KIU Journal of Humanities *Copyright©2018*
Kampala International University ISSN: *2415-0843*; 3(3): 151–159

Spatial Pattern of Landcover Changes in Obajana Watershed, Kogi State: A GIS Approach

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Abstract. This research characterizes the land use land cover of Obajana watershed and assesses the spatial pattern of land cover change in the area from 1987 to 2013. Primary and secondary data were used for the research. The primary data were index coordinates of geographic features within the study area, collected through the use of global positioning system. The secondary data were Geodetic Digital Elevation Model (GDEM) and Landsat TM / ETM imageries for three epochs (1987, 2006 and 2013) with path and row of 189 and 55 downloaded from Global Landcover Resources Website (http:www.glcf.com). Supervised image classification was done for the three series of remotely sensed imageries to extract the spatial pattern of land cover change. GIS techniques were used to derive the maps, and the various landuse systems were compared using percentage distribution. The Obajana watershed is characterized by a maximum and minimum elevations of 411 m and 134 m respectively with a two dimensional area of 43.4 km^2. Cement production in the area was largely linked with the increase in land cover change of the watershed, with areas covered by woodland reducing by about 37% while exposed and impervious land surfaces have increased by 40% and 111%, respectively, between 1987 and 2013. Assessment of the pattern of change indicated that while impervious land surfaces were concentrated in the north-eastern and north-western axis in 1987, they shifted to the central part, spreading towards the northern and eastern axis of the study area in 2013. The study concluded that integrating Remote Sensing and Geographic Information System (GIS) was adequate for generating spatio-temporal information for the assessment of landcover changes in the study area.

Keywords: Remote Sensing, GIS, Obajana Watershed, Land use, Land cover, Change.

1. Introduction

Environment is the totality of the surrounding that affects the occurrence and establishment of organisms in a particular area (Davis, 1989). It is the sum total of water, air and land interactions and their linkages with humans and other living organisms. It includes all the physical and biological elements and their interactions (Last, 2001). It can thus be seen as the sum total of all the surroundings of a living organism, including natural features and other living and non-living things, which provide conditions for growth and development. Environmental sciences generally seek to provide an understanding of the environment of the earth and the impact of human life upon the environment. Environmental researches have global relevance and they are multidisciplinary. It is thus of interest to everyone particularly as fundamental changes continue to take place in the various parameters of the environment around the world.

Environmental degradation on the other hand is the deterioration of the natural environment either through anthropogenic activities or natural disasters (United Nations, 1997). According to the International Strategy for Disaster Reduction (ISDR), it is the decrease in the capacity of the environment to meet human's ecological and socio-economic needs. Human activities are diverse and do take place in the environment. Thus human activities are closely dependent on the environment, resulting in various types of impacts directly or indirectly on the environment (Uchegbu, 1998). The various uses of the natural environmental resources cause soil erosion, deforestation, desertification and the attendant loss of biodiversity, and ozone layer depletion among others. All of these are believed to be contributory to the growing phenomenon of global warming and Climate Change (Adesina and Odekunle 2011).
This research examines the nature of the interactions between man and the environment from the perspective of man's use of the environment for socio-economic development. The objectives of this research are: i. Characterize the land use land cover of the watershed; ii. Assess the spatial pattern of land cover change in the area from 1987 to 2013

1.1 The Study Area

The Obajana region is located in the western part of Lokoja Local Government Area of Kogi State, Nigeria (Figure 1). Obajana Watershed is situated approximately between geographical coordinates of (Latitudes 7° 54'17.66" and 7° 57'13.58"North of the Equator) and (Longitudes 6° 24'27.72" and 6° 27'.46.15"East of Greenwich meridian).

The area has a climate that belongs to the Koppen's Aw classification experiencing two distinct seasons - rainy and dry seasons (Alabi, 2009). The rainy season lasts from April to October while the dry season lasts from November to March. The total annual rainfall ranges between 804.5mm and 1767.1mm (Audu, 2012a). Mean annual temperature is about 27.7^{o}C and relative humidity could be up to 30% during the dry season and 70% in wet season. The main vegetation type in the study area is the Southern Guinea Savanna with predominantly tall grasses and shrubby trees. (Nathaniel, 2012).

The study area is drained mainly by River Oinyi which is a third order stream in the River Niger basin complex (after Strahler, 1949). The Oinyi River is semi-perennial with portions of it seasonal in nature (ephemeral), flowing only after rains while most of the smaller streams and drainage lines that dissect the hills are water-barren during the dry season

2. Materials and Methodology

In this study, both primary and secondary data sets were used. The primary data collection involved is the latitude and longitude of selected features within the study area using the Global Positioning System (GPS). This data basically assist in image processing and the implementation of 'Supervised' classification procedure on the images. Universal Transverse Mercator (UTM) projection, Clarke 1880 ellipsoid, Minna Nigeria datum zone 32 north was used to define coordinates in the GIS environment using the 1st order polynomials The secondary data is made up of Remote Sensing data comprising of

Landsat TM / ETM imageries of the study area for (28th March 1986, 9th December 2006 and 25th December 2012) with path and row of 189 and 55 (downloaded from the Global Landcover Facility website) and Geodetic Digital Elevation Model (GDEM) of 2006.

2.1 Watershed Characterization

The first step in the characterization process of the watershed was outlining the approximate boundary of the study area. This was done using the digital elevation model (DEM) of Kogi State with 30m resolution. This is then followed by the other processes which involved; Sink Filling, Flow Direction, Flow Accumulation, Pour Point identification and finally Watershed Delineation

2.2 Land Use/ Cover Change Assessment

After restoring the satellite images, colour compositing were performed to boost visual interpretation. Using TM bands 5, 4, 3 for 1987, ETM+ bands 5, 4, 3 for 2006 and ETM+ bands 5, 4, 3 for 2013. Image classification were then carried out so as to map out the various land use of the entire study area. Four major categorization was made which include; Built up, Vegetation, Surface water bodies, Bare soil. Image functionality in ILWIS 3.3 was used to carry out the classification operations and maximum likelihood algorithm was used. It should be noted that the classification process was carried out for the year 1987, 2006 and 2013. Analysis of change was the next phase of the assessment which involves the calculation of percentage change in areas occupied by the various land use categories from 1987 to 2013 from which the trend was further analyzed.

3. Results and Discussion

Characterization of the Watershed

Figure 2 shows the extracted part of the DEM for Kogi State that was processed using the water body as a central point. The digital elevation model shows that the Obajana watershed has a maximum elevation of 424 m and minimum elevation of 155 m (point of discharge) as against that of entire Kogi state with maximum elevation of 674 m and minimum elevation of 12 m. (Figures 2 and 3). Results of Figure 3 indicate that the lowest region is to the Eastern part of the watershed while the highest region is to the South-Western part of the watershed. The elevation differences show that all the streams contribute to the major stream flowing towards the Eastern part of the watershed. And this could also affect the degree of surface water accumulation of the receiving higher order streams down the valley.

The watershed is estimated to have a two dimensional area of 43.432542 km^2 and a perimeter of 31.8525 km as depicted in Figure 2. These imply that it has a very rich and robust relief. Figures 4 and 5 show the Flow Direction map and Flow Accumulation map respectively. The purpose of the flow direction is to derive the key hydrologic characteristics of the watershed surface and to determine the direction of flow from every cell in the area. With the flow accumulation map, the nature of the stream channels and drainage network flows were identified. The stream network shows that the watershed has a "dendritic drainage pattern" in nature. Dendritic drainage pattern is a "branching, treelike drainage pattern. In areas of uniform rock, with little distortion by folding or faulting, the rivers develop a random branching network similar to a tree (WVCA, 2013).

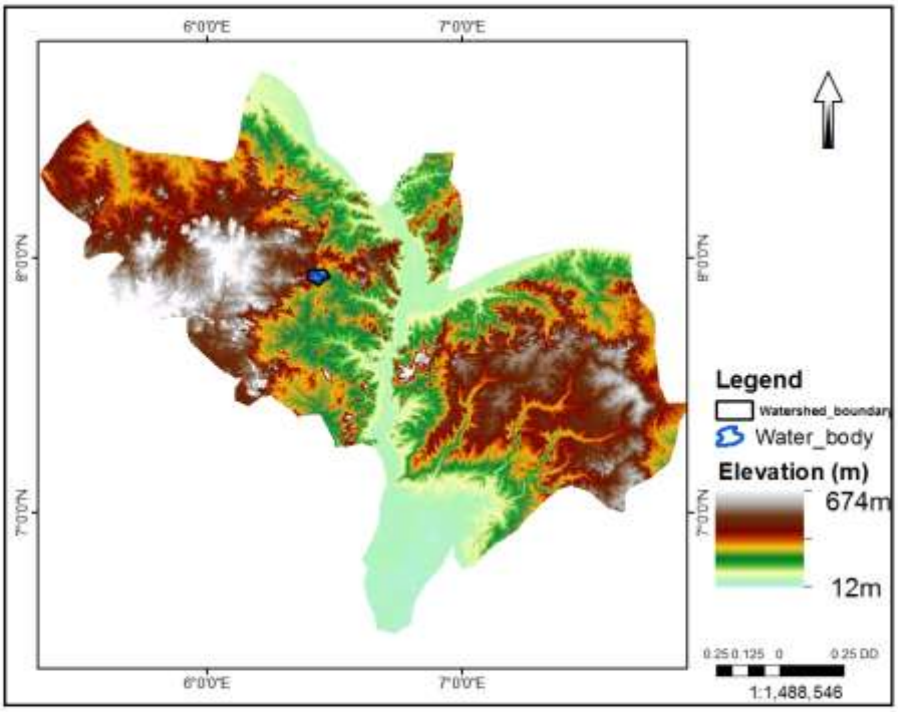

Figure 1: DEM of Kogi State (with the digitized water body

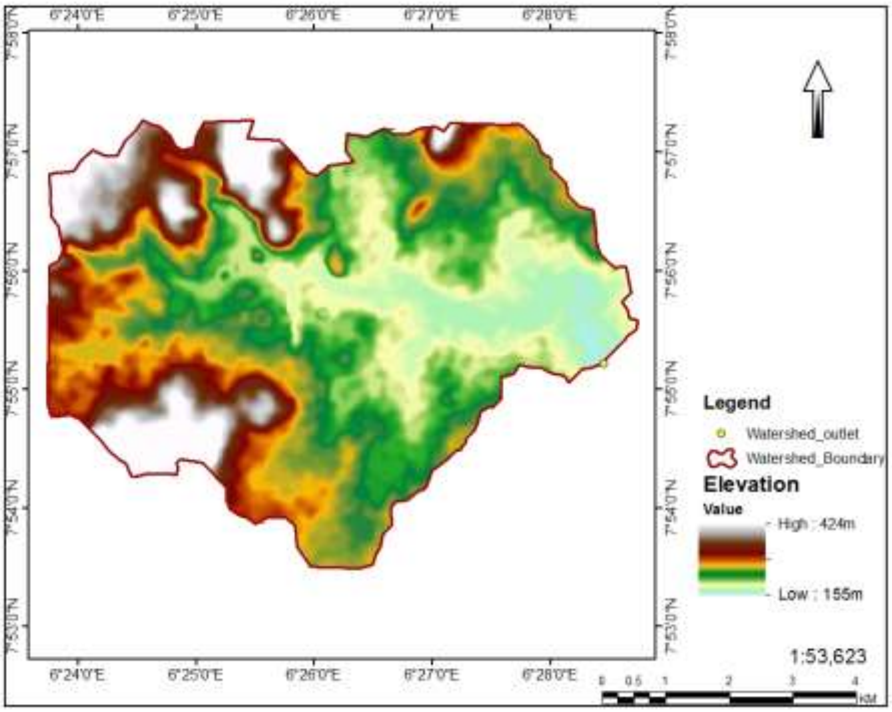

Figure 2: DEM of the delineated Watershed boundary and Watershed Outlet.

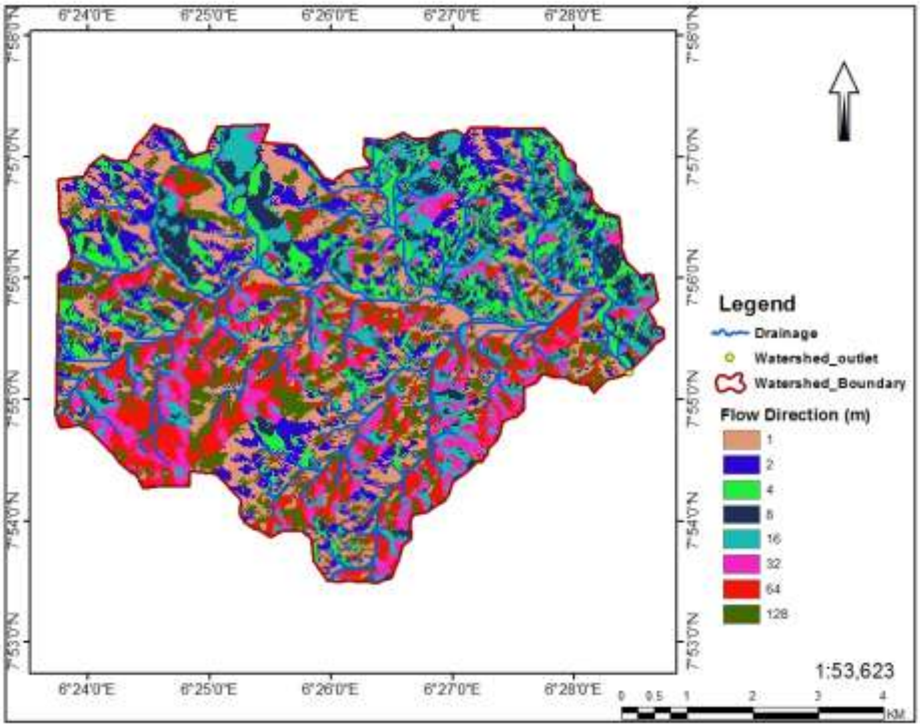

Figure 3: The Flow Direction and Watershed Outlet.

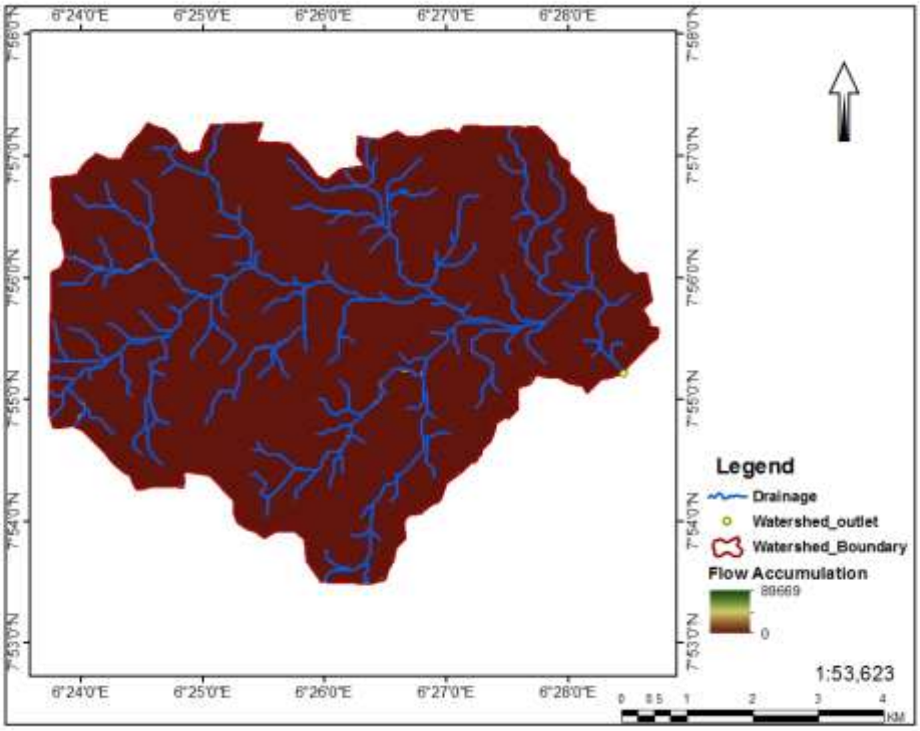

Figure 4: Flow Accumulation Drainage Networks and Watershed Outlet.

Spatial Extent of Land Cover Changes between 1987 and 2013

As shown in the result of the analysis in Figures 5 – 7 and Table 1, all the Land Cover features experienced tremendous changes between 1987 and 2013 (26 years). "Woodland" decreased very significantly in area. Between 1987 and 2006 it experienced a loss of 584.1ha. It continued to decrease from 2006 to 2013 with a loss of 353.61ha thus bringing the overall change from 1987 to 2013 to a decrease of 937.71 ha. This translates into an overall decrease of 36.98% of its actual coverage in the watershed. Field work shows that “Woodland” areas are being converted into farm lands, industrial/commercial areas and Impervious Surfaces (road, staff quarters/estates walkways amongst others). This result is in agreement with the work of Nathaniel (2012) which attributed the loss of vegetal cover in Lokoja to development, industrialization and expansion of roads. His result shows that vegetation experienced an overall decrease of 50.9% over a study period of 21years (1986-2007).

Unlike the “Woodland” category, “Shrubs” gained more areal coverage over the study with time. In 1987 it occupied 1,402.96 ha which constituted about 31.69% of the entire study area. By 2006 the area had increased to 1,108.71 ha i.e. 40.93% of the total land area. It continued to experience additional increase from 2006 to 2013. From Table 1 “Shrub” category shows an overall increase of 544.64 ha which means a change of 39.98%. This can be linked to persistent and increasing destruction of forest covers for domestic fuel and persistent felling of trees for timbers in the study area. “Surface Water Body” also increases in size over the study period. In 1987 it occupied 174.70 ha which was (4.38%) of the study area. In 2006 the area increased to 635.94 ha i.e. 5.87% of the total land area. From 2006 to 2013 it experienced an increase of 25.11 ha. From Table 1 in all, “Surface Water Body” experienced a total increase of 107.99 ha translating into a percentage change in area of +47.03%. The cause of this increase in the level of Surface Water Body within the study area cannot be completely disconnected from the establishment of a dam by the Obajana Cement Company. This is linked to increase in demand for water for factory operations and for the growing rural population and other expanding industrial concerns. “Impervious Surfaces” also gained more area with time. In 1987 it occupied 263.25 ha which is equivalent to 6% of the entire study area. In 2006 the area had increased with 115.83 ha i.e. 8.63% of the entire study area. It continued to experience additional increase from 2006 to 2013. Table 1 shows that it has an overall increase of 293.58 ha which means a change of 111.33%. Therefore, the implication of this level of increase of the Impervious Surfaces is that the volume and intensity of runoff in the study area would increase. Persistent increase in cement exploitation and its related activities in the watershed can therefore be said to be responsible for the change in land covers. A clear example is the conversion of very rich woodland area into area where the massive kiln plant is located, and also conversion to housing estates and commercial areas. Excess kiln dust which is constantly release into the environment is also a contributory factor to the reduction of woodland in the study area.

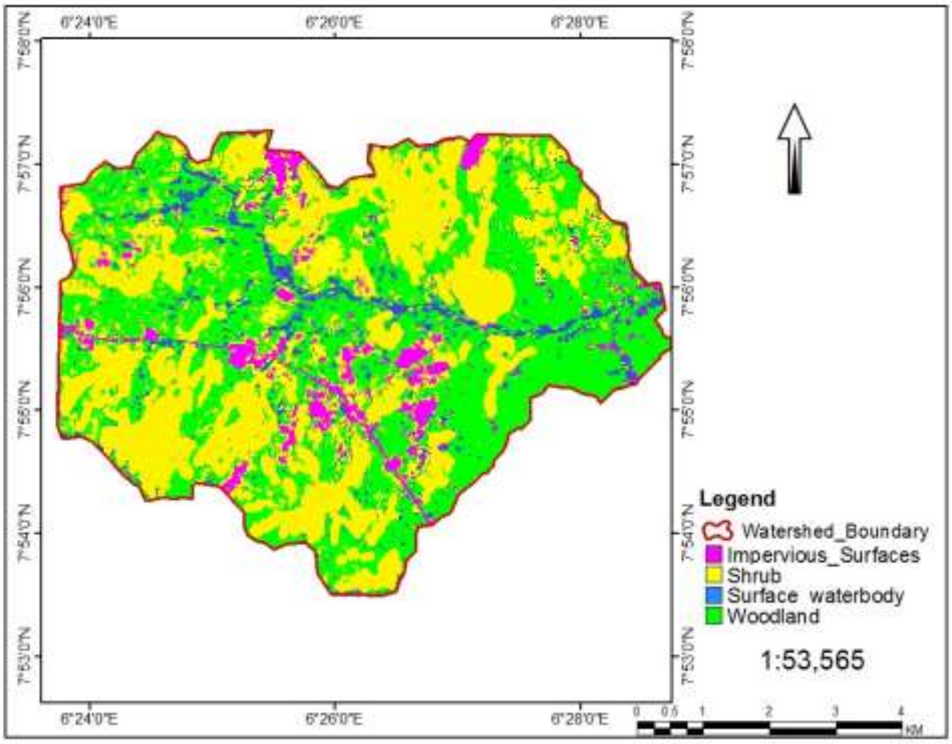

Figure 7: Land Cover Map in 1987.

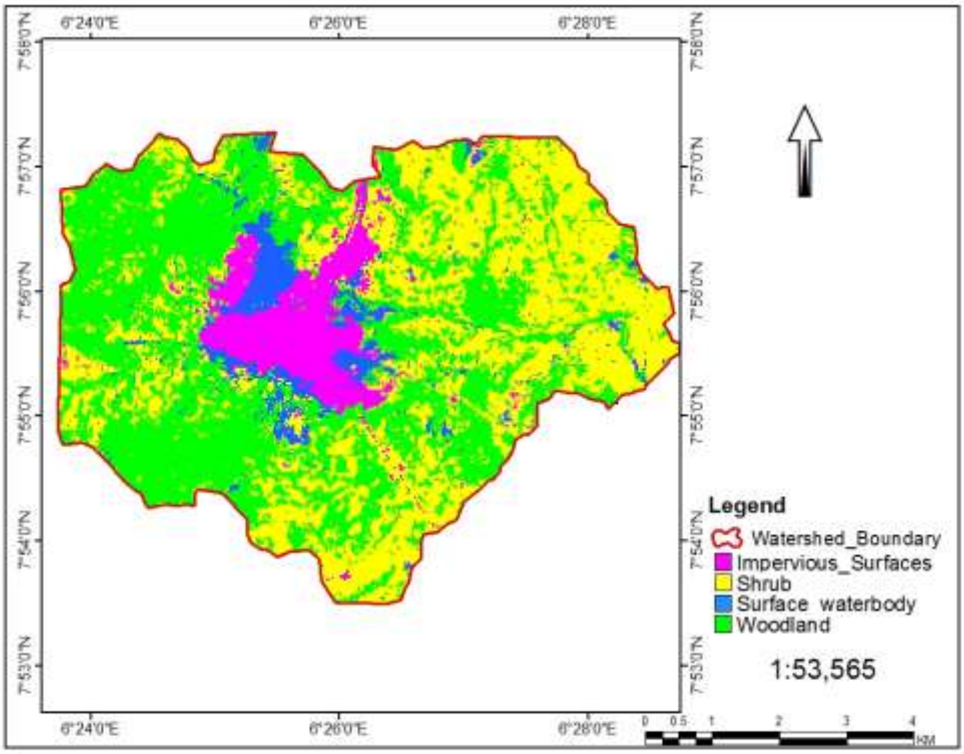

Figure 8: Land Cover Map in 2006

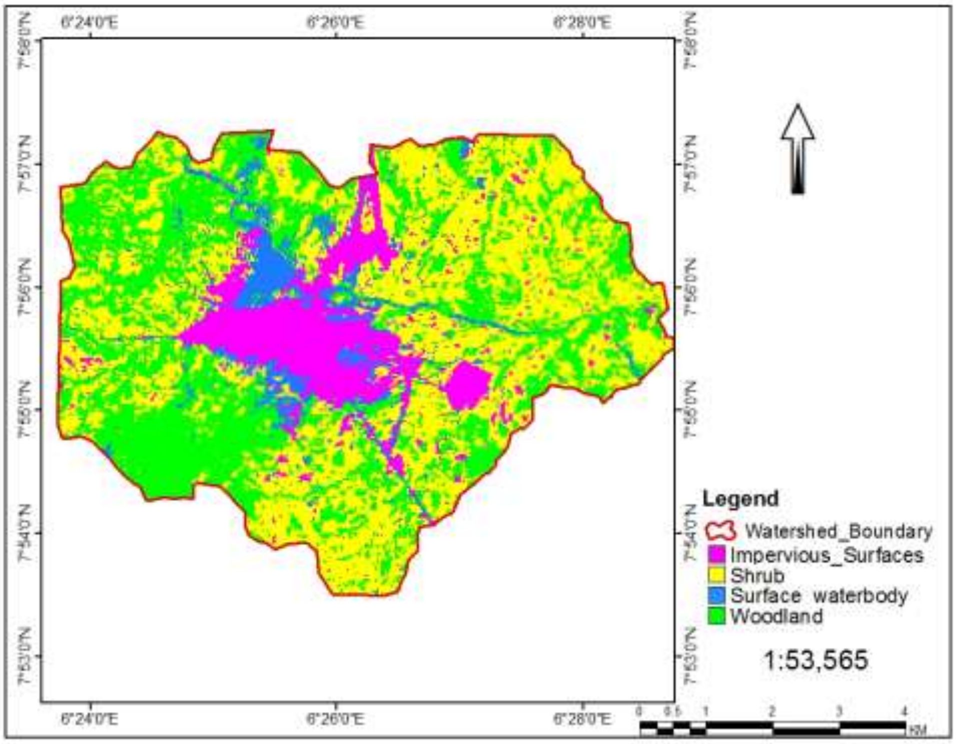

Figure 8: Land Cover Map in 2013

TABLE 1

Land Cover type	1987 Area (Ha)	2006	2013	Change in Area (Ha)	1987 Area (%)	2006	2013	Percentage Change in Area (%)
Woodland	2540.7	1956.6	1602.99	-937.71 (Decrease)	57.93	44.57	36.51	-36.98 (Decrease)
Shrub	1402.96	1796.85	1947.6	+544.64 (Increase)	31.69	40.93	44.36	+39.98 (Increase)
Surface Water Body	174.70	257.58	282.69	+107.99 (Increase)	4.38	5.87	6.44	+47.03 (Increase)
Impervious Surfaces	263.25	379.08	556.83	+293.58 (Increase)	6	8.63	12.68	+111.33 (Increase)

Source: Author's data analysis

- Overall change in area = (Final area – Initial Area)
- Percentage change in area = [(Final area – Initial Area)/Initial Area] *

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