GEOGRAPHICAL ANALYSIS

RESEARCH ARTICLE

Land Use Analysis in Arkavathy Watershed of Karnataka, India Using Remote Sensing and GIS

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Abstract

According to FAO, World's 33% of land has been degraded and continue to degrade even in the future. At the same time, world's population has crossed 8 billion putting more stress on land resources. Rapid urbanization, industrialization, infrastructure development has led to shrink earths land resources. There is huge challenge how the existing land has been used in logistic way. Bangalore which is one of the fastest rising metropolitan hubs in the world is facing major crisis regarding land use. The Arkavathy river that flows through Bangalore Metropolitan is also facing the difficulties in scientific use of land. The watershed lies in the western part of Bangalore Metropolitan Region in Karnataka. Land-Use change has a noteworthy influence on watershed developments such as hydrology, soil loss, carbon confiscation, etc. Hence, the study emphases on the Land use of Arkavathy watershed of Karnataka, India. This study tries to attempt and highlight the change in Land use of the watershed in last three decades. The drastic change in the watershed in last few many years has wider ramification on the environment on regional scale. Multispectral satellite data obtained from Landsat 4 for 2001, IRS P6 LISS IV for and Sentinel-2 for 2018 to classify the watershed. The watershed has been classified into six major classes viz. Agricultural Land, Forest or vegetation cover, Built-up, Wastelands, grazingland and waterbodies. The overall, set-up presented by the study discloses that the land use change is quite visible throughout the study area.

Keywords: Land use; watershed; Change; development

Introduction

Land use and land cover (LULC) are intrinsically tied to ecological and social dynamics. Still, classifying LULC in ecotones, where landscapes are commonly heterogeneous and have a wide range of physiognomies remains a challenge. Land use is a term used for the change of the earth terrestrial surface by humans, mostly the results of an interaction between natural and anthropogenic processes [1,2]. Since forestry and agriculture is the predominant user of land, their quality (soils) and quantity (area) is directly related to the nature of landforms. The main reason behind the LU/LC changes includes rapid population growth, rural-to-urban migration, reclassification of rural areas as urban areas, lack of valuation of ecological services, poverty, ignorance of biophysical limitations, and use of ecologically incompatible technologies. The change in the LULC can be attributed to various natural and man-made factors the most of which are related to human activities such as urbanization, Intensive agriculture, deforestation, overgrazing etc. The changes may be due to complex interactions between various social, economic and biophysical elements of a system[3]. Evaluating LULC change at varied spatial scales is imperative in wide range of perspectives such as environmental conservation, resource management, land use planning, and sustainable development. Land use changes during the past couple of decades are mostly linked to agricultural development attributed to factors such as population pressure and environmental changes. Mapping land use/land cover (LULC) to analyze the type, rate, and extent of changes in land use patterns has far-reaching significance for policy/decision makers and resource managers to provoke the wide range of applications at regional scales for erosion, landslide, land planning, forest management, and ecosystem conservation. Changes in landuse or human imprint on the land surface are usually accompanied by a corresponding change in the biophysical environment or land cover. The status of LULC of a particular region reflects the natural and socio-economic factors of that region and their utilization in terms of time and space.[1] The spatial distribution of land use and its patterns of change are prerequisite to design and develop effective and efficient land use policies related to the use and management of the resources. Landsat satellite is a major data source for regional to global LULC analysis. Owing to its technical advantages of wide coverage, abundant information, multi-resolution, and multi-temporal observation, remote sensing technology has been widely used for monitoring and analyzing land-cover changes, urban growth, and geographic processes. The traditional methods of evaluation, including referencing of images and topographic sheets for stratifying vegetation result in errors and subjectivity in interpretation. Such interpretation discrepancies can be solved by applying recent approaches of using digital satellite data with digital terrain modeling for classification of vegetation[4]. The urbanization process has led to chaotic growth in city, deteriorated the living conditions and has worsened the environmental scenario having detrimental impacts on human health. Therefore, it is required to determine the rate and trend of land cover/use conversion for devising a rational land use policy. An LUCC analysis using long-time-scale land-use data is effective for determining the major land-use conversion and provides useful information for planners and policymakers. Human-induced land use/cover change has been considered to be one of the most important parts of global environmental changes. Land use/land cover process is influenced from both natural and anthropogenic sources. Human impacts, on the other hand, are of primary concern due to larger commitment to LULC dynamics.

Bangalore which is one of the fastest rising metropolitan hubs in the world is facing major crisis regarding land use. The Arkavathi River that flows through Bangalore Metropolitan is also facing the difficulties in scientific use of land. The watershed lies in the western part of Bangalore Metropolitan Region in Karnataka. Land-Use change has a noteworthy influence on watershed developments such as hydrology, soil loss, carbon confiscation, etc.

Study Area

Arkavathy River originating in Nandi hills of Chikkaballapur district, Karnataka State is a tributary of Cauvery river which joins main Cauvery river after flowing through Ramanagara and Kanakapura districts. The Arkavathy watershed spans about 3833 sq. km on the western part of Bangalore city of Karnataka. Its latitudinal and longitudinal location is 12° 21'N and 77○ 10' E. The watershed contains a mixture of built-up, natural, and agrarian land uses. The watershed can be divided into eight sub watersheds and three major tributaries of Arkavathy that are (Kumudavathy, Vrishabhavati, and Suvarnamukhi), and five other sub watersheds identified by reservoirs or geographic area (Hesaraghatta, TG Halli East, Manchanabele, Kanakapura, and Harobele). The major reservoirs in the watershed differ from the tanks in that they are actively managed, providing water for urban and agricultural water users. For this reason, we focus our analysis of hydrological change on the behaviour of tanks.

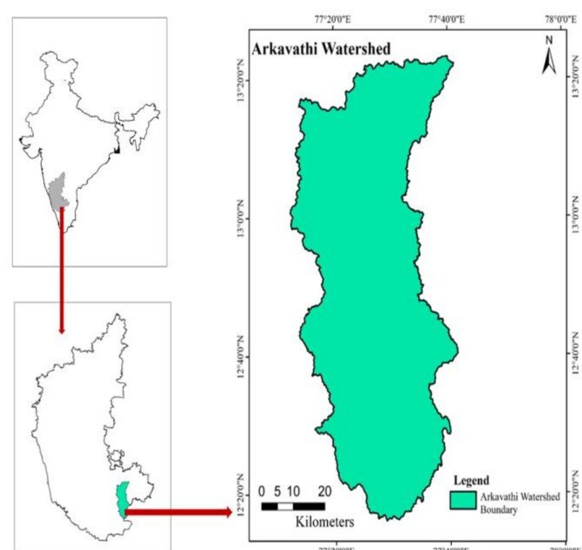

Fig. 1. Location map of Arkavathy watershed

Materials and Methods

Data acquisition and preparation

The methodological framework for the present study encompasses interpretation of satellites imageries followed by ground truthing and ancillary information for final analysis. Multi-temporal satellite images and Cartosat Digital Elevation Model (DEM) were used to develop the future land use/cover thematic maps. 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/). Table 1 shows the details of the images that were obtained.

Table 1. Satellite Image Characteristics

Year	Sensor	Date	Spatial resolution	Source
1991	Landsat TM	1991_3_16	30m	USGS
2001	Landsat TM45	2001 3 03	30m	USGS
2011	Landsat TM45	2011_3_07	30m	USGS
2021	Landsat 8	2021_3_02	30m	USGS

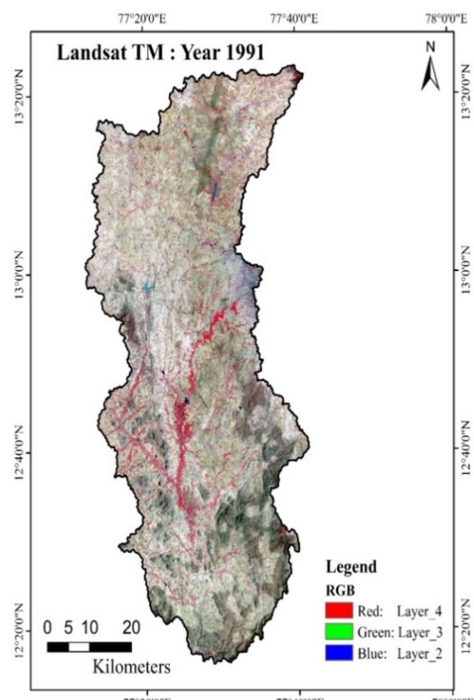

Fig. 2. Landsat Thematic Mapper (1991)

Misleading Color Composite (FCC) photographs were used for supervised classification to decrease issues with visual perception of land use/cover classes training regions.

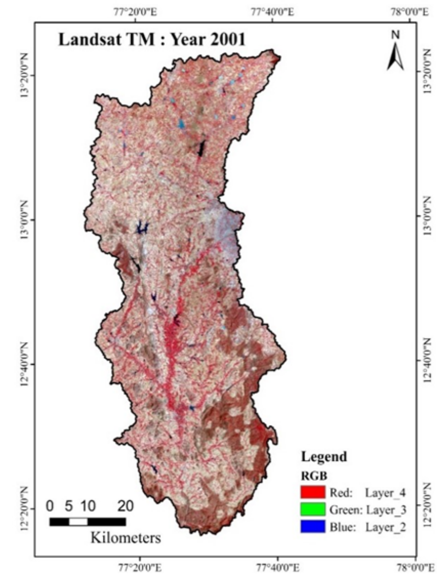

Fig. 3. Landsat Thematic Mapper 4, 5(2001)

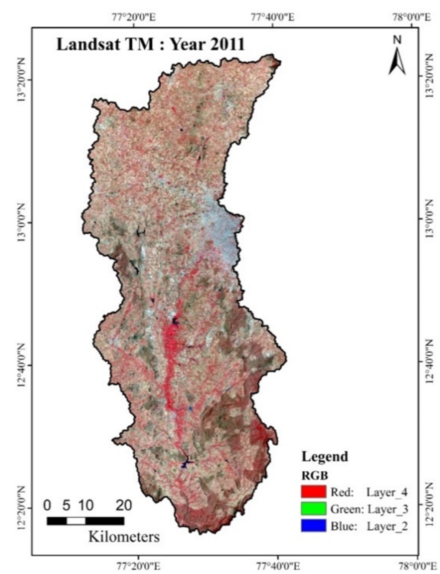

Fig. 4. Landsat Thematic Mapper 4, 5(2011)

The input data was pre - processed and prepared for land use/cover prediction using ERDAS Imagine and ArcGIS software. "Landsat imagery is recommended for its good precision and near and mid-infrared bands, that also enable detailed analysis of vegetative cover and landscapes". The images were chosen based on their availability and quality from four cloud-free ETM+ for 1991, Landsat 4, 5 (TM) for 2001, Landsat 4,5 (TM), and Landsat 8 satellite data for 2021. Image enhancement, Extraction, georeferencing, layer stacking (band selection and combination), topographic correction, were among the standard image processing

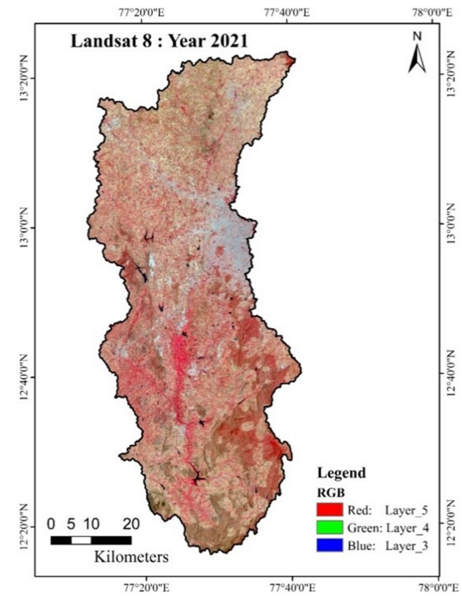

Fig. 5. Landsat 8 (2021)

techniques used.

Flow Chart

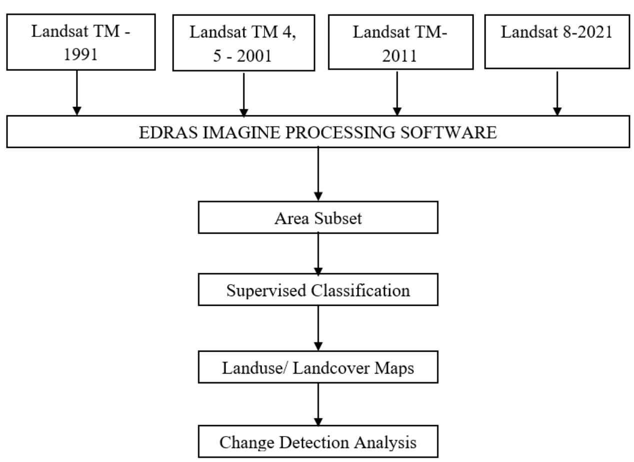

Fig. 6. Flow Chart of Methodology for Landuse/Landcover and change detection

Image Classification

The USGS Level 1 Land Use/Land Cover classification method was employed in this study. Six unique classifications were utilized to order the research region. The classes are depicted top to bottom in Table 2. These classes were distributed to pixels in picture order. Surface, tone, and shading were utilized to make each class. Utilizing multi-worldly Landsat photographs of the review region, land cover types were considered and arranged.

Table 2. NRSC Landuse Landcover Classification Scheme

Sl. No	LULC class Description	LULC class Description
1	Agricultural land	Agricultural lands, both cultivated and uncultivated, such as farms, cropland, horticultural lands, agro horticulture plantations
2	Built-up land	Transportation, Road Networks, Industrial and Commercial Infrastructure, Educational Institutions, Concrete and other man-made structures
3	Forest	Protected vegetation's, plantations, mixed forest lands, deciduous tress
4	Grassland	It includes natural/semi-natural grass/grazing lands and manmade grasslands.
5	Wastelands	Areas with or without sparse vegetation's, barren rocks, active excavations, degraded soils. Underutilized and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes
6	Water bodies	Rivers, ponds, streams, lakes, reservoirs, tanks

Post –Processing and Change Analysis

Following the supervised characterization, the essential post-processing was finished. The LULC change study was assessed using pair-wise correlation and weighted overlay in the Arc GIS 10.3 environment. In light of the ground approval, the proper alterations and changes have been performed. To investigate the primary changes, the region in hectares and rate changes somewhere in the range of 1991 and 2001, 2001 and 2011, and 2011 and 2021 were measured for each LULC type. On account of their minimal expense and excellent temporal resolution, remote detecting and GIS-based change recognition approaches are generally utilized. The post arrangement examination approach, which depends on greatest probability directed order, is the most broadly involved technique for distinguishing LULC changes. The post-characterization comparison procedure includes arranging photographs and endeavoring to contrast the connecting classes all together with recognizes districts of progress.

Results and Discussion

LULC Change Analysis

Horticulture, Waste Land, Built up Land, Forest Land, and Water Bodies were characterized as Land Uses in the arrangement layout delivered. Out of 4160 sq. km of the watershed the agricultural land is the most dominant category which covers more than 48.38 % of the watershed. The next dominant class in the watershed is the forest cover area which covers about 39.54 % of the watershed. The built-up area tends to be increasing from 2.8 % to 10.20 % over last few decades whereas forest cover shows very minute fluctuations in the past few years. Grassland also showed a declining trend from 0.19 % to 0.09 % of the watershed. Whereas the major category of the watershed i.e. water bodies increased from 0.42% to 1.05%.

The Table 2, below shows the areas of coverage of various categories of land use in the watershed from 1991-2021. The agricultural land seemed to decline in last 40 years gradually. The agricultural land covers the maximum area of 2253.67 sq. km i.e. 54.17% in 1991 which declined to 2012.18 sq km i.e. 48.38 % in 2021. The change percentage in agricultural land is 5.79%. The highest change is seen in built up land which increased by 7.36% followed by agricultural land which is declined by 5.79 % in the four decade. The grassland or grazing land is seen to have slight change of 0.1% whereas forest cover and water bodies also showed a slight change of 2.54 and 0.63 respectively. The wasteland cover has also detoriated from 229.63 sq. km in 1991 to 37.11 sq. km in 2021. The Arkavathy watershed was subjected to significant land use changes during three time periods (1991–2001, 2001–2011, and 2011–2021), according to the land use trend analysis.

Period 1: 1991-2001

During this period, the coverage of agricultural land was highest which covers an area of 2253.67sq km i.e. 54.17% in 1991 followed by forest cover. Forest covers about 37% of the watershed in 1991 which slightly increased to 37.23% in 2001. On the other hand, both built up area and water bodies have increased by an aerial coverage of 144.9 ha (3.04%) and 17.65 ha (0.42%), respectively. Furthermost, grassland and wasteland declined at an expanse of 1.99 ha (0.04%) and 57.03 ha (1.37%) respectively. Consequently, there was a rapid conversion of agricultural land to build up areas.

Period 2: 2001-2011

The table below shows the change that happened in land use from 2001-2011. In the mid-decade there is a very slight change of 0.72% seen in agricultural land whereas the built-up area is seen to increase every year. A total of 1.45 % built up area has increased in between 2001-2011. There is a slight negative decline of 0.02% and 1.76% is seen in grasslands, wastelands respectively. There is no much change seen in forest cover and water bodies as well. The major land cover in the watershed is agricultural land which covers about 50.73% in 2011 whereas grassland covers the least area of about 4.93 ha. Built up area has increased from 263.44 ha to 323.98 ha. The developed region, which is generally possessed by Bangalore City and is shown in red, is for the most part noticeable on the north eastern side of the watershed.

Table 3. LULC Change per class and decadal rate of change in 1991 and 2001

Categories	1991	%	2001	%	Changes	%
Agricultural land	2253.67	54.17	2140.39	51.45	-113.28	-2.7
Built-up land	118.5	2.84	263.443	6.33	144.9	3.4
Forest	1539.38	37	1549.1	37.23	9.72	0.23
Grassland	8.0622	0.19	6.0741	0.14	-1.99	-0.04
Wastelands	229.635	5.51	172.602	4.14	-57.03	-1.37
Water bodies	17.7282	0.42	35.3709	0.85	17.65	0.42

Source: USGS

Table 4. LULC Change per class and decadal rate of change in 2001 and 2011

Categories	2001	%	2011	%	Changes	%
Agricultural land	2140.39	51.45	2110.4	50.73	-29.99	-0.72
Built-up land	263.443	6.33	323.988	7.78	60.54	1.45
Forest	1549.1	37.23	1588.15	38.17	39.05	0.93
Grassland	6.0741	0.14	4.9563	0.11	-1.17	-0.02
Wastelands	172.602	4.14	99.3744	2.38	-73.23	-1.76
Water bodies	35.3709	0.85	40.1041	0.96	4.73	0.11

Source: USGS

Period 3 (2011-2021)

The results of the year 2021 compared to that of the previous year remained almost constant. The agricultural land declined from 2110.4 ha in 2011 to 2012.18 ha in 2021 whereas the built-up area has increased from 323.98 ha to 424.68 sq. km (10%) in 2021. The agricultural lands, grassland covers and wasteland has showed negative trend with 98.22%, 0.83% and 62.26 % respectively. The wasteland has detoriated from 99.37 ha to 37.11 ha which showed 62.26% of negative decline in wasteland cover. The grassland cover is seen to decline 4.93 ha in 2011 to 4.12 ha in 2021. The grassland covers only a small area in the watershed whereas built up area showed a positive increase in its land cover from years and is still tend to continue. The built-up area has doubled in between 10 years from and the maximum change is seen to be in this class whereas in the last decade grassland and water bodies showed a very minute change in the watershed. The waste lands and grasslands were converted to satisfy the increasing demands of human population.

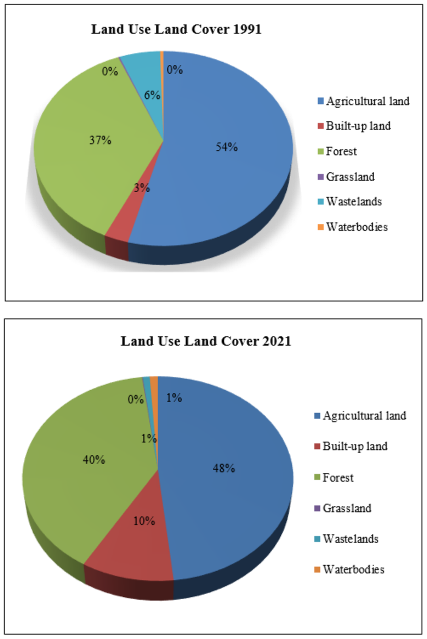

Fig. 7. Pie Charts of Landuse/ Landcover for 1991 and 2021

Table 5. LULC Change per class and decadal rate of change in 2011 and 2021

Categories	2011	%	2021	%	Changes	%
Agricultural land	2110.4	50.73	2012.18	48.38	-98.22	-2.36
Built-up land	323.988	7.78	424.687	10.2	100.07	2.4
Forest	1588.15	38.17	1645.16	39.54	57.01	1.37
Grassland	4.9563	0.11	4.1243	0.09	-0.83	-0.01
Wastelands	99.3744	2.38	37.1142	0.89	-62.26	-1.49
Water bodies	40.1041	0.96	43.7112	1.05	3.61	0.08

Source: USGS

Land Use/Cover Change Detection

The watershed appears to have undergone significant alterations in most land-cover types and years. According to satellite photos of the Arkavathy watershed from 1991 to 2021, agricultural land covers 54.17 percent of the area in 1991, making it the watershed's most populous land cover. But in 2021 the agricultural land cover decline to 48.38% which showed a negative decline of 5.79% in a span of 40 years. The built-up land or the settlement areas have increased by 7.36%. The built-up area is mostly concentrated near Bangalore Metropolitan Region which covered an area of about 118.5 sq. km in 1991 which later increased to 424.68 sq. km in 2021. The forest cover didn't show much change in the four decades. The grassland and wasteland showed a slight negative decline of 0.1 and 4.62 % in that period of time respectively. There is an increase in water bodies. The water bodies spanned an area of roughly 17.72 square kilometers in 1991, which expanded to 43.71 square kilometers in 2021.

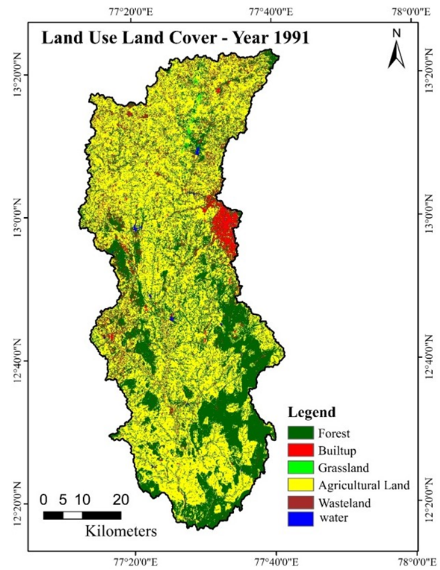

Fig. 8. Landuse/ Landcover Map (1991)

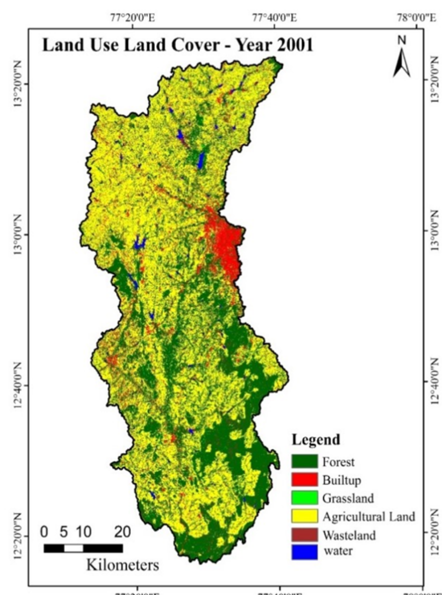

Fig. 9. Landuse/ Landcover Map (2001)

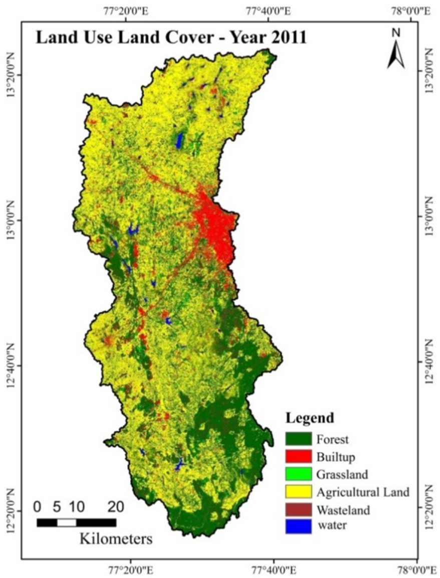

Fig. 10. Landuse/ Landcover Map (2011)

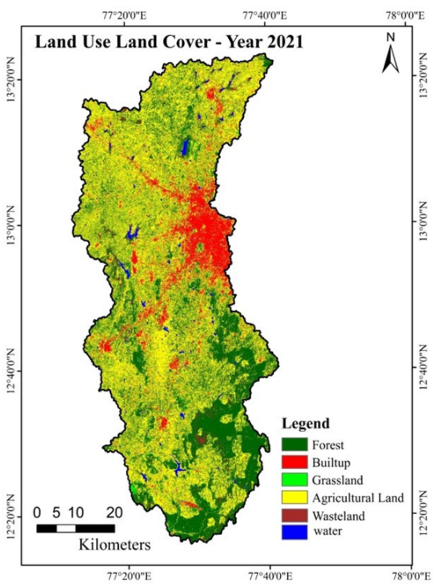

Fig. 11. Landuse/ Landcover Map (2021)

Conclusions

To sum up, the land use of Arkavathi watershed has undergone drastic change in last four decades from 1991-2021 as a significance of normal growth of population and abnormal growth of urbanization. This research is critical in understanding land invasion in many land categories. The multi-temporal satellite photos were also crucial in quantifying the watershed's geographical and temporal features. Due to rising population and need for settlement, profitable agricultural land is being converted into built-up areas. There is a continuous deterioration of agricultural land cover and grassland in the watershed. This study reveals that and its surround areas. The increasing anthropogenic activities and settlements and declining of natural vegetation cover in the watershed is a major concern. Moreover, the expansion of Bangalore city is having another serious impact on the watershed and other major land covers. The whole arrangement of changes is the result of a complicated cooperation between different causes. As a result, making informed decisions for sustainable resource development and environmental conservation strategies for a better tomorrow is critical in order to prevent land use and land cover from further degradation.

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