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Accurate evaluation of Land Use Land Cover (LULC) Dynamics in the Southern part of Mali, West Africa

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ABSTRACT: In an area, the spatial and temporal variation of the various units of LULC of is the response of natural and socioeconomic factors and their spatially usage by human. This LULC differs from one type to another. The LULC change affect negatively the natural resources because the process is irreversible. Thus, the analysis of monitoring and quantitative of the changes in land use over time and identification of landscape pattern variation related to growth modes in different periods are essential. Change in land use is one of the difficult that exacerbate environmental problems. The complex and dynamical land use/land cover change at different scales has environmental implications. Previous studies investigated mainly the basic socioeconomic drivers of LULCC.
Remote sensing is a central tool for making Land use and land cover maps via the classification from satellite images. For correct image classification, there are factors that could be considered which are: the accessibility of Landsat imagery quality and secondary data. Moreover, the accurate classification and the experiences from the users and expertise in the procedures are required. The chief aim of this work was to evaluate the land-use/land-cover change of the study zone from 1990-2016 applying remote sensing and Geographical Information System (GIS) techniques. This work comprises two parties (1) Land Use/Land Cover (LULC) classification and (2) the evolution of the spatiotemporal dynamics of the diverse units of LULC over the study area. The Envi 4.5 Software coupled with Arcgis was used to make the supervised Classification of Land Use Land Cover. Five dominant LULC classes, bareland, cultivated land shrubby savannah, herbaceous savannah and degraded savannah, were recognized in the catchment. The outcomes showed that the ration of cultivated land augmented to 14.9 % and bare land increased by 23.5 % however, the savannah classe decreased: degraded savannah by 10.32%, herbaceous savannah by 24.4%, and Shrubby Savannah by 3.6 %. The evaluated coefficient of kappa (K) was classified satisfactory with a range from 82% to 91 %.
Savannah areas in studied catchment is converted to agricultural land and urban area due to human activities. The knowledge of the variation in terms pf time and space of the LULC change could be a management resources tool for the decision makers and prevent the natural risks. The results of this current research could help to well understanding the different water cycle components within the Koda catchment under a changing LULC.

KEYWORDS: LULC change, Remote Sensing, GIS, Koda catchment, Mali.

1 INTRODUCTION

In several countries specially in developing countries, one of the major driving forces of general environmental change is Land Use and Land Cover (LULC) change (Botlhe et al., 2019). According to Wondie et al. (2011*),* the economy of many countries is mainly negatively affected due to LULC effects. Changes in the LULC are mostly due to the intensity of land use and the surface area extension. Temporally, LULC changes from a few months to some years, characterized by short term and long changes, respectively (Lambin & Ehrlich, 1997). The long-term change is one of the main concern and the most important for general environmental change. Additionally, water resources (groundwater and surface water) are managed by many factors including the LULC change (Stonestrom et al., 2009; Ashaolu et al., 2019). Numerous authors (Scanlon et al., 2005; Lin et al., 2018; Ashaolu et al., 2019) have examined the long term LULC change to assess the sustainability of natural resources. Most of the results from the previous researches showed clearly that the causes of LULC change are mainly being of natural and anthropogenic effects (Tamba & Li, 2011; Pervez & Henebry, 2015; Yin et al., 2017; Diallo et al., 2019). The anthropogenic effects are based on the increases of population growth rate, rural-urban migration, agricultural expansion, deforestation and climate change. In developing countries urban land expansion has been detected since the 1980s that is more related to urban population growth than the growth in the Gross Domestic Product (GDP) (Ashaolu et al., 2019). In West African countries, large of extents of natural land cover classes have been substituted by human influenced landscape chiefly dominated by agriculture (CILSS, 2016). Several populations from the rural are migrating for a better survival opportunities (Pandey et al., 2013). So to take care of the growing population, the agricultural land area has been enlarged to meet the food demand (Jamtsho & Gyamtsho, 2003). All these activities contribute to LULC changes. In Mali, the parts of savannah and forests land have been decreased by 23 % from 1975 to 2013 (CILSS, 2016), this is mainly due to the population growth and food demand.

The southern portion of Mali including the study area is the greatest populated region over the country, which increase high fresh water demand. The population of the study area known an increase of 26 % from 2009 to 2019, with 3.6 % of population growth rate (RGPH, 2009). The main land use in the catchment is agriculture. Then, quantification of LULC change is crucial to better understanding the variability and its ecological impacts on the natural resources (Turner, 2005). The focus of this study is to evaluate the effects of LULC change on groundwater resources over Koda catchment from1990-2016 period. To attain this objective, the remote sensing coupled with GIS is used to study the dynamics of the LULC over Koda catchment between 1990 and 2016. The supervised classification method has been used to classify the LULC classes existing in Koda catchment.

In the current study, the dynamics of LULC change was assessed for the period 1990-2016 and the outputs could be used for water resources management tool.

The study area, Koda cathment, is located in the semi arid zone of West Africa. It, occupies the southern part of Mali at 120 km in the North of Bamako, capital of Mali. Koda catchment lies between in Latitude: 13° 56’00" N and 12° 57’ 80 " N and Longitude: 7° 30’ 8" W and 8° 28’ 5 " W. With a surface area of about 4921 $Km^{2,}$ the Koda catchment belongs to sudano-sahelian climate. The mean annual temperature is about 28.3°C with minimal temperature varying from 15°C to 26.6 °C and the maximal temperature ranges from 31.4 °C to 40.5 °C (Diancoumba et al., 2018). The overall annual minimum of precipitation for the last 30 years (1987-2016) is 500.4 mm in 1992 and the maximum in 1164.3 mm in 1988 at Katibougou station, while the overall average is 836 mm (Diancoumba et al., 2020).

The main crops are millet, maize, cotton etc. Two types of permeability are characterized the catchment, the porous permeability in the sandstones and the permeability due to the fissures in the dolerites (Diancoumba et al., 2019).

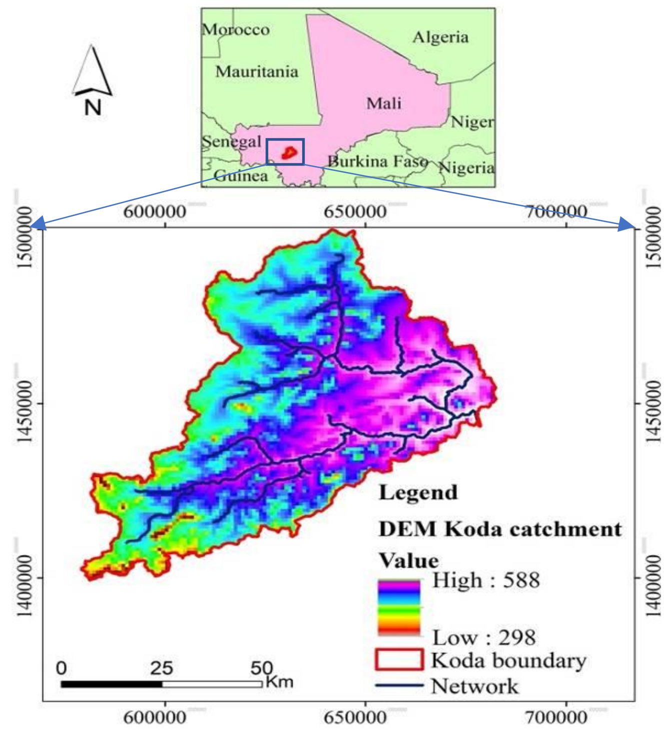

Fig. 1. Location of the study area

2 OBJECTIVE OF THE STUDY

The main aim of this research is to assess the dynamics of the Land Use and Land Cover change in the past 27 years (1990-2016) using Remote Sensing and Geospatial Information System (GIS) techniques. The choice of those years has been based on the availability of the Landsat data set with good quality.

3 METHODOLOGY

The Supervised Classification method, using Envi 4.5 Software coupled with Arcgis 10.3, was applied to subset Landsat images from 1990 to 2016.

The production of the land cover map requires the coordinates of some points that were taken throughout the catchment scale on May 2016. This is based on the presence of no cloud from the images in this period of the year. These points have been selected as the unit pixel of the study area to facilitate the land cover classification. The supervised classification method was chosen using the Envi 4.8 software, and the Landsat images, downloaded from the USGS website[1,] were used for that. Three years of Landsat images (March 1990; March 1998 and February 2016) were used in evaluating the evolution over time of LULC change. The time steps of the Landsat images are based on the quality of the available data. The output from Envi software was used into ArcGIS for the mapping purpose (Figure 2).

Figure 2 shows the flow chart of the methodology used in this study.

Maximum likelihood classification algorithm was applied to get the best algorithm for classification. The threshold option has been used to calculate the area of each LC units over the Koda catchment.

The change of LULC over Koda catchment was carried out based on the 1990, 1998 and 2016 LULC maps developed for the catchment. Using the overall function in ArcGis 10.3 and the Microsoft excel 2007, the percentage changes in LULC was calculated for the twenty-seven (27) years period.

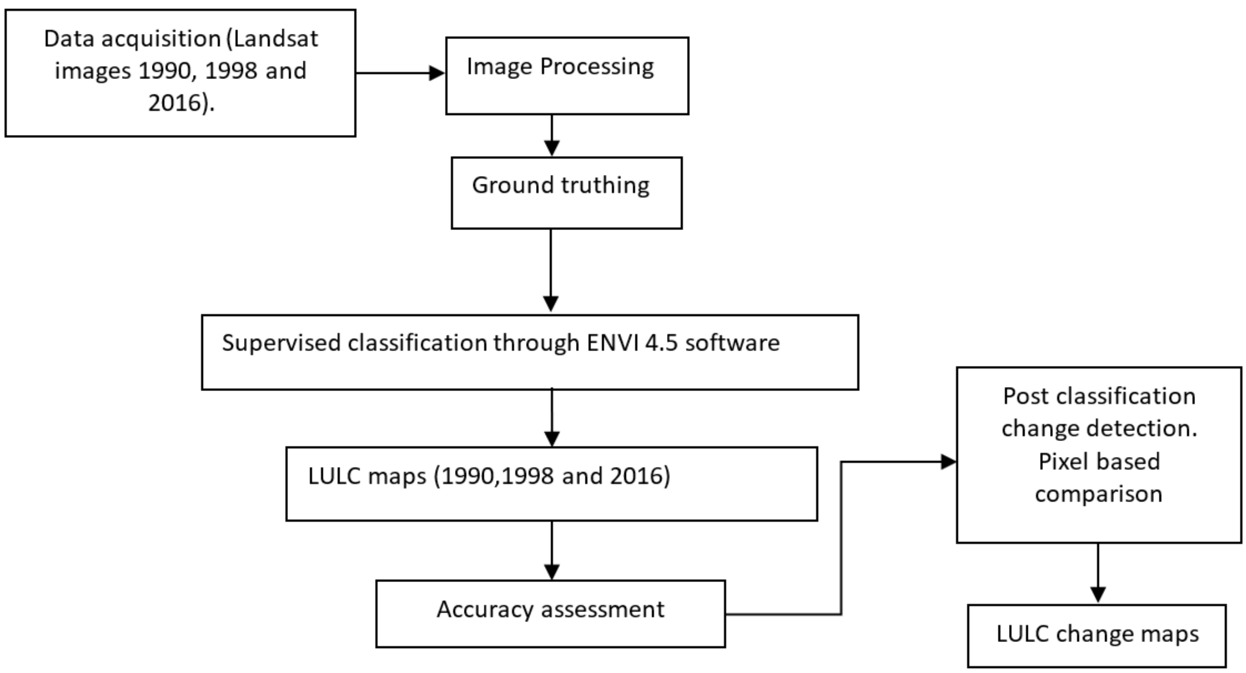

Fig. 2. Flow chart of the methodology of LULC change

[1] https://www.usgs.gov/earthexplorer

The main objective of this work is to evaluate the dynamics of the land cover change in the past 27 years. The choice of those years is mainly due to the availability of the Landsat data set with good quality.

4 ACCURACY ASSESSMENT

The coefficient of KAPPA (K) has been evaluated in the view to better assess the classification of LULC units done over Koda catchment. The Kappa coefficient (K) is computed based on the error matrix (equation 1).

According to Amler et al. (2015) and Ren et al. (2018), the K value is used to evaluate the accuracy of remote sensing data using equation (1).

$$K = \frac{N\sum_{i=1}^{n} P_{ii} - \sum_{i=1}^{n}\left(P_{i+} * P_{j+}\right)}{N^2 - \sum_{i=1}^{n}\left(P_{i+} * P_{j+}\right)} \quad (1)$$

Where P_{ij} is error matrix, P_{i+} row total pixel, P_{j+} colum total pixel, P_{ii} corrected mapped pixel of a particular class i and N total number of pixel.

The quantification disagreement and allocation disagreement method have been proposed by Pontius & Millones (2011) and showed the limitations of the use of the K values in comparing the maps viewed. Nevertheless, in several studies, K is still considered as a vital tool for accuracy assessment measurement (Biondini & Kandus, 2006; Ren et al., 2018). The value of K that shows the consistency of data classification has been statistically classified by Fitzgerald and Lees (1994) from poor to excellent as follows:

Poor if K <40

Good if 40 ≤ K < 75

Excellent if K ≥ 75

5 RESULTS AND DISCUSSION

5.1 DYNAMICS OF LULC

The Koda catchment is mainly characterized by five (5) types of Land Cover units and these are Herbaceous Savannah, Degraded Savannah, Cultivated Land, Shrubby Savannah and Bareland. These five (5) types of LULC over the study area could be represented by three major types of LULC based on the classification proposed by Penman et al., (2003) in the IPCC Guidelines in the Kyoto protocol in 2001. The three LULC are savannah, cropland and settlement. Savannah is represented by three types of savannahs: herbaceous savannah, Shrubby Savannah and degraded Savannah. The cropland includes the cultivated land which is seasonal rained crops land and farms. Settlement is called bare land in this study and it is defined as villages, towns and cities, roads and others buildings.

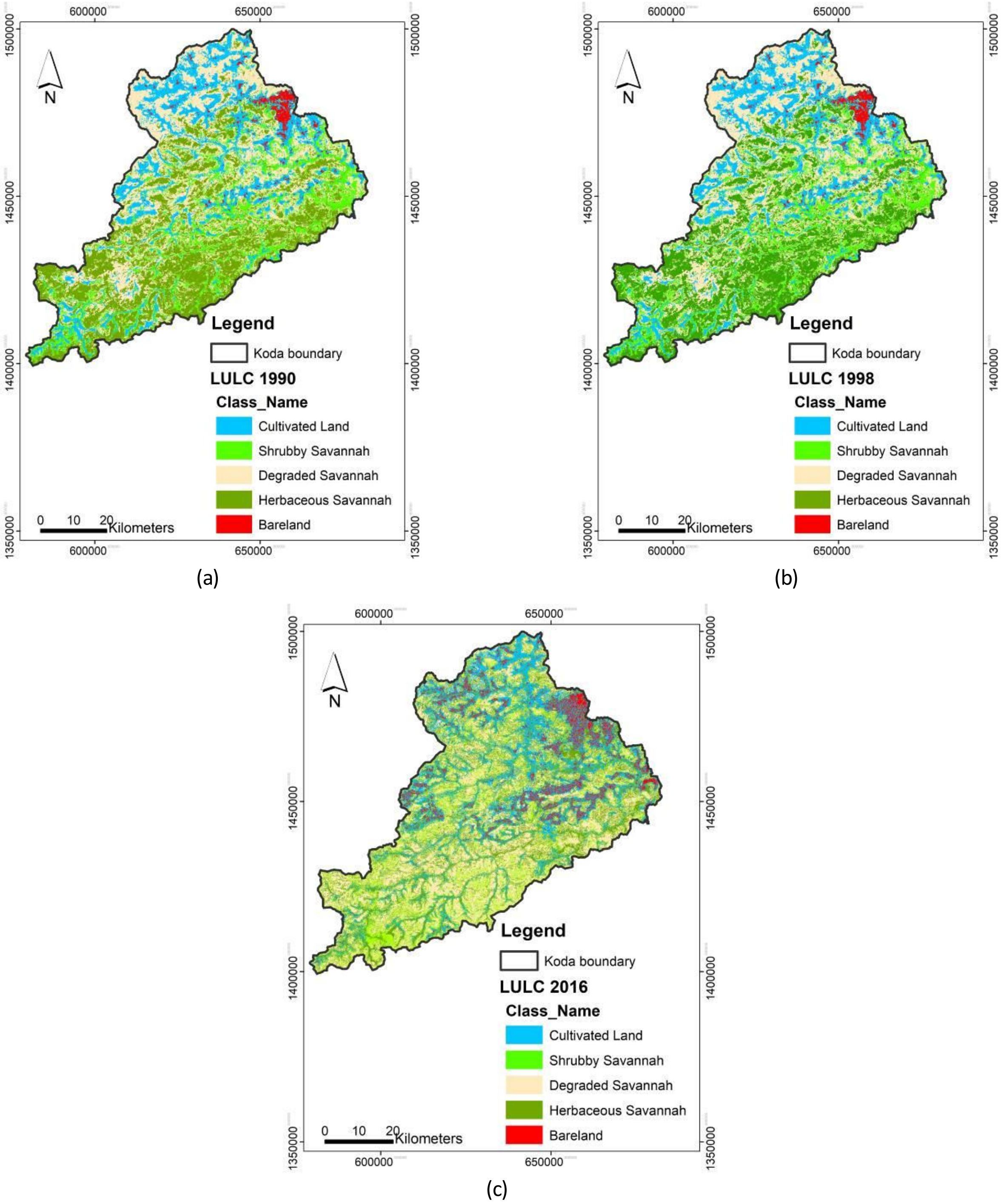

Fig. 3. Different units of LULC in the Koda catchment, (a) year 1990, (b) year 1998 and (c) year 2016

The comparison in terms of total area of LULC category has been done and the results are outlined in Table 1.

Table 1. Land Use and Land Cover area and area change for the years 1990, 1998 and 2016

Unit	Area km²			Ratio of LC unit over Koda's total area (%)		
	1990	1998	2016	1990	1998	2016
Cultivated Land	125	200.39	856	2.55	4.07	17.40
Bareland	50	69.11	1204.76	1.02	1.4	24.49
Herbaceous Savannah	2827.68	2815.3	1627.54	57.46	57.21	33.08
Degraded Savannah	1282.9	1222.54	774.886	26.07	24.84	15.75
Shrubby Savannah	635	613.04	458.49	12.9	12.49	9.32
Total	4920.58	4920.38	4920.52	100	100	100

The land used for agriculture purposes changes considerably from 125 Km^2 in 1990, 200.39 km^2 in 1998 and to 856 km^2 in 2016 representing respectively an increase of 2.54%, 4.07 % and 17.40 %. In general, bare land varied from 50 km^2 to 1204 km^2 between 1990 and 2016 while there was an increase of 23.5 % (representing 1154.57 km^2 of the basin). Herbaceous savannah decreased from 57.46 % of the total area of the catchment (2827.68 km^2) to 57.21% in 1998 and 33.08 % in 2016 respectively. This is followed by degraded savannah with a total coverage area of 26.07 % (1282.90 Km^2) in 1990, 24.84 % in 1998 and 15.75 % in 2016 while there was a decrease of 10.32 %. In 1990, the shrubby savannah represents 12.90 % (635 km) but, this was decreased to 12.49 % (613 km) in 1998 and 9.32 % (458.54 km) in 2016.

The graphic representation of the results is given by Figure 4. This figure clearly shows the increase in the areas of cultivated land and bare land and the decrease of degraded savannah and shrubby savannah areas.

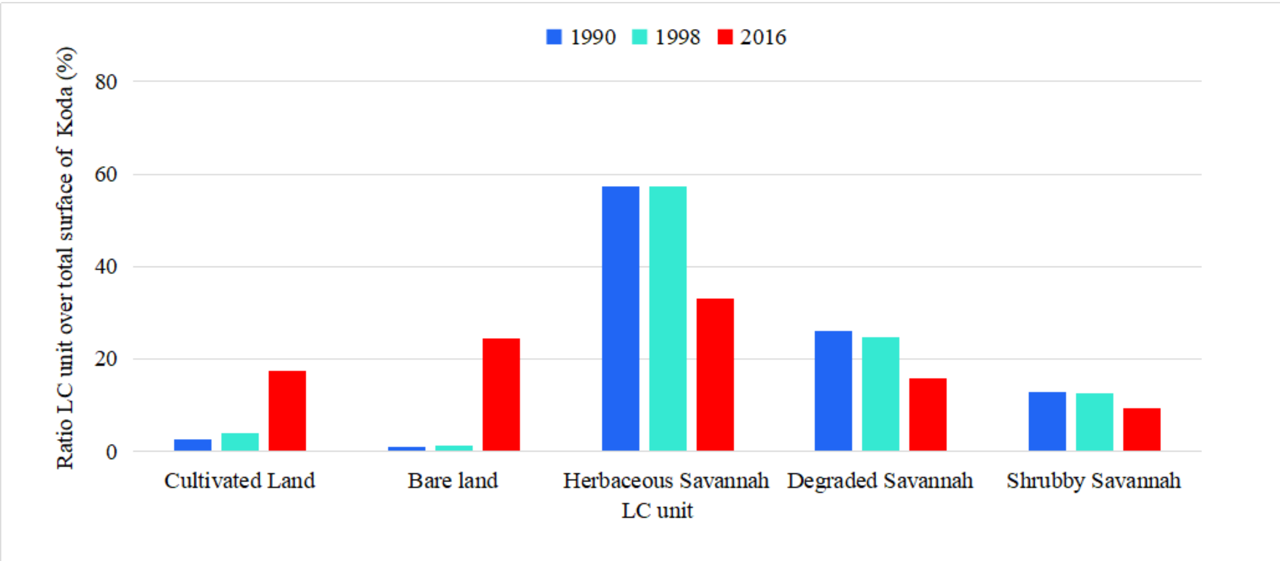

Fig. 4. Ratio of LULC unit over the total surface of Koda catchment in the years 1990, 1998 and 2016

Based on these results, there was an increase of 1 % and 9.78 % of Bare land and Cultivated land respectively. The increase of these two LULC units in Africa has been explained by many authors such as (Koglo et al., 2018). The same trend has been examined in Mali by (CILSS, 2016) where the increase of the cultivated land increased by a factor of 2.3 for the period 1975-2013 (38 years) equivalent to an average annual increase of 3.5 percent.

For many authors, this increase could be related to the increase in population and food demand (Koglo et al., 2018; CILSS, 2016; Daou et al., 2019). The decrease of different types of Savannah area is represented by a decrease of herbaceous savanna area of 24.4 % degraded Savannah 10.32 % and 3.6 % for shrubby savannah.

According to Koubodana et al. (2019) and Aziz (2017), the decrease of the savannah is further amplified by using wood as energy sources and the lack of forest management. In the Koda catchment, deforestation is still occurring.

No water body is observed in the study area as a land cover unit, that lack of water bodies can be explained by the following reasons: the Landsat image used is dated of February (dry period) corresponding to the period where there is no surface water because only few surface water characterize the Koda catchment are present during the rainy season. The existence time of all these surface water bodies is driven by the amount of rainfall received within the study area.

5.2 Accuracy Assessment

In this study, all the values of Kappa coefficient (K) are greater than 75 %, therefore, the results are considered excellent. The results of K values are outlined in the Table 2.

Table 2. Coefficient of Kappa (K) values of each land use and land cover type

Year	1990	1998	2016
K values (%)	82	83	91

6 Outputs Of The Study

Significant progress in the understanding of land-use/cover changes has been achieved over the last decade.

7 Outcomes Of The Study

The expected outcomes of the project will be very useful for the local population by increasing their knowledge regarding the dynamics of the LULC and the adoption of strategies to deal with LULC impacts.

The results of this study can be used for predicting future LULC changes.

The results will help also to take some adaptation measures to Land Use and Land Cover change, we recommend to policymakers to promote and develop the use of sources of energy (SoLar energy, wind energy) in order to reduce the use of renewable fuel wood.

The results can be a tool for natural risks management.

8 Conclusion

The study showed a decrease in savannah and an increase in bare land and cultivated land from 1990-2016 over the Koda catchment. The decrease might become so more significant in the future if the current rate of deforestation continues in the Koda catchment. Therefore, a proper LULC management strategy is needed within the study catchment. The results of this study can be used for predicting future LULC changes. To reduce the vulnerability of the Koda catchment from the effects of Land Use Land Cover Change, we recommend to policymakers to promote and develop the use of sources of energy (Solar energy, wind energy) in order to reduce the use of renewable fuel wood

Author Contributions

O. D. was responsible for this current research paper. O.D. and A.T. designed the study and developed the methodology. O.D., A.T. and I.D. collected data. O.D. performed the analysis while A.T., S.K. supervised the data analysis. O.D. initially wrote the manuscript. I.D., S.K. and contributed to the paper write up while A.T. improved the quality of the manuscript.

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Conflicts Of Interest

The authors declare no conflicts of interest.

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