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Forest Cover Change Assessment of Tangaza Forest Reserve, North-West of Sokoto State, Nigeria

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Abstract

Tangaza forest reserve is one of the forest reserves in the northern Nigeria aimed at checking desertification. However, it is reportedly undergoing rapid degradation due to encroachment of human activities. The assessment of forest landscape change is a necessity for improved forest management, desertification prevention planning and decision-making. The study therefore aimed at assessing and predicting the dynamics of the forest reserve. Remote sensing technique was used in this study where 1986 and 2005 Landsat and 2007 SPOT data were processed and analyzed within the Idrisi Andes and ArcGIS environments. With maximum likelihood supervised classification method preceded by unsupervised classification and ground truthing, five classes namely bare surface, shrub-grass, tree-shrub, forest and cultivated land were derived at 88% degree of classification accuracy. Descriptive statistical tools were used to assess changes between both dates. Also Markov-Chain was used to predict 2020 land covers. Results showed that between 1986 and 2005, bare-surface expanded by 1,033% and will further expand by 15% in 2020. The shrub-grass expanded by 55% and will expand by 17.2% in 2020. Tree-shrub reduced by 42% between 1986 and 2005 and will further reduce by 13.3% in 2020. Cultivation expanded by 271% between 1986 and 2005 and will marginally expand by 0.01% in 2020. The forest cover reduced by 66% between 1986 and 2005 and will further shrink by 48% of its size in 2005 by the year 2020. Also, between 1986 and 2005, 23.5% of the forest got converted into bare surface, 18.8% into tree-shrub, 11.8% into shrub-grass and 10.5% into cultivation. The study concluded that the area will continue to undergo forest degradation in the face of perpetual human activities without corresponding forest management. Public enlightenment, tree planting, establishment of cattle ranches, improved farming practices, reduction in kerosene price to reduce the pressure on the existing but fragile forests and employment of more forest guards for improved forest management were recommended.

Keywords

Forest Reserve, Desertification, Global warming, Green house gas, Carbon stock

Introduction

The increasing amount of carbon dioxide released by conversion of forests to other land uses has been an issue of global worry (Palubinkas, 1996). According to Obama (2006), the White House believes that climate change is real, serious and

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accelerated by the continued release of carbon dioxide, and that humanity is doomed if the trends of melting icecaps, rising sea levels, changing weather patterns, frequent hurricanes, violent tornadoes, endless dust storms and decaying forests are not reversed.

Desertification, especially land degradation in arid, semiarid and dry sub-humid areas resulting from various factors, including climatic variations and human activities, is becoming one of the world's more serious environmental problems (Glenn *et al*, 1998). According Abdu *et al* (1982), Tangaza forest reserve is one of the forest reserves in the northern Nigeria aimed at checking desertification. But due to human activities such as grazing, crop cultivation, bush burning, fuel wood extraction, among others, accelerated by climatic fluctuation, this reserve has reportedly been degraded, thereby reducing the carbon sink of the environment and increasing the atmospheric carbon. The importance of trees in terrestrial ecosystem sustainability cannot be over emphasized. Green trees are the principal absorbers of the principal greenhouse gas (carbon dioxide) from the atmosphere. Also they replenish the atmospheric oxygen for life sustainability.

The assessment of forest landscape change is a necessity for improved forest management, desertification prevention planning and decision-making (Robert and David, 2007; Danfeng *et al*, 2007).

However, one of the most significant intellectual challenges to ecologists and bio-geographers is to understand spatial patterns in biodiversity (Liu *et al*, 2007; David, 2000). Computer models are increasingly being used by forest ecologists and managers to simulate long-term forest landscape changes (Robert and David 2007). Remote Sensing technique has proved to provide a solution to many problems of land use inventory, monitoring and management for land managers, land administrators, among others. This technique is less tedious and very effective (Rhett and Douglas, 2010; Syed *et al*, 2007). It is in the light of this that the study adopted RS method to assess Tangaza Forest Reserve dynamics. This study will classify the area into land cover classes, determine the area coverage of each class, assess the trade offs among the classes and predict future change.

Study Area

Tangaza is a Local Government Area in Sokoto State, covering an area between longitudes 4.58°E and 4.97° E and latitudes 13.31° N and 13.52° N wherein the Tangaza Forest Reserve is located (Figures 1 and 2). It is found in the semi-arid region of Nigeria – an area believed to have been encroached upon by desertification. Annual rainfall is about 400mm, and raining season lasts between May and October (Yelwa, 2008).

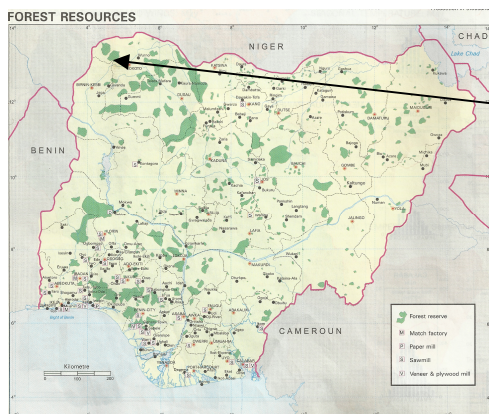


Figure 1: Forest Resources Map of Nigeria Showing Tangaza Forest Reserve

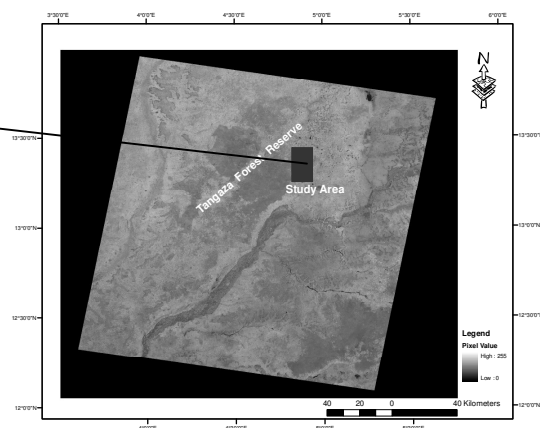


Figure 2: Band 4 of Landsat ETM+ (2005) showing the Study Area

Temperature peak is about 45 °C experienced in the middle of the dry season, while it can be as low as 20 °C in the cold season. Except for the forest reserve which comprises trees of 10m average height, vegetation is mainly of shrubs and grasses. *Azadirachia indica* (Neem), *Dalbergia sissoo*, *cassia siamea* (horse cassia) and *Callitris spp* are some of the exotic species while *Anogeissus leoucarpus* (Marke), *Acacia nilotica* (Bagaruwa) and *Butyrospermum paradoxum* (Kalgo) are some of the indigenous species found in the forest. Tangaza has a population of about 113,853 according to the 2006 population census report. Human activities are mainly grain cultivation and animal rearing.

Materials and Method

Figure 3 gives a schematic representation of the activities carried out in this study.

The data used for the study were Landsat TM of 21st September 1986 (28.5m resolution) and Landsat ETM+ of 15th October 2005 (30m resolution) which were downloaded from the Global Land Cover Facility (GLCF) website using <http://www.landcover.org>. The data were archived in path/row 191/051 of Landsat global coverage. Each scene has a size of 170 km x 183 km, and for each date, bands 1 to 7 together with their metadata were downloaded. The images were imported into the Idrisi Andes environment and corrected for atmospheric distortion using the *Cost Model* of Chaves (1996). Atmospheric and sensor viewing condition parameters as contained in the metadata served as input to the model. The data sets were later projected to 28.5m resolution after which the study area was sub-mapped from the entire scene.

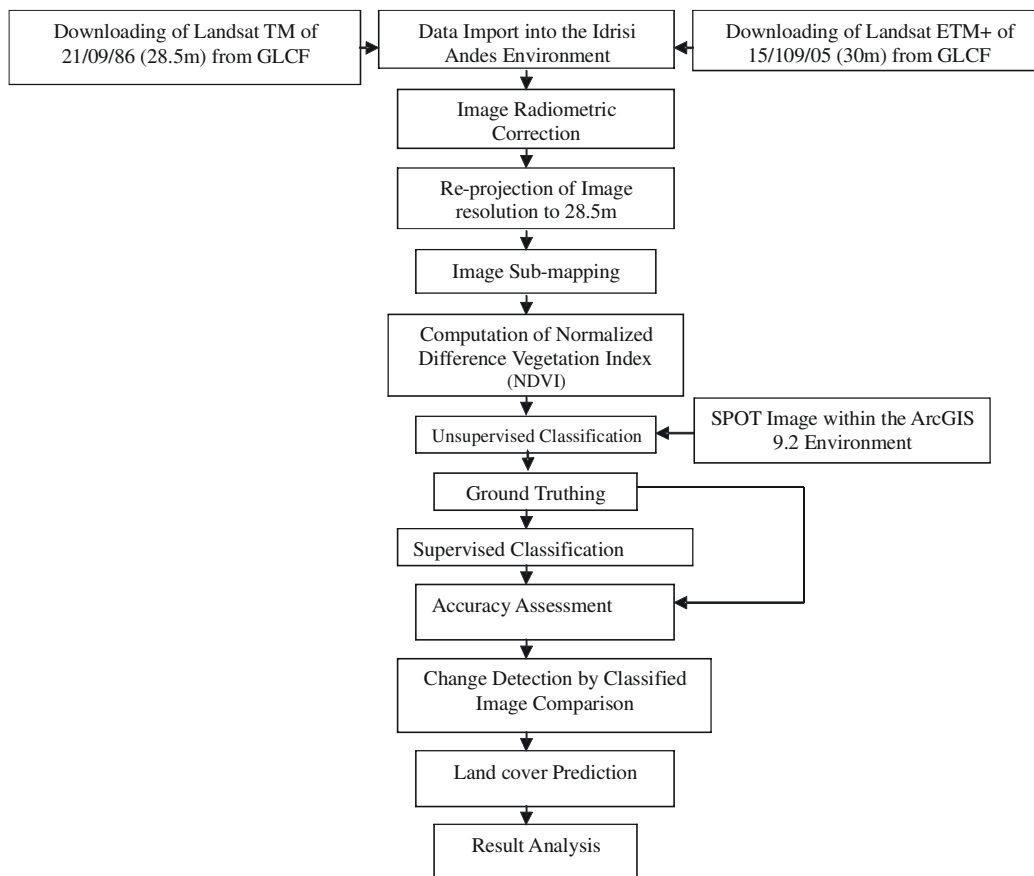


Figure 3: Flow Chart for the Method

Normalized Difference Vegetation Index (NDVI) (Figure 4) was computed for each year, followed by unsupervised classification (Figure 5). Figure 6 is a SPOT image of 2007 used for labeling the classes. A ground truth exercise capturing 150 training sites was carried out for the supervised classification of the NDVI images (Figures 7 and 8).

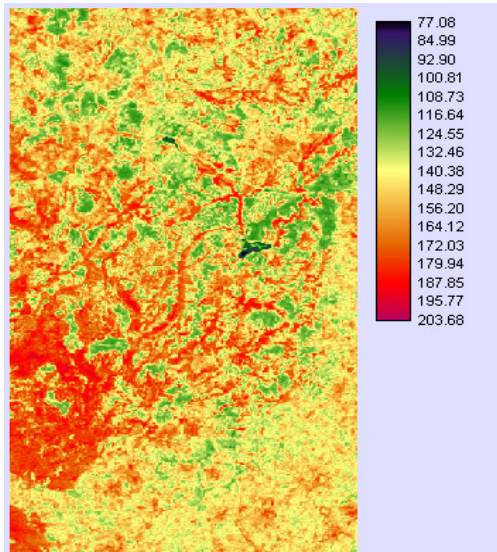


Figure 4: 2005 NDVI Image

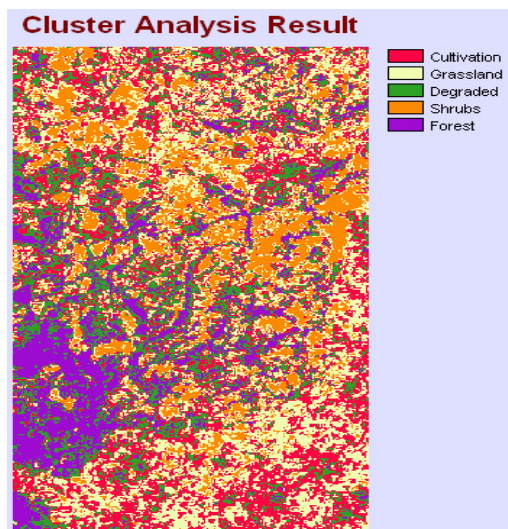


Figure 5: 2005 Classes by Unsupervised Classification

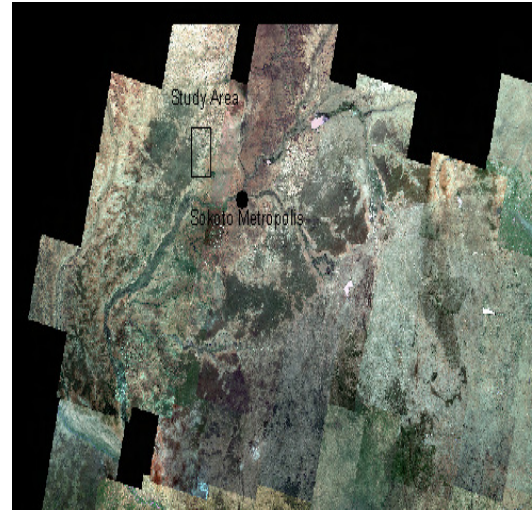


Figure 6: SPOT Image Used for Land Cover Classification

According to Janssen (2004) the optimal size of the sample depends on the heterogeneity of the classes. Therefore, since the classes are not many, 52 Ground Control Points (GCPs) were selected randomly from classes of the 2005 classified map for classification accuracy assessment. The *Errmat* module of Idrisi was then used to perform the accuracy assessment by comparing the ground-truth observed classes and those in the 2005 classified map. The overall accuracy of the classification is 88% (Table 1). This value is a little above the global minimum of 85% (Munyati, 1999).

The area coverage (in hectare) of all the classes in each year was evaluated and change detection by gains-and-loss method (trade-off analysis) was carried out. Assessments of the trade-offs between forest class and other classes were also ascertained. The classified maps were later submitted for MARCOV-Chain Analysis to predict the land cover for the year 2020. According to Eastman (2006), MARCOV analyzes a pair of land cover images and outputs transition and probability data.

Results and Discussion

Figures 7 and 8 show that the study area was classified into five classes for each date namely bare surface, Shrub-Grass, Tree-Shrub, Forest and Cultivation, with classification accuracy of 88% as shown by the overall Kappa Index of Agreement (KIA) in Table 1. The KIA measures the degree of agreement between classes observed on the field and those on the classified map of 2005.

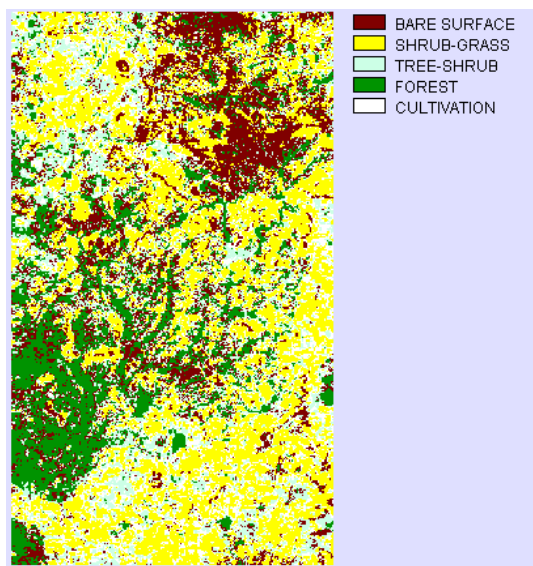


Figure 7: 1986 Land cover Classes

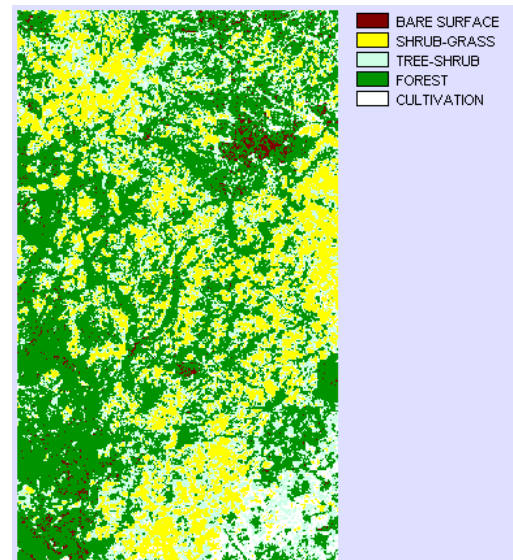


Figure 8: 2005 Land cover Classes

Table 1: Error Matrix Analysis of MAT (columns: truth) against LANDCOVER_2005 (rows: mapped)

	1	2	3	4	5	Total	Error C
1	9	0	0	0	1	10	0.1000
2	0	9	0	1	0	10	0.1000
3	0	1	10	1	0	12	0.1667
4	0	0	0	9	0	9	0.0000
5	1	0	0	0	10	11	0.0909
Total	10	10	10	11	11	52	
Error O	0.1000	0.1000	0.0000	0.1818	0.0909		0.0962

KAPPA INDEX OF AGREEMENT (KIA)

Using LANDCOVER_2005 as the reference image

Overall Kappa = 0.8799

From Figures 7 and 8, it can be seen that forest cover had the largest area coverage in 1986 (8,500 hectares) but the class became constricted south-westwards in 2005 to 2,900 hectares, representing 66% reduction in size. The bare surface, which was 300 hectares in 1986, expanded to 3,400 hectares (1,033% increase) through the forest from the north in 2005, and more of the forest got converted into shrub-grass

category in the latter year. The shrub-grass increased from 3,750 hectares in 1986 to 5,800 hectares in 2005 (55% increase), cultivated area increased from 750 hectares in 1986 to 2,780 hectares in 2005, representing 271% increase. The tree-shrub class reduced from 4,500 hectares in 1986 to 2,600 hectares in 2005 (42% decrease). The trade-offs among the classes between 1986 and 2005 are further presented in Figure 9.

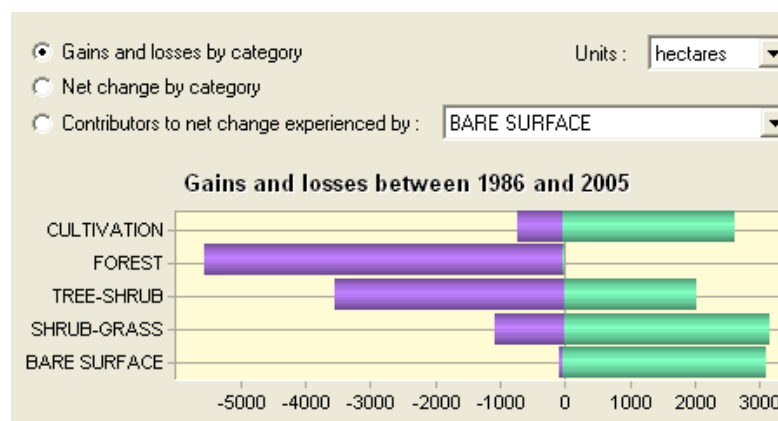


Figure 9: Trade-offs between Forest and other Land Cover Classes
Source: Generated within the Land Change Modeler Tool of Idrisi Andes

Figure 9 shows that cultivation lost about 750 hectares and gained 2780 hectares, while forest lost about 5,600 hectares but did not gain any space. The tree-shrub lost about 3,500 hectares and gained 2,000 hectares, while shrub-grass lost about 1,150 hectares and gained 3,200 hectares. The bare surface lost 0 hectares but gained 3,000 hectares. These show that all the classes lost and gained spaces to and from one another with the exception of the forest that lost without gaining. The forest had the highest loss without gain. Tree-shrub class had the second highest loss and the second least gain. The highest gainers but least losers are bare surface, cultivation and shrub-grass. Figure 10 also presents how the forest loss of 5,600 hectares was shared among bare surface, tree-shrub, shrub-grass and cultivation between 1986 and 2005. 23.5% of

the forest got converted into bare-surface, 18.8% into tree-shrub, 11.8% into shrub-grass and 10.5% into cultivation. From the above, it can be seen that the major contributor to forest degradation is bare surface. The bareness is a direct consequence of anthropogenic consumption and disturbance of the forest resources without replacement. The surface, with slow rate of regeneration, is consequently predisposed to soil erosion, aggravated by climatic influence.

Figure 11 presents the result of the land covers predicted for the year 2020. From Figure 11, forest cover is expected to further reduce from 2,900 hectares in 2005 to 1,500 hectares by 2020, representing 48% reduction, while tree-shrub will reduce from 3,000 hectares in 2005 to 2,600 hectares by 2020 (by 13.3%).

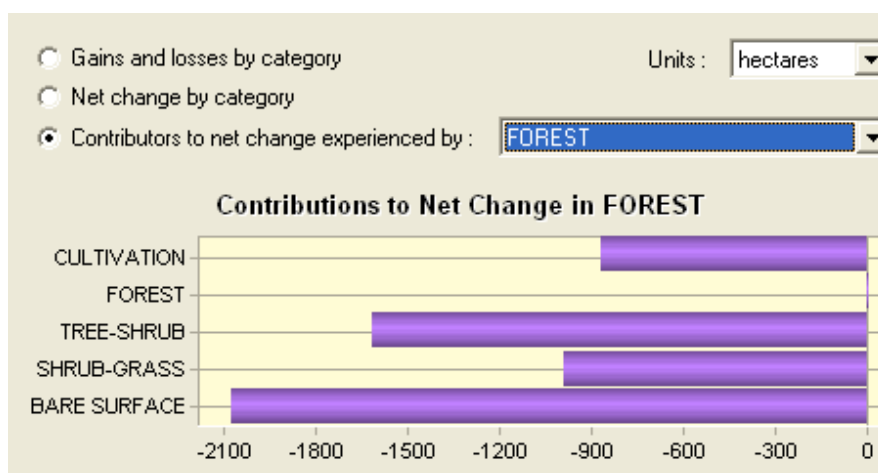


Figure 10: Loss of Forest to other Land Cover Classes
Source: Generated within the Land Change Modeler Tool of Idrisi Andes

Cultivated land is expected to increase marginally from 2,780 hectares in 2005 to 2,800 hectares by 2020, representing 0.01%, while shrub-grass will increase from 5,800 hectares in 2005 to 6,800 hectares by 2020 (by 17.2%). The bare surface is expected to increase from 3,400 hectares in 2005 to 3,900 hectares by 2020, representing 15% increase.

Figures 12, 13, 14, 15 and 16 compare the land covers for 1986, 2005 and 2020. It is evidently clear from these data that forest and tree-shrub categories have downward trends, while other classes have upward trends.

The downward trends in Forest and Tree-shrub suggest degradation and further desertification. It is also clear that the forest is tending towards extinction in the study area. Cultivation is a potent factor of this phenomenon. As the population around the study area increases, so will the need for space for cultivation. Field work revealed that cultivation, animal rearing, fuel wood extraction, bush burning are grossly responsible for forest degradation in the study area. Man's interaction has domino effects on the environment. Human practices that lead to forest degradation result in exposure of the land to erosion, thereby reducing the fertility of the soil and eventual reduction in agricultural productivity. Furthermore, it leads to reduction in the carbon content of the landscape for increase in the atmospheric carbon, the consequence of which is increase in the intensity of global warming. Reductions in rainfall and water quantity, sporadic flooding, water quality problem, loss of biodiversity, among others, are also concomitants of global warming (UNEP, 2009; UNFCCC, 2007).

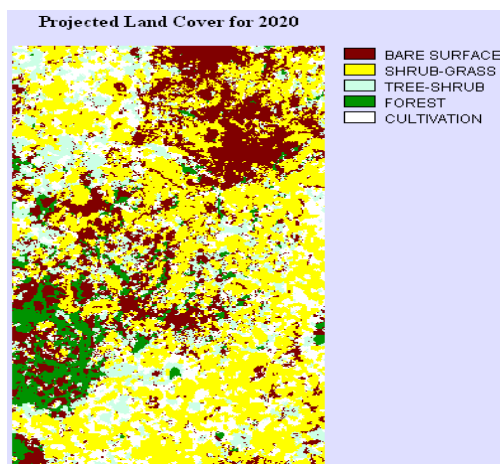


Figure 11: Predicted Land Cover for 2020

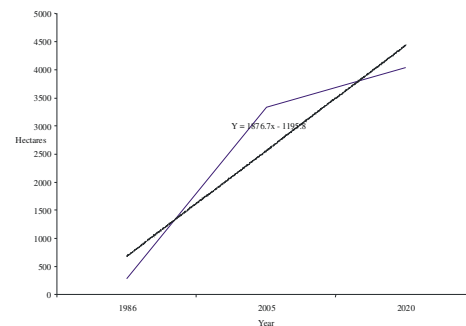


Figure 12: Bare surface Trend

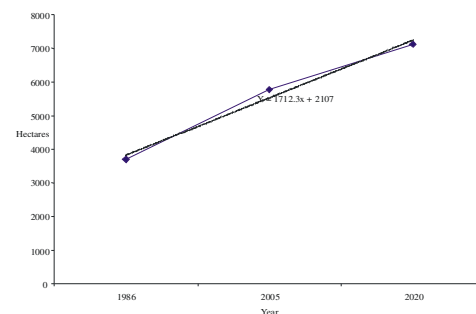


Figure 13: Shrub-grass Trend

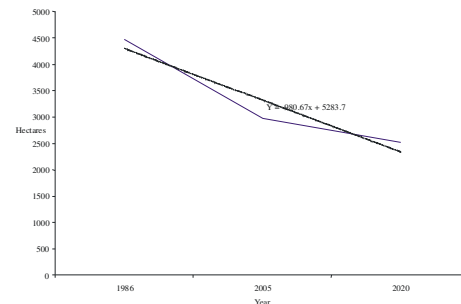


Figure 14: Tree-shrub Trend

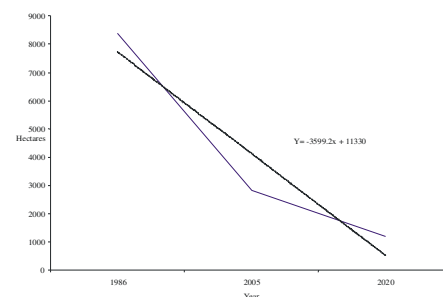


Figure 15: Forest Trend

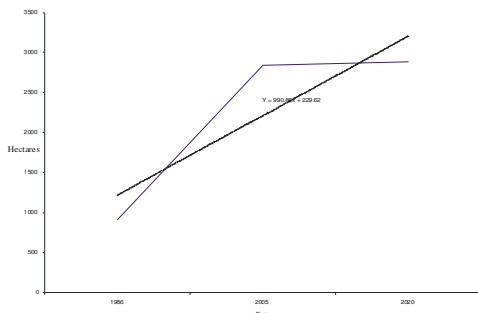


Figure 16: Cultivation Trend

Conclusion

The classification performed yielded 88% overall accuracy and produced five classes, namely cultivation, bare-surface, shrub-grass, tree-shrub and forest. Between 1986 and 2005, bare-surface expanded by 1,033% and will further expand by 15% in 2020. The shrub-grass expanded by 55% and will expand by 17.2% in 2020. Tree-shrub reduced by 42% between 1986 and 2005 and will further reduce by 13.3% in 2020. Cultivation expanded by 271% between 1986 and 2005 and will marginally expand by 0.01% in 2020. The forest cover reduced by 66% between 1986 and 2005. The class will further shrink by 48% of its size in 2005 by the year 2020. Also, between 1986 and 2005, 23.5% of the forest got converted into bare surface, 18.8% into tree-shrub, 11.8% into shrub-grass and 10.5% into cultivation.

Results from this study have shown that the Tangaza Forest Reserve is undergoing perpetual degradation due to human activities. Also, the regeneration is not in pace with the deforestation between 1986 and 2005, an indication that the forest is not well managed. According to Ogunjobi (2009), the Sahara and semi-arid parts of Africa a region to which the study area belongs would warm by as much as 1.6⁰C by the year 2050. Going by the trend of forest loss in the study area, the forest would totally have gone into extinction by 2050, making the effects more biting on biodiversity. Therefore, it is recommended that public enlightenment be made to raise the consciousness of the people for a better disposition to tree planting. Also, tree planting should be matched with establishment of cattle ranches to curtail the movement of animals which results in

soil and vegetation loss. Improved farming practices (e.g. Agroforestry) that are friendly with the environment should be introduced to farmers. Kerosene price should be made affordable so as to reduce the pressure on the existing but fragile forests. More forest guards and personnel should be employed, towards improved forest management.

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