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Land Use and Land Cover Change Analysis and Prediction in the Guntur District Andhra Pradesh

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Urban planners and other environmental experts' top concerns in recent years have been the expansion of urbanization and rising urban populations, particularly in emerging nations. This is well recognized and has been observed. For the Guntur District, the current study uses multi-temporal satellite data together with statistical models to map and track LULC change patterns and forecast urban growth in the years to come. With the aid of our research, we also attempted to illustrate how urban sprawl affects the ecosystem. Using Landsat satellite data from 2007 to 2021, modelling of long-term LULC and urban spatial change was done. The assessment of the outcome showed that increase in urban built-up areas favored a substantial decline in the agricultural land and rural built-up areas, from 2007 to 2021. The analysis of the results revealed that, between 2007 and 2021, a growth in urban built-up areas significantly outweighed a decrease in agricultural land and rural built-up areas. Based on the statistics for land-use change, Shannon's entropy index was also employed to gauge the spatial growth trends over time in the research area. ArcGIS software was used to predict the land-use expansion of the study area for the years 2028, 2035, 2042, and 2049 using an artificial neural network algorithm. The simulation model's findings indicated that the proportion of urban built-up regions will rise by 26.26% by 2028, 55% by 2035, 81% by 2042, and 104% by 2049. According to the findings of the current study, the predicted LULC map of the area will be valuable information for policy and decision makers for sustainable urban development and natural resource management in the area for food and water security. This conclusion is based on the long-term classification of satellite data, statistical methods, and field survey.

Keywords: LULC change, Urban sprawl, Landsat images, Shannon entropy, Guntur District.

1. Introduction

Urbanization is one of the most important factors influencing LULC change in terms of human population and economic growth (Weng 2001). The rapid population expansion in metropolitan centers, particularly in emerging nations, is one of the biggest problems facing government planning organizations and decision-makers globally. Urban sprawl, which results from cities expanding their limits to accommodate the growing population pressure in urban areas, is caused by population growth (Hassan et a1. 2016). To avoid issues with ecosystem imbalance and to promote sustainable development, the detrimental effects of the spatial expansion of metropolitan areas on natural resources must be reduced (Burgess and Jenks 2002).

The main issues with rising urbanization and changes in LULC are the negative social, environmental, and economic repercussions (Buiton 1994; EEA 2006; Hasse and Lathrop 2003). Large-scale urban development may encroach upon and change nearby natural areas, such as croplands, marshes, and woods (Xu et al. 2001). Therefore, for urban planners and decision-makers to achieve a more sustainable urban expansion, effective and efficient land-use planning is required.

Urbanization is an unavoidable phenomenon, but there are ways to manage natural resources sustainably while also meeting human needs through wise land-use planning (Soffianian et al. 2010). Accurate mapping and monitoring of urban expansion are rapidly becoming more important globally (Guindon and Zhang 2009). Over a number of years, as these issues with increased urban growth worsened, new procedures and strategies for achieving a more sustainable urban form by observing and studying the process of urban expansion and its issues were developed (Ewing 1997; Kushner 2002; Shaw 2000; Jenks and Dempsey 2005). Planning urban landscapes provides numerous environmental advantages. Planning an urban landscape entails making decisions about how urban land will develop in the future. It is necessary to foresee how the land has changed over time, as well as the impacts of both natural and human forces. Effective and sustainable landscape planning studies are possible in this way.

Traditional surveying and mapping approaches took a long time and were expensive, thus alternative statistical methods, combined with remote sensing and GIS capabilities, have been employed as an effective replacement for measuring urban sprawl (Yeh and Li 2001; Punia and Singh 2011; Sudhira et al. 2004). If used with the proper technique and sufficient knowledge, these strategies have proven to be effective for mapping, monitoring, and predicting urban growth and LULC change (Yeh and Li 1997; Masser 2001; Jat et al. 2008a; Belal and Moghanm 2011; Butt et al. 2015; Singh et al. 2015; Dadras et al. 2015; Epsteln et al. 2002; Haack and Rafter 2006). Land cover is one of the most important data used to determine the effects of land-use changes, especially human activities. Creation of land-use maps can be done by using different methods on satellite images. Several studies have been conducted to generate land-use/land-cover mapping using variety of techniques and models over Landsat satellite imagery (Yang et al. 2012; Tian et al. 2011 ; Castella and Verburg 2007). By using land-cover maps, the changes in urban development and green cover over time have been assessed. At the same time, the association between changes in the land cover over time and changes in the urban population has been scrutinized (Cetin 2015a, b, c, d; Cetin and Sevik 2016a, b; Cetin 2016a, b; Cetin et a1. 2018a, b; Yucedag et a1. 2018).

Noteworthy work has been carried out using remote sensing, GIS techniques and Shan- non entropy method for the assessment of urban expansion trends (Sun et a1. 2007; Sudhira et al. 2004; Sarvestani et al. 2011; Joshi et a1. 2006). Shannon's entropy is an information system-based method. It acts as a symbol of spatial distribution and can be useful to explore geographical units. It is a statistical method where spatial and temporal changes over an area are considered to measure urban expansion patterns (Gar-on Yeh and Xia 1998). It can likewise express the level of urban sprawl by investigating whether the land development is discrete or dense (Lata et al. 2001).

Since the majority of the metropolitan cities in India are situated in the core of fertile agricultural lands, understanding and monitoring the urban expansion and LULC change is important. It is also helpful for the city organizers and chiefs to take the judicious decision for future development (Simmons 2007; Sudhira et al. 2004; Singh et al. 2017). Kikon et al. 2016 and Sarkar et al. 2017 has carried out an important work on impact of urbanization and its effect on urban temperature and water resources of Guntur District based on remote sensing data. They found that large-scale LULC change and climate variations in the study area are the major causes of rising trend of temperature and development of impervious surface area over the last 2 decades. Very few studies have been reported on the present study area based on long-term land-use change and urbanization and its effect on agriculture and urban growth prediction. In the present study we showed how the future land use land cover changes interlinked to urban sprawl and agriculture.

2. Study area

Guntur is situated in Andhra Pradesh along the east coast of the Bay of Bengal. The Guntur city is located in between the latitudes 15°18′N to 16°50′ N and the longitudes 79°10′E to 80°55′ E, covering an area of 11,328.23 km^2 (Fig. 1). Guntur district comes under a semi-arid climate having a maximum temperature up to 450 C during summer and a minimum temperature of 170 C during winter. The mean annual rainfall is about 900 mm. Most of the rainfall occurs during the monsoon period (July to September).

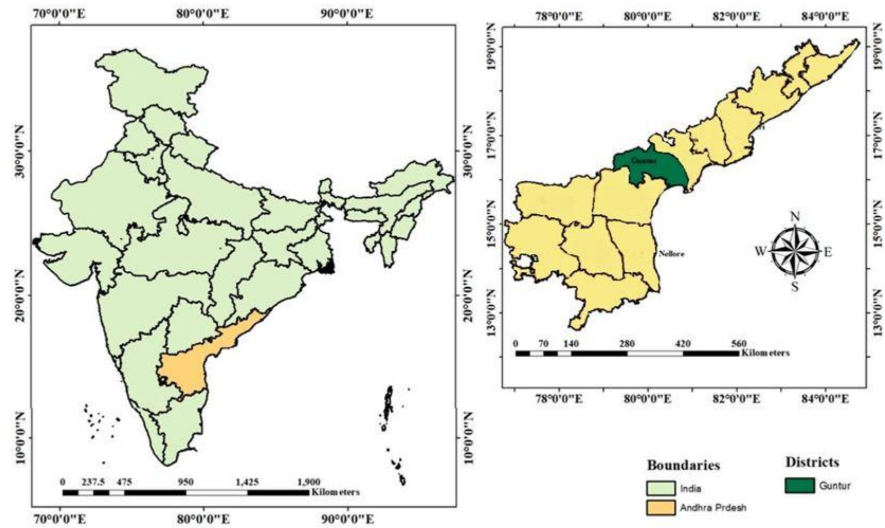

Figure 1. Study area map with the state boundary

3. Methodology

Collected maps and images were sorted and classified for analysis and interpretation. Classification was performed based on the Landsat image from USGS earth explorer (2007, 2014 and 2021) were employed in this study to produce land use/cover categories of 2007 and 2021 respectively. Arc GIS and Erdas Imagine software were used to device land use/cover classification in a multi-temporal approach. All the enhanced images were then subjected to image classification. The maximum likelihood classifier, minimum distance classifier and Mahalanobis classifier in case of supervised classification and Isodata clustering in case unsupervised classification were used for classification of the Landsat images using ERDAS IMAGINE 9.1. Five land-cover classes were recognized in the study area, namely urban built up, rural built up, wasteland, agricultural land and water body.

Further, accuracy assessment for each classification method is necessary for an effective exploration of LULC change (Butt et a1. 2015). Thus, to decide the nature of extracted data from the image, classification accuracy of all different methods of classification was performed on Landsat image of 2016 using ERDAS Imagine 9.1. Further, based on error matrix (Congalton and Green 1999) and field verification using the accuracy of LULC maps was portrayed. According to accuracy statistics, namely the overall accuracy (92.49), user's accuracy, producer's accuracy and Kappa coefficient (0.883) as per error matrices, supervised classification using Mahalanobis classifier was selected and used to classify the images of the study area for 2001 and 2010. As indicated by Anderson (1976), 85%, as a minimum precision esteem is worthy. The detail methodology followed in the present work is shown in Fig. 2.

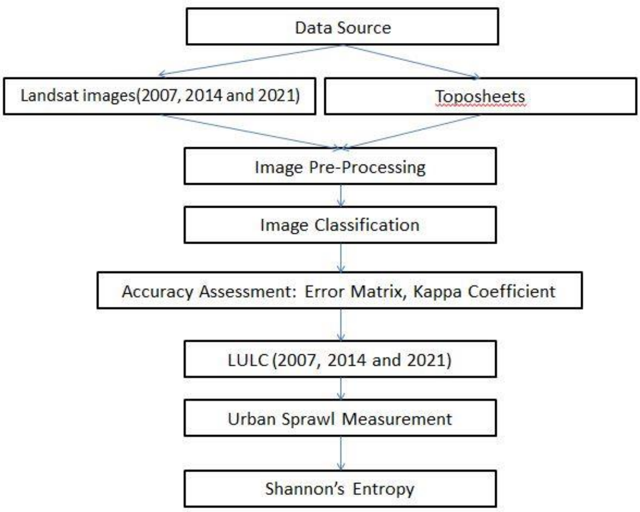

Fig. 2 Methodology followed in the present work

3.1 Change detection

Change detection was carried out post-classification and accuracy assessment. The best classified images were selected for performing the LULC change detection in two intervals (i.e., 2007—2014 and 2014—2021). A pixel-based comparison method was used to produce the changes in information using ArcGIS 10.2, and further, this changed information was used to efficiently interpret the variations in land-use classes. Classified image pairs of year 2007—2014 and 2014—2021 were compared using the cross-tabulation to determine the qualitative and quantitative aspects of the changeover years.

3.2 Urban sprawl measurement

Urban expansion over the time of 2001—2016 was examined utilizing Shannon's entropy with the assistance of GIS methodologies. Shannon's entropy is one of the most frequently employed and efficient methods for observing and evaluating urban expansion (Jat et a1. 2008b; Sarvestani et at. 2011; Punia and Singh 2012). It helps in understanding the level of compactness and dispersion of a land-use class (urban built up in the present study) among 30 spatial units (Theil 1967; Thomas 1981). Shannon's entropy is measured as mentioned below:

$$H_n = -\Sigma P_i \mathrm{Log}(1/P_i) \qquad \text{eq (1)}$$

where P_i is the probability of the urban built up within the districts. The Shannon's entropy of an area ranges between 0 and Log(n), where n is 30, i.e., total number of zones in which the district was divided. The value towards zero depicts higher density urban growth, while values towards 'log n' specify scattered distribution of urban built-up areas. The multiple ring buffer tool of ArcGIS was employed to define zones from the top of the district along with density data. The area divided into 30 zones with a radius of 2.5 km used to measure the urban sprawl.

4. Result and discussion

4.1 LULC change analysis

The investigation of LULC variations in view of change detection and landscape measurements has uncovered that during 2007—2021 (Fig 3 to Fig 5), the developed region was expanded, The unexpected expansion of urban developed regions not just brought about the discontinuity of crop land, but also decreased the productivity of crop and groundwater resource due to reduction in surface recharge area. Ultimately, it caused a serious problem for food and water security.

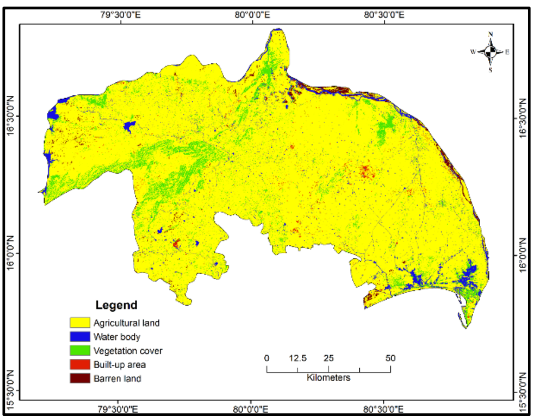

Fig 3 Land use land cover map of Guntur (2007)

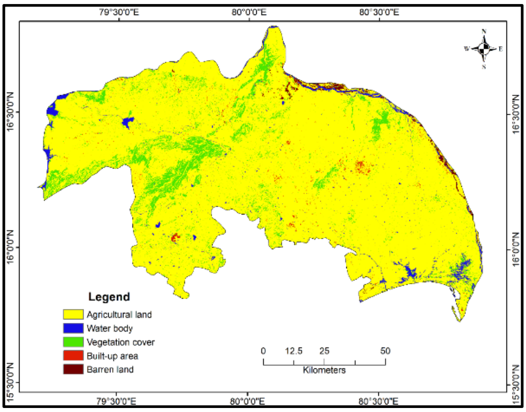

Fig 4 Land use land cover map of Guntur (2014)

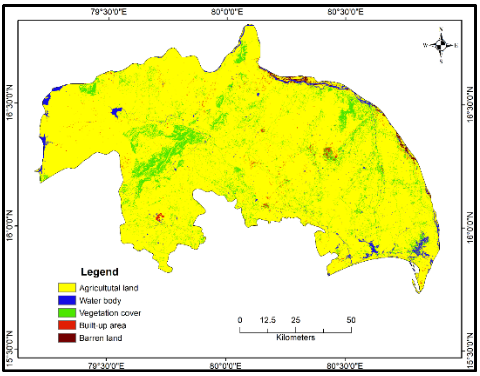

Fig 5 Land use land cover map of Guntur (2021)

4.2 LULC prediction modeling

LULC maps of 2007 and 2014 were identified as input data to predict 2021 land use, according to the analysis during the study, the land-use change will reach to extreme in 2028, 2035,2042 and 2049 and urban area will increase and occupy 26%, 55%,81% and 104% of the district's area, respectively. However, cultivated land will decrease, respectively, year after year, resulting in potential loss (Table 1). The future predicted map is shown in figure 6 to 9 is prepared using ANN technique.

Table 1 Land use land cover in different year in Km^2

	Land use land cover in different year in Km^2						
Class Name	2007	2014	2021	2028	2035	2042	2049
Agricultural land	9952.80	9984.40	10015.39	10075.60	10114.50	10157.50	10202.20
Water body	354.84	332.34	285.64	197.37	134.22	91.51	43.12
Vegetation cover	891.92	881.84	820.55	805.44	783.04	726.63	680.90
Built-up area	79.37	90.98	226.70	285.98	350.85	409.64	461.72
Barren land	126.18	115.54	56.42	39.69	22.33	19.45	16.86

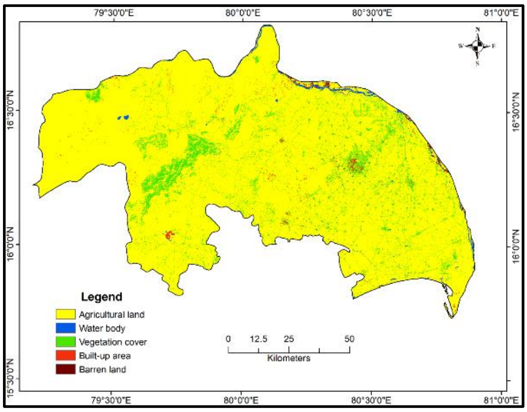

Fig 6 Land use land cover map of Guntur (2028)

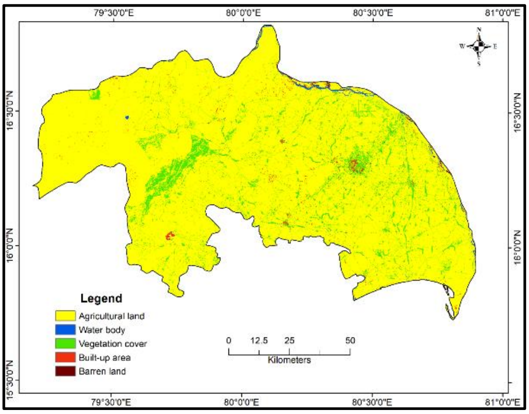

Fig 7 Land use land cover map of Guntur (2035)

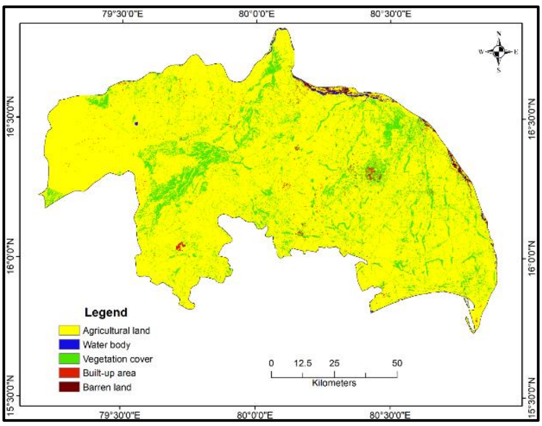

Fig 8 Land use land cover map of Guntur (2042)

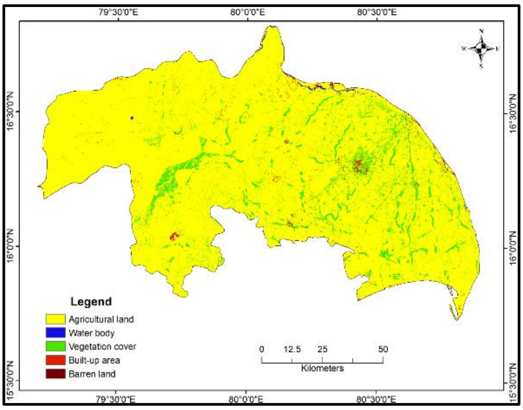

Fig 9 Land use land cover map of Guntur (2049)

5. Conclusions

The extensive use of temporal satellite image along with statistical tools is one of the promising methods for long-term LULC analysis and change assessment for monitoring of urbanization and natural resources. The results observed from the present study for LULC change analysis and its future growth prediction using GIS model for 30-year period will be very useful database for future urban planning and sustainable management of natural resources of the area. The satellite data combined with Shannon entropy method go about as a good indicator to identify and calculate the spatial reaches of land development at both local and regional levels. Change detection analysis exposed that the urban built-up area has increased persistently over the last 15 years and agriculture land, and rural areas have decreased constantly. The unexpected urban sprawl has led to the loss of agriculture land and rural built-up land, from 2007 to 2021. The future scope of the present study is to develop an appropriate management of natural resource management plan using fine-resolution satellite images and use of socioeconomic parameters for any developmental program in the area.

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