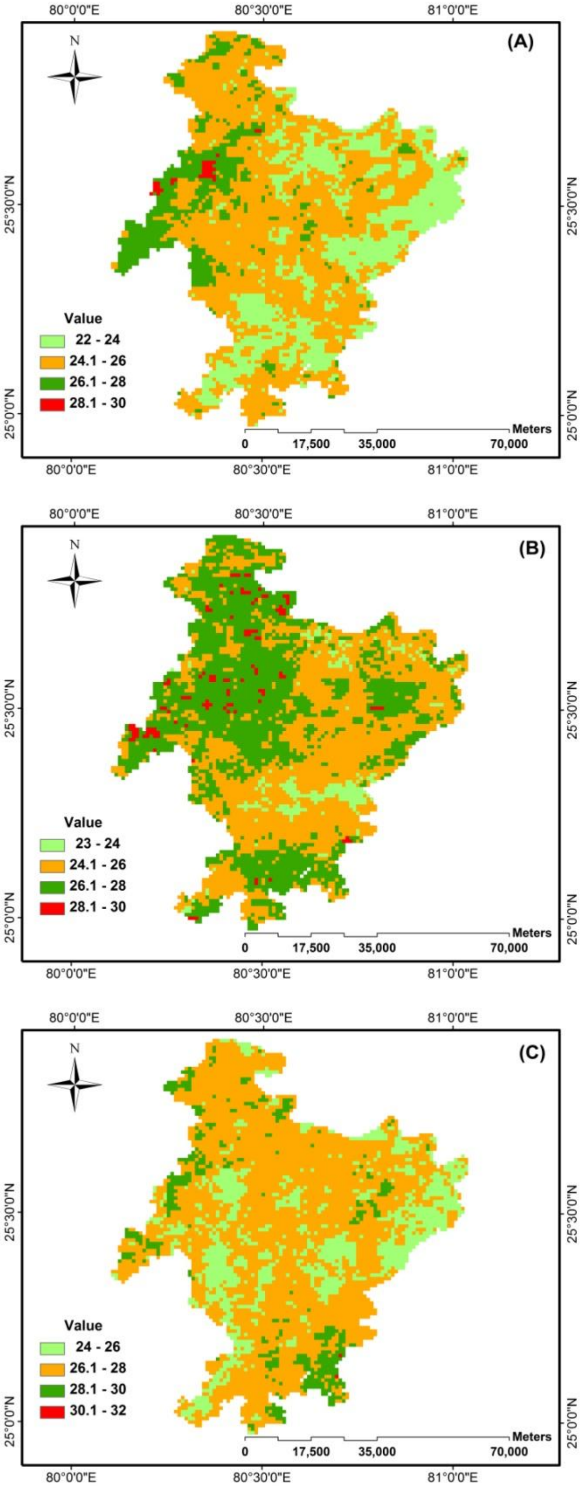


Figure 5: *Land surface temperature (LST) obtained via MODIS Terra product for the period 2001-2015 over the Banda district (A) mean LST map of 2001, (B) mean LST Map of 2007, and (C) mean LST map of 2014*

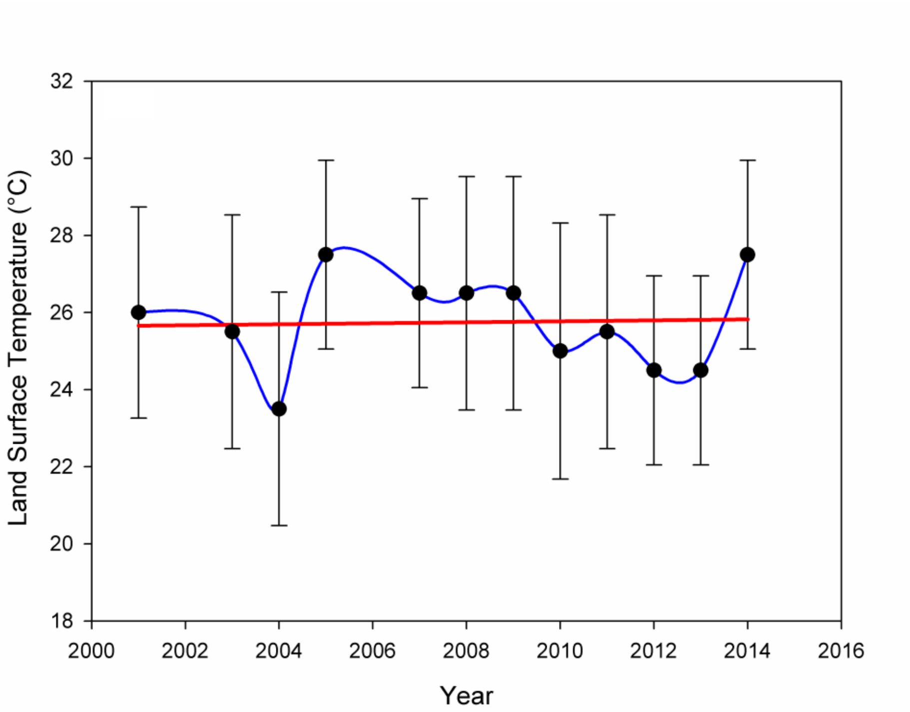


Figure 6: *Mean Land surface temperature trend in the Banda district for the period 2001-2014*

5. Conclusions

This study highlights the impact of population growth and urbanization on the Bundelkhand landscape of Central India. Temporal satellite data products were used for the estimation of urbanization and its impact on landscape. The population of the district has been increased manifold and agriculture and built-up area were increased by 8.8% and 358.7% respectively however forest cover was reduced by 53.9%, from 1989 to 2013. The conversion of natural lands to croplands, pastures, urban areas, reservoirs, and other anthropogenic landscapes represents the most visible and pervasive form of human impact on the environment. The population has been increased four times compared to 1901 and urbanization rate was higher (1.4 km^2a^{-1}) for the current period (2000-2013). The decrement in the natural resources and increment in the land surface temperature of the district could be due to population growth, and urbanization. Regular monitoring of natural resources of the region is a prime need and also a recommendation. The path for sustainability might be achieved through the conservation and management of resources (forest, ground water and geological). Geospatial techniques can be used to explore the landscape dynamics, artificial ground water recharge zone and impact of urbanization for the sustainability of district. A systematic analysis of local-scale land use studies to provide an explanation for effective planning is required.

Acknowledgements

The Authors are grateful to the Vice-Chancellor MGCGV Chitrakoot and the Director, NCAOR for their support. We are also grateful to USGS, Census of India, for providing datasets. This is the NCAOR contribution number 09/2016.

References

[1] Jenerette, G.D. and Potere, D. *Global Analysis and Simulation of Land-Use Change Associated with Urbanization.* Landscape Ecology. 2010. 25 (5) 657-670.

[2] Vitousek, P.M., Mooney, H.A., Lubchenco, J. and Melillo, J.M. *Human domination of Earth's ecosystems.*1997. Science. 277; 494-499.

[3] Rasul, G. *Food, Water, and Energy Security in South Asia: A Nexus Perspective from the Hindu Kush Himalayan Region.* Environmental Science and Policy. 2014. 39; 35-48.

[4] Wear, D. and Bolstad, P. *Land-use Changes in Southern Appalachian Landscapes: Spatial Analysis and Forecast Evaluation.* Ecosystems. 1998. 1; 575-594.

[5] Turner, B.L., Meyer, W.B. and Skole, D.L. *Global Land-Use Land-Cover Change - Towards an Integrated Study.* Ambio. 1994. 23 (1) 91-95.

[6] Taubenböck, H., Esch, T., Felbier, A., Wiesner, M., Roth, A. and Dech, S. *Monitoring Urbanization in Mega Cities from Space* 2012. Remote Sensing of Environment. 117; 162-176.

[7] Paudel, S. and Yuan, F. *Assessing Landscape Changes and Dynamics Using Patch Analysis and GIS Modeling.* International Journal of Applied Earth Observation and Geoinformation. 2012. 16; 66-76.

[8] Liu, H. and Weng, Q. *Landscape Metrics for Analysing Urbanization-Induced Land Use and Land Cover Changes.* Geocarto International. 2013. 28 (7) 582-593.

[9] Liu, H. and Weng, Q. *Seasonal Variations in the Relationship between Landscape Pattern and Land Surface Temperature in Indianapolis, USA.* Environmental Monitoring and Assessment. 2008. 144 (1-3) 199-219.

[10] Sharma, R., Ghosh, A. and Joshi, P.K. *Spatio-temporal Footprints of Urbanisation in Surat, the Diamond City of India (1990-2009).* Environmental Monitoring and Assessment. 2013. 185; 3313-3325.

[11] Sharma, R., Ghosh, A. and Joshi, P.K. *Analysing Spatio-Temporal Footprints of Urbanization on Environment of Surat City Using Satellite-Derived Bio-Physical Parameters.* Geocarto International. 2014. 1-19.

[12] Sun, Y., Tong, S.T.Y., Fang, M. and Yang, Y.J. *Exploring the Effects of Population Growth on Future Land Use Change in the Las Vegas Wash Watershed: An Integrated Approach of Geospatial Modeling and Analytics.* Environment, Development and Sustainability. 2013. 15 (6) 1495-1515.

[13] Liu, Y., Lv, X., Qin, X., Guo, H., Yu, Y., Wang, J. and Mao, G. *An Integrated GIS-Based Analysis System for Land-Use Management of Lake Areas in Urban Fringe.* Landscape and Urban Planning. 2007. 82; 233-246.

[14] Pielke, R.A., Pitman, A., Niyogi, D., Mahmood, R., McAlpine, C., Hossain, F., Goldewijk, K.K., Nair, U., Betts, R., Fall, S., Reichstein, M., Kabat, P. and de Noblet, N. *Land Use/Land Cover Changes and Climate: Modeling Analysis and Observational Evidence.* Wiley Interdisciplinary Reviews: Climate Change. 2011. 2 (6) 828-850.

[15] Chengappa, C., Edwards, R., Bajpai, R., Shields, K.N. and Smith, K.R. *Impact of Improved Cookstoves on Indoor Air Quality in the Bundelkhand Region in India.* Energy for Sustainable Development. 2007. 11 (2) 33-44.

[16] Gupta, A.K. and Singh, A. *Traditional Intellect in Disaster Risk Mitigation : Indian Outlook – Rajasthan and Bundelkhand Icons*. Indian Journal of Traditional Knowledge. 2011. 10; 156-166.

[17] Avtar, R., Singh, C.K., Shashtri, S., Singh, A. and Mukherjee, S. *Identification and Analysis of Groundwater Potential Zones in Ken-Betwa River Linking Area using Remote Sensing and Geographic Information System.* Geocarto International. 25 (5) 379-396.

[18] Singh, R., Garg, K.K., Wani, S.P., Tewari, R.K. and Dhyani, S.K. *Impact of Water Management Interventions on Hydrology and Ecosystem Services in Garhkundar-Dabar Watershed of Bundelkhand Region, Central India.* Journal of Hydrology. 2014. 509; 132-149.

[19] Radhakrishna, T., Chandra, R., Srivastava, A.K. and Balasubramonian, G. *Central/Eastern Indian Bundelkhand and Bastar cratons in the Palaeoproterozoic Supercontinental Reconstructions: A Palaeomagnetic Perspective.* Precambrian Research. 2013. 226; 91-104.

[20] Srivastava, A., Tripathi, N.K. and Gokhale, K.V.G.K. *Basement Topography and Aquifer Geometry around Ken Graben, India.* International Journal of Remote Sensing. 1999. 20 (11) 2295-2305.

[21] Zhou, D., Shi, P., Wu, X., Ma, J. and Yu, J. *Effects of Urbanization Expansion on Landscape Pattern and Region Ecological Risk in Chinese Coastal City: A Case Study of Yantai City.* The Scientific World Journal. 2014. 1-9.

[22] Wan, Z., Zhang, Y., Zhang, Q. and Li, Z. *Validation of the Land-Surface Temperature Products Retrieved from Terra Moderate Resolution Imaging Spectroradiometer Data.* Remote Sensing of Environment. 83 (1-2) 163-180.

[23] Vancutsem, C., Ceccato, P., Dinku, T. and Connor, S.J. *Evaluation of MODIS Land Surface Temperature Data to Estimate Air Temperature in Different Ecosystems over Africa.* Remote Sensing of Environment. 114 (2) 449-465.

[24] Tian H., Banger K., Bo, T. and Dadhwal V.K. *History of Land Use in India During 1880-2010: Large-Scale Land Transformations Reconstructed from Satellite Data and Historical Archives.* Glob Planet Change. 2014. 121; 78-88.

[25] Booth, D.B., Hartley, D. and Jackson, R. *Forest Cover, Impervious-Surface Area, and the Mitigation of Stormwater Impacts.* Journal of the American Water Resources Association. 2002. 38; 947-835.

[26] Richards, J.F. and Flint, E.P. *Historic Land Use and Carbon Estimates for South and Southeast Asia 1880-1980.* In: Daniel, R.C. (ed.), ORNL/CDIAC-61, NDP-046. Oak Ridge National Laboratory, Tennessee, USA. 326.

[27] Badreldin, N. and Goossens, R. *Monitoring Land Use/Land Cover Change using Multi-Temporal Landsat Satellite Images in an Arid Environment: A Case Study of El-Arish, Egypt.* Arabian Journal of Geosciences. 2014. 7; 1671-1681.

[28] Mohan, M. and Kandya, A. *Impact of Urbanization and Land-Use/Land-Cover Change on Diurnal Temperature Range: A Case Study of Tropical Urban Airshed of India Using Remote Sensing Data.* The Science of the Total Environment. 506-507, 453-65.

[29] Zhang, Y., Odeh, I.O.A. and Han, C. *Bi-temporal Characterization of Land Surface Temperature in Relation to Impervious Surface Area, NDVI and NDBI, using A Sub-Pixel Image Analysis.* International Journal of Applied Earth Observation and Geoinformation. 2009. 256-264.

[30] Chen, X.L., Zhao, H.M., Li, P.X. and Yin, Z.Y. *Remote Sensing Image-Based Analysis of the Relationship Between Urban Heat Island and Land Use/Cover Changes.* Remote Sensing of Environment. 104 (2) 133-146.