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Three decadal land use and land cover changes in the Cauvery river Basin, India

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ABSTRACT

The Cauvery river basin is one of the most agriculturally intensive basin, has been facing water shortage and climatic variations in the last decade. To understand the influence of human interventions on the natural environment, it is essential to critically examine the changes in land use and land cover over the decades. The objective of this study is to assess land use and land cover change in the Cauvery river basin, for the last three decades using LANDSAT series satellite images. The changes in land use and land cover change were mapped and computed using geospatial techniques. The multitemporal LANDSAT images were classified by supervised maximum likelihood method to generate the corresponding land use/cover maps; the post-classification technique subsequently detected changes in land use and land cover in the river basin. The results of the study revealed a drastic decrease in forest and grassland due to urbanisation, agricultural expansion and other anthropogenic activities.

Key words: *Cauvery river basin, Land use and land cover change, Supervised classification, Forest degradation, River basin management*

Introduction

Understanding the changes in Land Use and Land Cover (LULC) is one of the critical components in managing the river basin. The LULC pattern of a region is a result of both natural and anthropogenic activities influenced by environmentaland socio-economic factors (Debnath *et al.*, 2017; Sundarakumar *et al.*, 2012). LULC is under immense pressures for anthropogenic activities such as agricultural expansion, forest logging, commercial plantation, mining, industry, urbanisation and road building, etc. (Dubovyk, 2017; Geist and Lambin, 2002; Pawe and Saikia, 2018). Further, LULC change has a substantial impact on the world's ecosystems (Polasky *et al.*, 2011). Therefore, information on LULC and possibilities for their optimal use is essential for the selection, planning and implementation of schemes to meet the increasing demands for basic human needs and their welfare. Over the past years, data from remote sensing satellites have become critical in representing the earth's features, managing natural resources and analysing environmental change (Sreenivasulu *et al.*, 2013)

The changing patterns of LULC and their driving factors have been studied in different countries at various scales. In India, the changing patterns of LULC with the decrease in forest cover, expansion of cropland and increase in built-up areas have been identified from 1880 to 2010 (Tian *et al.*, 2014). In another study on LULC changes in India (Roy *et al.*, 2015), a significant increase in built-up areas and cropland and decrease in fallow land, forest and wasteland have been identified during 1985 to 2005 using satellite images. In a similar study in North-east China (Shen *et al.*, 2009), changes in built-up, cropland, forest, grassland and wetland were analysed from 1970 to 2004 that highlighted the effectiveness of forest and wetland protection and restoration projects. A decrease in ecosystem services value was found in Su-Xi-Chang region of Yangtze river delta, East China, due to the loss of cropland and water bodies by urban expansion (Yirsaw *et al.,* 2016). In Bonsa catchment of Ankora river basin in Ghana, West Africa, land cover transitions from 1986 to 2011 showed that increase in population growth, agriculture expansion and increased surface mining activities were responsible for increased deforestation rate (Aduah *et al.,* 2015). In Poland, the effect of LULC on the ecological quality of rivers was analysed, which showed a decline in the population of bryophytes due to the loss of forest (Zgola, 2014). Human-induced LULC changes were revealed in the Kagera Basin of Lake Victoria (Wasige *et al.*, 2012). Role of socio-economic and physical drivers on land degradation was identified in Vietnam (Vu *et al.,* 2014). It is difficult to link the drivers of LULC change in a heterogeneous landscape because of uncertainty associated with misclassification and availability of data atdiverse scales (Alvarez Martinez *et al.*, 2011). LULC change is dynamic in nature, and it is difficult to obtain real-time information on LULC change through conventional methods. Satellite remote sensing, along with GIS that can bring different types of data at one platform for analysis has brought a new dimension to study LULC changes at varied scales (Wang *et al.,* 2012). Collection of remote sensing data facilitates the synoptic analysis of earth-system function, patterning, and change at local, regional and global scales over time (Amin and Fazal, 2012; Rajeshwari, 2006). As such, utilisation of multispectral-multitemporal remote sensing data has been widely used to generate thematic LULC inventories for a range of applications including urban planning, agricultural crop characterisation, forest ecosystem classification and also for the identification of LULC change drivers (Aguirre-Gutiérrez *et al.,* 2012; Dewan and Yamaguchi, 2009; Duraisamy *et al.*, 2018; Khorram *et al.*, 1987; Mishra *et al.*, 2019; Sharma *et al*., 2019). Despite having such importance, there are very fewer attempts to study the LULC in the Cauvery river basin. Thus, this study aims to understand three decadal LULC changes in the Cauvery river basin, India

Study Area

The Cauvery Basin lies between 75°272–79°542 East longitudes and 10°92–13°302 North latitudes (Fig. 1) and extends over the States of Tamil Nadu, Karnataka, Kerala and Union Territory of Pondicherry. It is draining an area of 81,155 km^2 that forms 2.7% of the total geographical area of the country. It has a maximum length of about 560 km and width of 245 km. It is bounded by the Western Ghats on the west, by the Eastern Ghats/Bay of Bengal on the east and the south and by the ridges separating it from Krishna Basin and Pennar Basin on the north.

Methodology

Multi-temporal satellite images were used to develop the LULC thematic maps of the catchment

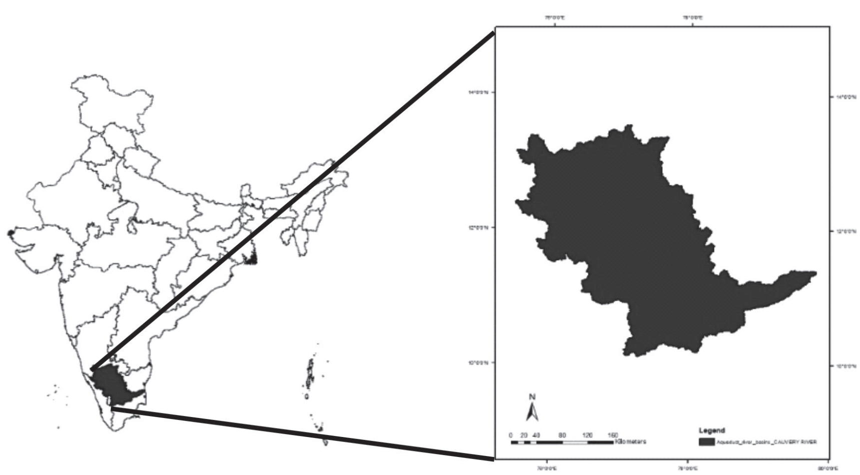

Fig. 1. Map of the Cauvery River Basin

from the historical land use/cover change pattern. The LANDSAT series multi-temporal satellite images of the study area were obtained from the official website of the US Geological Survey (https://earthexplorer.usgs.gov/). The details of the images obtained are presented in (Table 1). The False Color Composite (FCC) images were prepared for classification. The LULC classification criteria for the study area were formulated on modifying the IGBP (International Geosphere-Biosphere Programme) LULC classification scheme (Loveland and Belward, 1997). The supervised maximum likelihood approach was adopted to develop LULC maps of the Cauvery river basin. In this approach,

Initially, a set of pixels (training areas) belonging to each LULC class was identified. From the training area, the spectral signature of each land use/cover class was determined. Then, every pixel in the image was compared with the training samples to evaluate its closeness to a particular LULC class, and classification of the pixels was performed based on this. This classification is based on the assumption that the training samples in the training areas are normally distributed. From the images, ten LULC classes were identified viz., Cropland, Plantations, Built-Up, Shrubland, Grassland, Barren/Waste Land, Water Bodies, Mixed Forest, Deciduous Forest and Evergreen Forest. The accuracy of the LULC classification was assessed by two commonly used indices, viz., overall accuracy and Kappa coefficient. Overall accuracy is the ratio between the number of correctly classified pixels and the total number of reference points considered for validation. The basis of Kappa coefficient analysis is the error matrix; it shows the extent of agreement between the remotely sensed classification data with the reference data.

Land Use/ Land Cover Change Detection

Change detection was performed to recognise the changes that had occurred within the identified LULC classes in the study area over time. In this study, an apparent method of change detection the post-classification comparison was employed. In this method, independently derived LULC maps are compared, and the changes that have occurred within the catchment are detected. This method brings out LULC class transitions in the basin in the form of a matrix. Hence, we can obtain the transitions within and between the categories. The loss and gain of each category due to transition can bedetermined.

Table 1. Satellite data used for LULC mapping.

Period	Satellite	Spatial Resolution	Sensor
1985	Landsat 4	80 m	MSS
1985	Landsat 5	30 m	LISS I
2005	Landsat 5	30 m	LISS III
2015	Landsat 8	30 m	OLI and TIRS

Results and Discussion

The LULC maps of the catchment were derived through the supervised maximum likelihood classification. These maps help to identify the LULC change pattern visually and to quantify the changes. The LULC maps of the study area for the years 1985, 1995, 2005, and 2015 are presented in Fig. 2 and Table 2.

Results of accuracy assessment of the classified images show that the overall accuracy is higher than 85%, and the Kappa coefficient is greater than 0.8. These two indices indicate that the derived LULC map is in reasonably very good agreement with reality (Monserud, 1990).

The LULC analysis revealed that the basin is dominated by cropland and plantations, which cover 51.34% and 14.15% land area, respectively. The built-up area in the basin is rapidly growing and occupies 6.04% of the basin area. The deciduous, evergreen, mixed forest occupies 12.75%, 5.17% and 1.69% areas respectively. Shrubland and grassland occupy 3.12% and 1.39%. Water bodies and waste/barren land occupy 3.53% and 0.82% of the land area.

The post-classification comparison technique clearly shows they are at hath as under gone transition from one LULC class to another. The change matrix clearly shows the transition that has occurred between each LULC during the time interval of each decade (Fig. 3).

LULCanalysis of the basin shows that the accelerated developmental activities implemented resulted in a drastic and complicated LULC transition. During the period 1985–2015, the noticeable changes that were observed in the basin were the expansion of built-up-land and the shrinkage of plantations, mixed forest, and grassland. In the first decade 1985-1995, agriculture and built-up land increased by 1.33% and 0.54%. The area under the plantations and forest area reduced over three decades. There

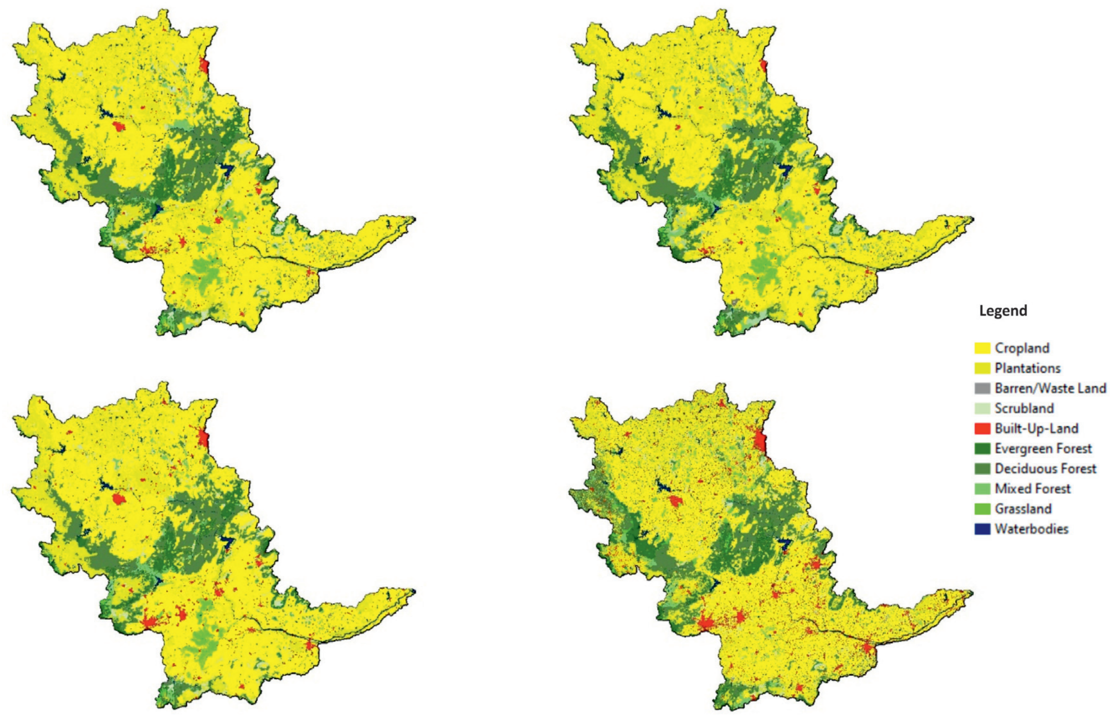

Fig. 2. LULC maps for the Cauvery river basin 1985 (Top-Left), 1995 (Top-Right), 2005 (Bottom-Left) and 2015 (Bottom-Right)

Table 2. Area of LULC classes in 1985, 1995, 2005 and 2015

Land Cover Type	1985 (Km²)	%	1995 (Km²)	%	2005 (Km²)	%	2015 (Km²)	%
Deciduous Forest	961287	12.27	945844	12.08	910604	11.63	998502	12.75
Evergreen Forest	358448	4.58	342112	4.37	330066	4.21	404570	5.17
Mixed Forest	206206	2.63	180305	2.30	164162	2.10	132503	1.69
Cropland	4115052	52.54	4219035	53.87	4323506	55.20	4021098	51.34
Plantations	1381912	17.64	1377282	17.59	1348696	17.22	1108443	14.15
Grassland	158694	2.03	145536	1.86	128353	1.64	108478	1.39
Shrubland	286392	3.66	226950	2.90	217744	2.78	244641	3.12
Built-Up-Land	68320	0.87	110592	1.41	179818	2.30	472814	6.04
Water Bodies	208213	2.66	210262	2.68	202429	2.58	276580	3.53
Barren/Waste Land	87447	1.12	74053	0.95	26593	0.34	64341	0.82

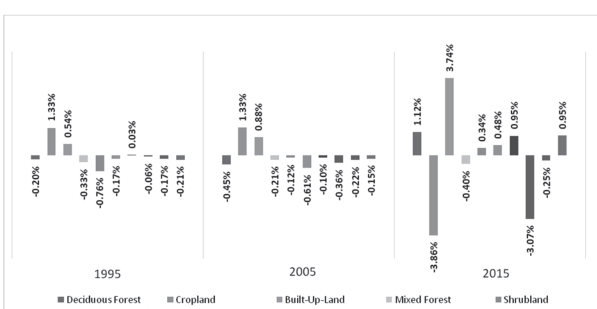

Fig. 3. Change Matrix for the year 1995, 2005 and 2015

was encroachment in both deciduous and evergreen forests. Similarly, grassland areas have been reduced due to fire and grazing. Shrubland and mixed forest were converted into cropland. In the second decade 1995-2005, a similar trend of conversation of forest land into cropland and built-up-land was noticed. Such, similar trends are seen in the studies done at riparian scale in the basin (Deepthi *et al.*, 2019; Sunil *et al.*, 2010). Later during 1980-2000, massive afforestation programme has been undertaken in the form of the social forestry programme in the basin. Subsequently, restoration and protection were given priority.

Conclusion

LULC change is a major factor that adversely affects the physical, chemical, and biological characteristics of a river basin. The drastic LULC change that occurred in the Cauvery river basin, between 1985 and 2015 shows that natural forest diminished due to anthropogenic factors such as agricultural expansion, grazing and forest fire in the river basin. The river basin had abundant water resources in the earlier decades; however, population explosion and over-exploitation of water by industries and for the agricultural purposes increased the pressure on water resources, making it water-stressed since 1995.

The urban developmental pattern of the river basins shows the rapid growth of Tire-I and Tire-II cities, primarily because of enhanced transportation facilities and waterbodies, leading to habitat fragmentation. Various factors, such as socio-economic and water utilisation patterns, have to been taken into account to identify sensitive regions. This also calls for the formulation and implementation of sustainable watershed development policies for the conservation of natural resources in the basin.

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