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Assessing Changes in Kagoro Forest, Kaduna State Nigeria using Remote Sensing and Gis

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Abstract: Already georeferenced satellite imageries for 1987, 1994 and 2005 were used to study the land cover changes in the Kagoro forest. The results of the study revealed that settlement and cultivated area increased between 1987 and 2005 by 72 and 17.77% respectively while undisturbed forest decreased 24.06%. This result shows a significant depletion of the Kagoro forest as a consequence of human activities particularly cultivation for agricultural purposes. At the present rate, the forest is in danger of being destroyed and laid bare in the nearest future. This trend has implication for global carbon dioxide loading and temperature.

Key words: Land cover, forest, cultivation, carbon dioxide, temperature, settlement

INTRODUCTION

Pressures on forest especially in the tropical world, to provide economic resources have been increasing rapidly as a consequence of burgeoning population in the region. This has led to unabated deforestation, which has been recognized as one of the major drivers of biodiversity loss as well as a threat to the existence of the global ecological lung (Salami, 2006). According to FAO Forest Resource Assessment (2005) each year about 13 million hectares of the world's forests are lost due to deforestation, but the rate of net forest loss is slowing down, thanks to new planting and natural expansion of existing forests. From 1990 to 2000, the net forest loss was 8.9 million hectares per year. From 2000 to 2005, the net forest loss was 7.3 million hectares per year - an area the size of Sierra Leone or Panama and equivalent to 200 km^2 per day. Primary forests are lost or modified at a rate of 6 million hectares per year through deforestation or selective logging. Plantation forests are established at a rate of 2.8 million hectares per year. The ten countries with the largest net forest loss per year between 2000 and 2005 (Brazil, Indonesia, Sudan, Myanmar, Zambia, United Republic of Tanzania, Nigeria, Democratic Republic of the Congo, Zimbabwe, Venezuela (Bolivarian Republic of)) had a combined net forest loss of 8.2 million hectares per year. Thirty-seven countries and territories lost 1 percent or more of their forest area each year between 2000 and 2005, while 20 countries gained more than 1 percent per year due to natural expansion of forests and afforestation.

In Nigeria, about 350,000 to 400,000 hectares of forest is being lost per annum (Oyebo, 2006). This situation is brought about by over exploitation due to the demand for food, energy and fodder and also through illegal logging and non-replacement of the natural vegetation. The energy and the high cost of kerosene have caused recourse to firewood as an alternative source of energy for domestic uses. A dimension is added by the felling and burning of wood to produce charcoal and this is causing serious depletion of forest resources. According to Oyebo (2006) Nigeria has a total of 1,160 constituted forest reserves, covering a total land area of 10, 752,702 hectares, representing about 10% of the total land area. Most of the forests in Nigeria are man-made for the purpose of timber exploitation, and in some cases for fuel wood and furniture making industries. The total plantation hectarage in Nigeria was estimated at 269,000 hectares in 1988. They compose of 109,377 hectares of *Gmelina arborea* and 159,623 hectares of others. The *Free areas*, which are land use types located outside forest and games reserves are 9,136,726 hectares. These have major forest types dominantly trees/woodlands/shrubs (5,611,392 ha), lowland rain forest (1,187,488 ha) and freshwater swamp forest (1,430,175 ha) (Oyebo, 2006).

Forests are important in the maintenance of an attractive forest environment, provision of opportunity for relatively intense outdoor recreation, provision of habitat for wildlife, watershed function, general conservation including minimization of soil erosion and the production of wood for various uses (Aweto, 1990). Forest also serves as effective sink for carbon dioxide and releases oxygen from its photosynthetic activity.

The Kagoro forest is a natural rain forest type of vegetation within the savannah. This is because of the location of the forest on the south-western slope of the plateau. Kagoro is on the windward side of the plateau thereby experiencing more rain than the surrounding environment. The forest is located between 9º22 and 9º35 and 8º11 and 8º24 in Kagoro District of Kaura Local Government Area of Kaduna state. The area is located in

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the sudan savannah which characteristically experiences the tropical wet-dry climate with about seven months of rainfall between April and October and five months of dry season from November to March. The vegetation is a mosaic of savannah and forest with forest occurring mainly in river and stream valleys, but also elsewhere due to high annual precipitation of more than 1,550 mm (Ezealor, 2001, 2002). The district is recognized as one of the centres for agriculture which provides raw materials for industrial use and commerce especially in the southern part of Kaduna state, and as such the area has been attracting an appreciable amount of developmental services. In response to this, several transformations have taken place in such sectors. For instance, growing industries require raw materials for their manufacturing hence endangering the Kagoro forest; they also need to site their industries close enough to their raw materials, and housing quarters may also have to be built for such workers. Since such sectors have direct bearing with the land, it is expected that their developments would be associated with the land cover changes in the area.

The present state of the Kagoro forest hence has a lot to do with the growing local industries especially carpentry where trees are felled and used to make furniture for offices, and homes and also for the building industry, because many people have left the interior villages to settle in Kagoro, Kafanchan and other neighbouring towns and want to build houses, build companies and industries, so the forest has been continually tampered with. This is apart from the growing prices of fuel and fuel products leading to the cutting of trees for cooking and keeping warm during the cold dry season.

The effects of deforestation manifests in the loss of biodiversity, loss of soil fertility through loss of nutrients, desiccation of previously moist forest soil, dramatic increase in temperature extremes, more desertification, less carbon dioxide and nitrogen exchange, loss of effective sink for carbon dioxide enhancing global warming and climate change.

In light of the potential negative effects of such changes on land quantity, quality and productivity, information on the nature and magnitude of such change is certainly needed. This study on the land use/land cover changes in the Kagoro forest though on a smaller scale will provide data on the rate at which forest resources are being depleted globally. Locally, providing data on land use/land cover changes and encroachment of other land use types into the forest will help in identifying the area, rate and extent of the degradation of the forest. It will also assist in the review of already proposed and ongoing land development plans.

This study involves the use of GIS and remote sensing to assess changes in Kagoro forest, Kaduna State, Nigeria.

MATERIALS AND METHODS

Data: Data was acquired from Land sat TM (30m resolution) imageries 1987 (Fig. 1).
SPOT XS (20m resolution) 1994 (Fig. 2)
Land sat ETM (15m resolution) satellite 2005 (Fig. 3).

Software: Earth Resource Data positioning System (ERDAS) version 8.3.1,
Arc View 3.2a

The imageries were already geo-referenced to UTM mode; this process involves relating the coordinates of the study area to that of the map (that is relating coordinates on map to those on the ground). The imageries came in scenes, with one scene larger than the study area, in order to get the study area; the outline of the coordinates of the study area was used to subset the scene to get the outline on the imageries. The process of subset is getting the study area through the whole area.

Interpretation: Onscreen visual interpretation was done; the process of digitization was automatically done together with the interpretation using Arc View 3.2a. First there was a creation of sample map which indicated a domain, then impact data from the 1987, 1994 and 2005 maps was done after which four basic categories were classified. These categories include; cultivated area, rock outcrops, settlements, and the undisturbed forest, an interpretation key was used to help in the identification of the features to be identified and interpreted (Fig. 4-6).

The first to be interpreted was the cultivated area as it is also described and identified by the presence of regular patterns of defining light red colour indicating crops, at other times very light reflectance were observed indicating bare surfaces for harvested fields. Secondly, the rock outcrops were identified and interpreted as irregularly shaped, exhibiting very fine texture. The colour is greyish, and the reflectance could either be dark or light depending on the mineral constituents of the rock. Thirdly, the settlements were identified and also interpreted as mostly irregularly shaped and usually linked by road networks. They are also identified by their bluish green colour, which is reflective of the roof top materials. The fourth category to be identified and interpreted was the undisturbed forest, with irregular patterns and no signs of cultivation. It is very deep red in colour, which is associated with the chlorophyll content of fresh vegetation. The roads were identified and interpreted as the fifth category as linear features usually linking settlements. Light reflectance interpreted for un-surfaced roads, and dark reflectance for surfaced roads. The last to be identified and interpreted were the rivers, which were identified and interpreted as linear features, associated with several tributaries and are aligned by deep red reflectance indicating vegetation along the banks.

After these processes have been completed, corrections of overshooting and undershooting were

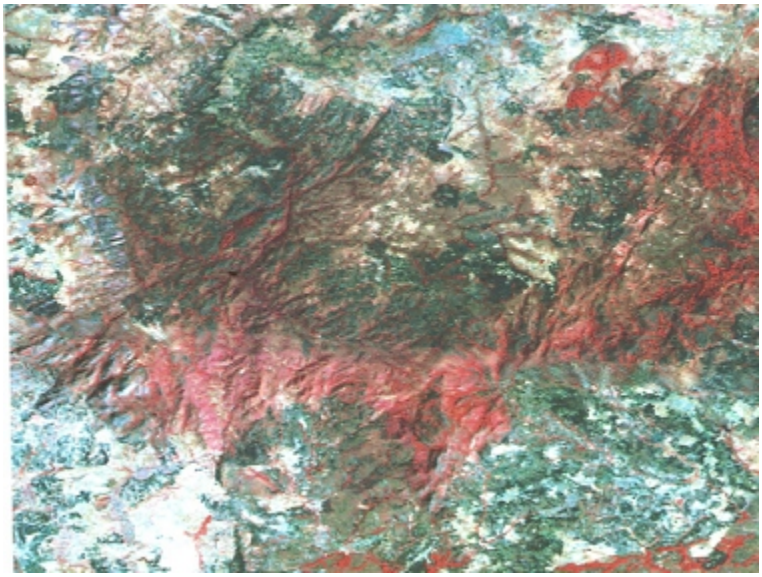

Fig. 1: Landsat TM (30m resolution) 1987 of the study area

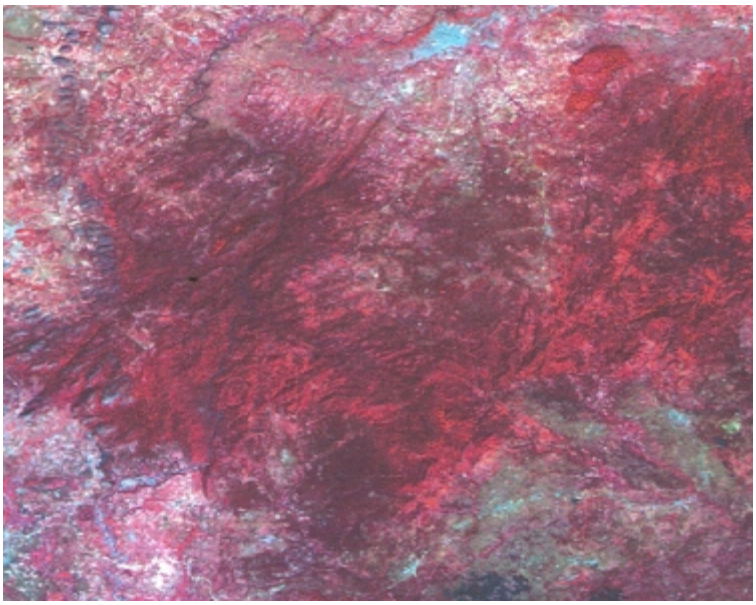

Fig. 2: SPOT Xs (20 m resolution) 1994 of the study area

made. This was followed by the creation of topology that is, the creation of database for land use/ land cover data. The database was created immediately after interpretation and corrections automatically. Two more fields were added to the polygons that were created without any interpretation; this had to be done to give it more meaning. These two created fields (code and description) were populated that means going into the database and assigning codes and description to the polygons of the database.

Field reconnaissance survey: Field reconnaissance survey was carried out and some pictures were taken at the forest site (Plates 1- 4).

Map composition: Here, north grid lines are coordinated to the map in which the scale is already assigned. This process involves overlaying the various layers of land use/ land cover of the various decades on a single map. This was done using colours to differentiate the various years and to clearly show the changes that occurred during

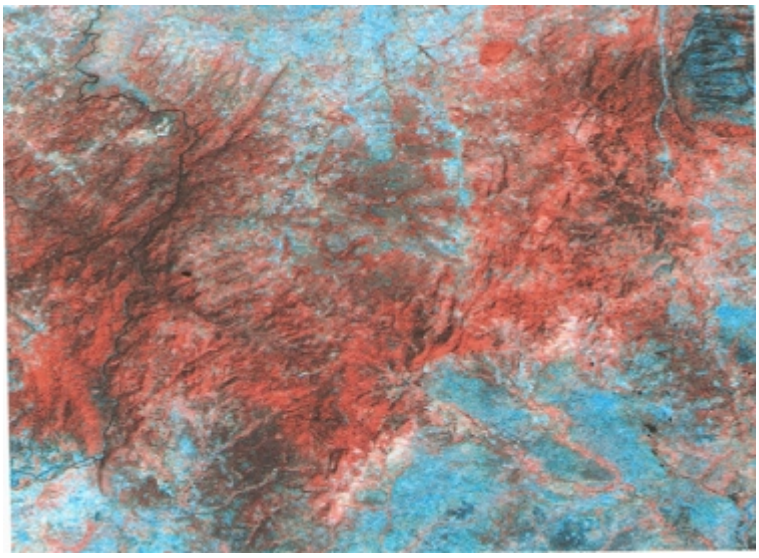

Fig. 3: Landsat ETM (15 m resolution) 2005 of the study area

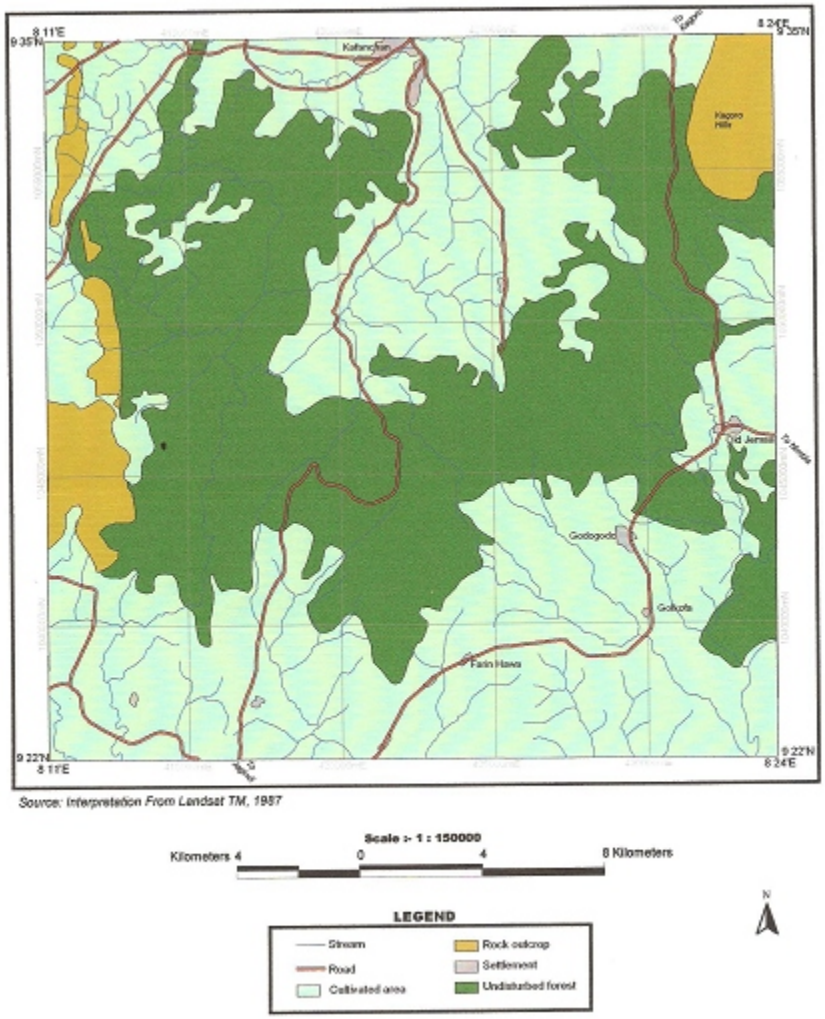

Fig. 4: Land use/land cover of the study area 1987

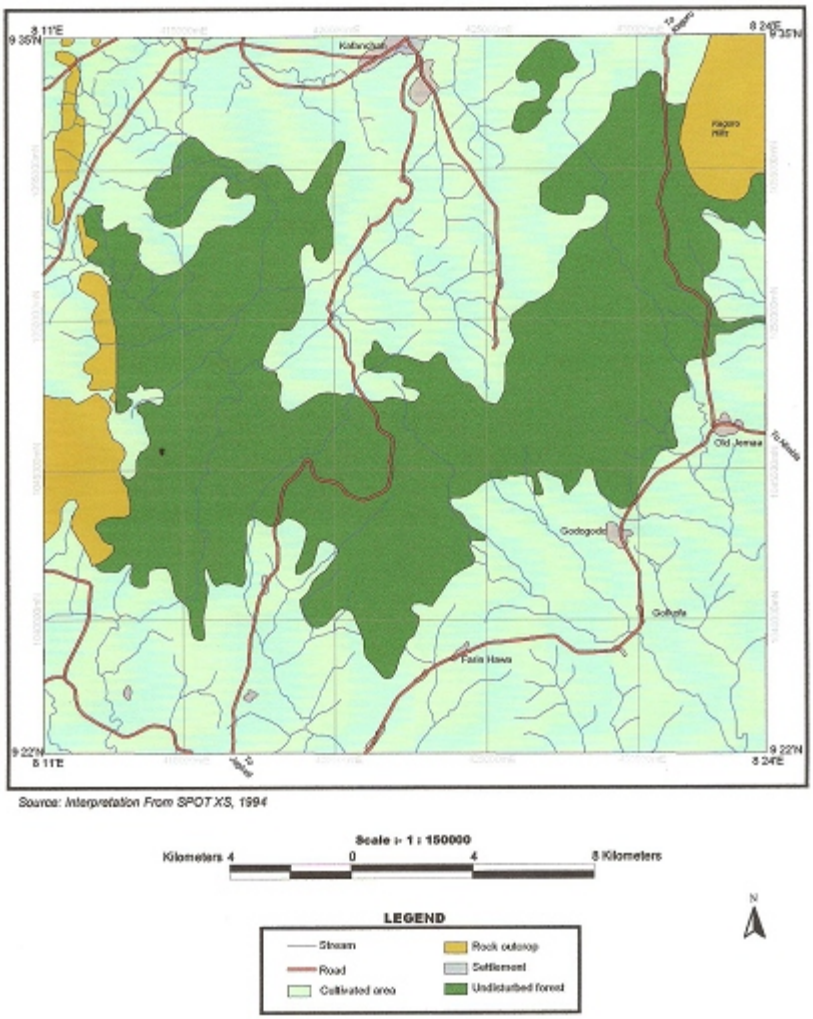

Fig. 5: Land use/land cover of the study area 1994

those years. Hence a legend was designed with the appropriate colours to represent the mapped features.

The different land use/land cover each had a separate map which showed the distinctions during the various decades depicted on the maps (Fig. 7-10).

Statistical method: The chi-square statistical method was used to detect the land cover changes in the Kagoro forest that can be noticed. The chi square analysis method can be used to show significant relationship within three variables that is more than two variables, in this case 1980s, 1990s and 2000s.
The formula is given as:

$$x^2 = \frac{\sum (Oi - Ei)^2}{E}$$

Where:
Σ = Summation sign
0 = Observed values for the various land use/ land cover categories
E = Expected values for the various land use/ land cover categories
i = Number of total values starting from 1
The formula for finding the expected values is given as;
Row total × Column total = Expected Value
Grand total used.

RESULTS AND DISCUSSION

Introduction: The relative distribution of land use/land cover categories in the study area in 1987, 1994, 2005 are presented in the Table 1- 4.

Cultivated area: The cultivated areas as shown in the maps are represented by a light green colour. In 1987, it covered about 303.23 Km^2 of the total area of 568.56 Km^2, consisting of about 53.3% of the total area studied. In 1994 the cultivated area has increased from 303.23

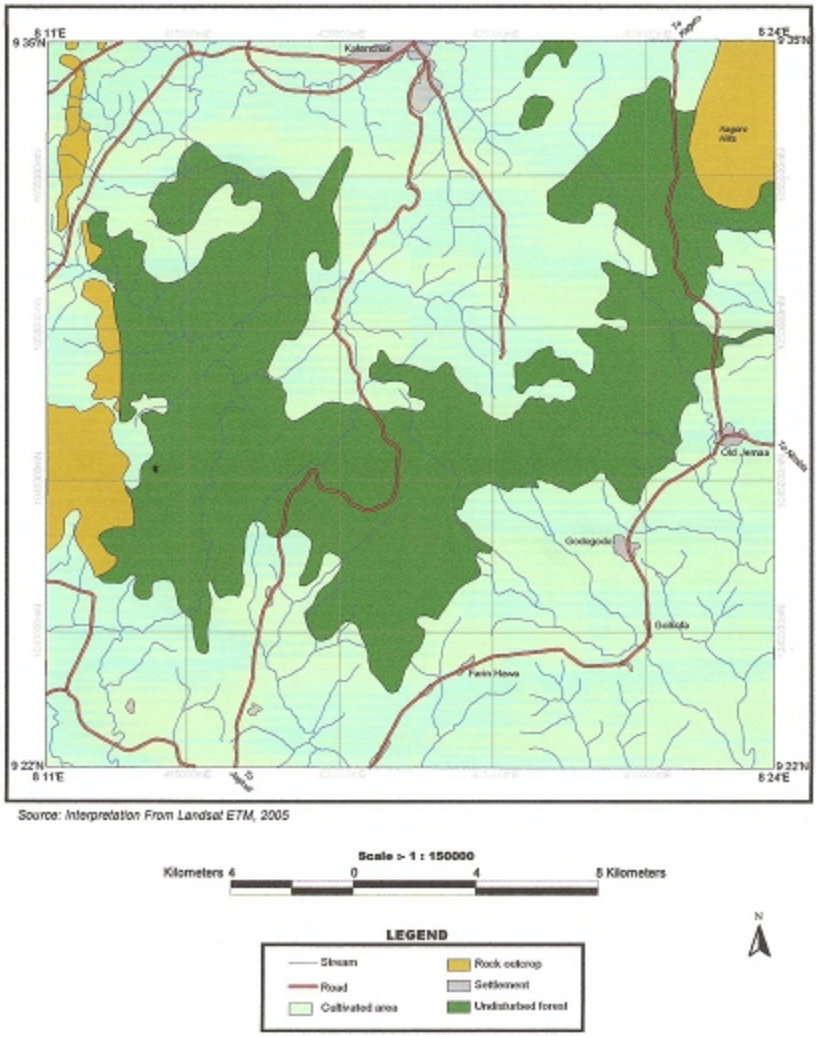

Fig. 6: Land use/land cover of the study area 1987

Km^2 to 341.60 Km^2 about 60.08% of the total area and increase of 12.65%. By 2005 the cultivated area has increased to 357. 357.1 Km^2 covering up to 62.81% of the total area (Table 1- 3). From 1987 to 2005 the increase in cultivated area was 53.87 Km^2, an increase of 17.77% (Table 4).

Rock outcrop: As shown on the maps in Fig. 4 - 6 the rock out crop is represented by a yellowish brown colour. The change in area covered by rock outcrop is marginal from 31.06 Km^2 in 1987 to 30.92 Km^2 , which is less than 1%.

Settlements: In Table 1, the total areas covered by settlement in 1987 are about 2.75 Km^2 (0.48%) of the total area. This increased to 3.95 Km^2 in 1994 0.7% of the total land area (Table 2). By 2005 areas covered by settlement increased to 4.73 Km^2 an increase of 72% (Table 4).

Undisturbed forest: As at 1987 the undisturbed forest covered an area of 231.52 Km^2 that is about 40.72% of the study area (Table 1). In 1994 the undisturbed forest decreased to 192.56 Km^2 about 33.87% of the total land area (Table 2). By 2005 the undisturbed forest has decreased to 175.82 Km^2 about 30.92% of the total land area (Table 3 and Plate 1). The land area lost by the forest as at 2005 was 55.7 Km^2 with percentage change of 24.06% (Table 4).

Table 1: Land use/Land cover statistics for 1987

Land use/Land cover category	Area (Km^2) 1987	Percentage Area
Cultivated area	303.23	53.33
Rock out crop	31.06	5.46
Settlements	2.75	0.48
Undisturbed forest	231.52	40.72
Total	568.56	100

Source: Land Sat Tm 1987

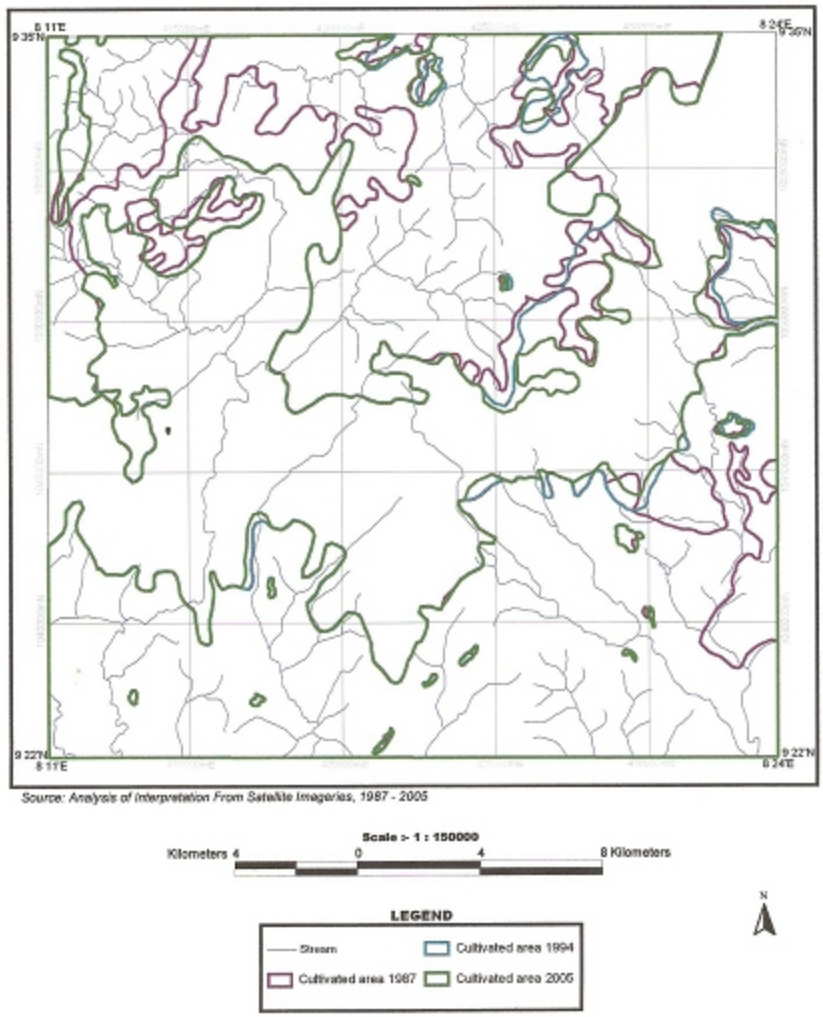

Fig. 7: A composite of cultivated area 1987-2005

Table 2: Land use/Land cover statistics for 1994

Land use/Land cover category	Area (Km^2) 1994	Percentage Area
Cultivated area	341.60	60.08
Rock out crop	30.88	5.43
Settlements	3.95	0.7
Undisturbed forest	192.56	33.87
Total	568.56	100

Source: SPOT XS 1994

Table 3: Land use/Land cover statistics for 2005

Land use/Land cover category	Area (Km^2) 2005	Percentage Area
Cultivated area	357.10	62.81
Rock out crop	30.92	5.44
Settlements	4.73	0.83
Undisturbed forest	175.82	30.92
Total	568.57	100

Source: Land Sat ETM 2005

Table 4: Change in land use/ land cover in the study area between 1987, 1994 and 2005

Land use/Land Cover category	Area (Km^2)		
	1987 (a)	1994 (b)	2005 (c)
Cultivated area	303.23	341.60	357.10
Rock out crop	31.06	30.88	30.92
Settlements	2.75	3.95	4.73
Undisturbed forest	231.52	192.56	175.82
Total	568.56	568.56	568.57

Magnitude Change and Percentages (%)

Change b a (Km^2)	(%) increase/ decrease (b-a/a) x 100	C - b (Km^2)	(%) increase/ decrease (c-b/a) x 100	C - a (Km^2)	(%) increase/ decrease (c-a/a) x 100
38.37	12.65	15.50	4.54	53.87	17.77
-0.18	0.58	0.04	0.13	-0.14	0.45
1.20	43.64	0.78	19.75	1.98	72
-38.96	16.83	-16.74	8.69	-55.7	24.06

Sources: Land Sat Tm 1987, SPOT XS 1994, LandSat ETM 2005.

Analysis of change: Showing at Table 2 it is observed that between 1987 and 1994, settlement had the highest magnitude of change with about 43.64% increase in the area used for settlement. This is followed by undisturbed forest with a 16.83 decrease in the area of undisturbed forest. Cultivated area increased by 12.65% while the

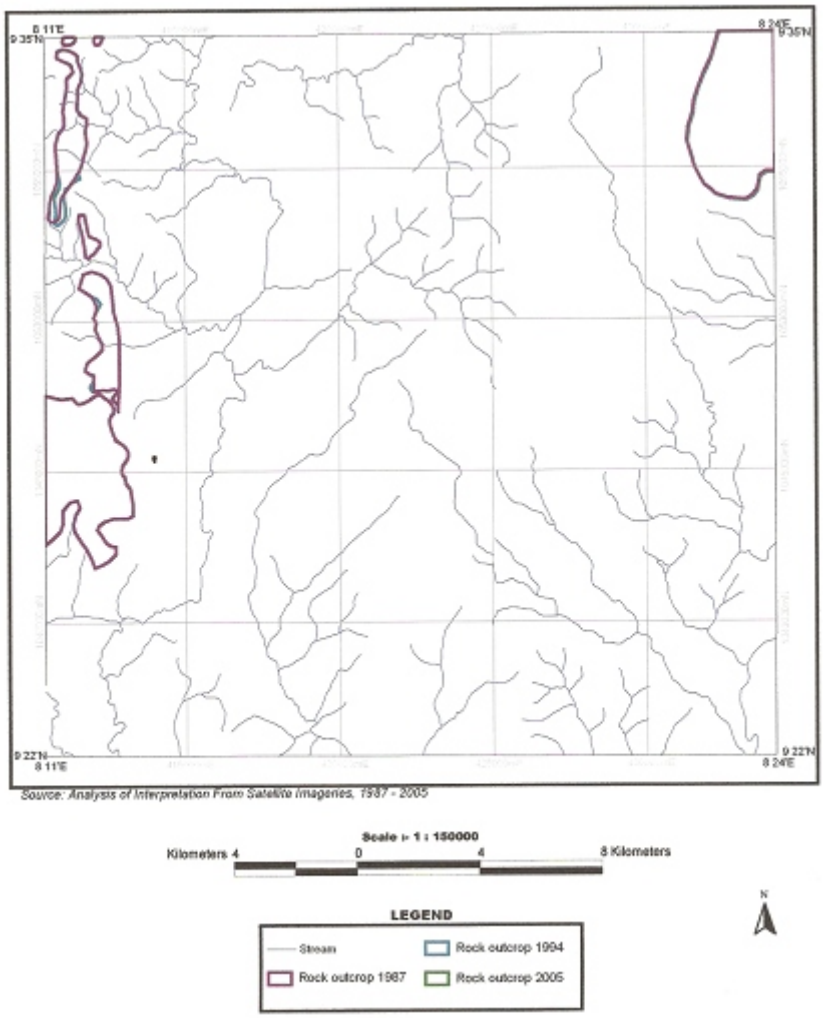

Fig. 8: A composite of rock outcrop 1987-2005

change in area of rock outcrop was minimal. Between 1994 and 2005, the highest change was in the land used for settlement with a percentage change of 19.7% followed by undisturbed forest with a change of 8.69% and cultivated area with 4.54%. The percentage change for observed land uses was higher between 1987 and 1994 compared to between 1994 and 2005. Generally, land under settlement increased from 2.75 Km^2 in 1987 to 4.73 Km^2 in 2005 a change of 72% while area of undisturbed forest decreased from 231.52 Km^2 in 1987 to 175.82 Km^2 in 2005 representing a change of 24.06%. Area under cultivation increased from 303.23 Km^2 in 1987 to 357 Km^2 in 2005 representing a change of 17.77%. The change in rock outcrop was less than 1%.

The results of the analysis of change are shown in Fig. 11. Looking at the composite bar graph, it is observed that the cultivated area generally occupies the largest land area followed by the undisturbed forest, Then rock outcrops and settlements. Comparing land use/land cover changes, it is observed that the cultivated area were increasing by the decades while the undisturbed forest was decreasing by the decades, rock outcrops were relatively constant. The area under settlement may seem to have increased slightly given the land area covered, but it is poses the greatest danger to the undisturbed forest for two reasons.

- Cultivation is a function of human settlement. As the settled areas increase, it is expected to increase the area brought under cultivation and a slight increase in settlements will cause significant increase in cultivated area.
- With a percentage change of 72% between 1987 and 2005 it means the settlement is building up at a very fast rate. It is expected, therefore, that very soon the area under settlement would have more than doubled impacting on the forest by also increasing the cultivated area.

Statistical analysis: The Chi Square test was used to test whether the change in land use/land cover was significant. The calculated χ^2 of 19.84 was greater than the table

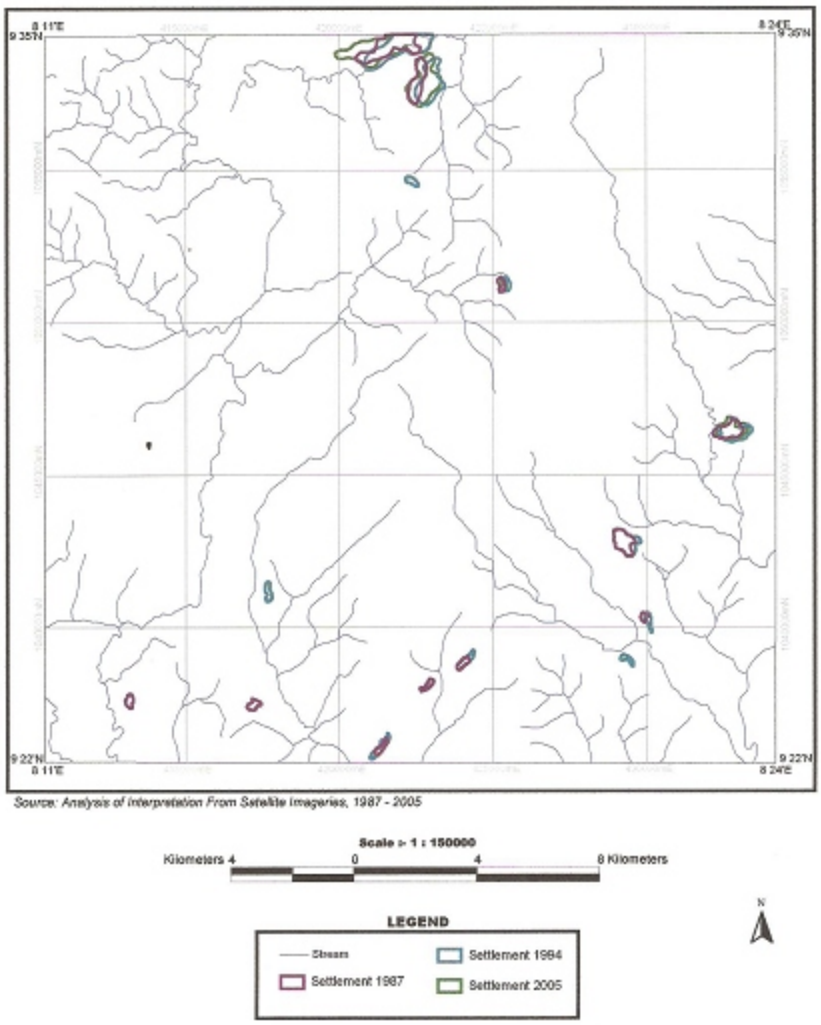

Fig. 9: A composite of settlement 1987-2005

value of 19.68 at the 0.05 level of significance. So, we can say that there is a significant change in the land use/land cover in the Kagoro forest.

DISCUSSION

There have been noticeable changes in the study area within the decades. The changes have led to the present state of the Kagoro forest. From the analysis the additional area used for cultivation between 1987 and 2005 is 53.87 Km^2. The additional land use by settlement is 1.98 Km^2 within the same period. The extra land taken by both cultivated area and settlement is minus the decrease in rock outcrop (0.14) is equal to 55.71 Km^2. This is exactly the land area lost by undisturbed forest within the period of study.

Generally, there is an increase in settlement and cultivated land (Plates 2 and 3).

Increased settlements mean higher population of people which amounts to more activities that lead to the degradation of the forest of study. However, there seem to be a decrease in the magnitude of loss of the undisturbed forest from about 16.83% (between 1987 and 1994) to about 8.69% (between 1994 and 2005). This is in agreement with FAO (2005) *Op Cit.* The activities of man has been known to be one of the major threat to the forest

Plate 1: Undisturbed forest

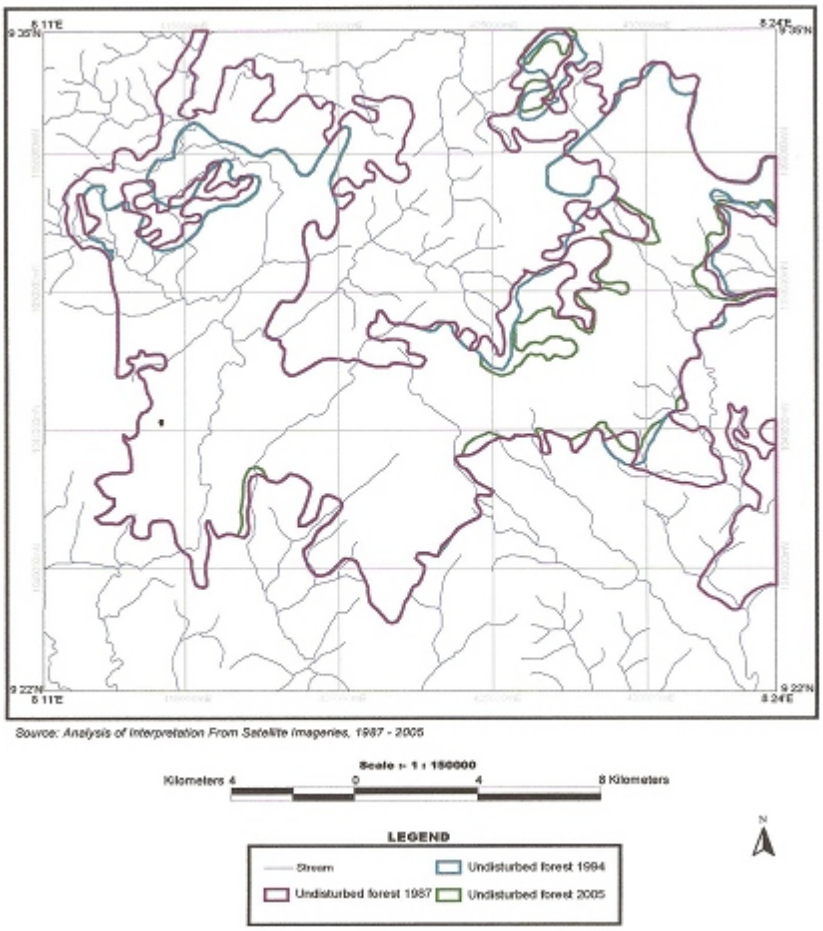

Fig. 10: A composite of undisturbed forest 1987-2005

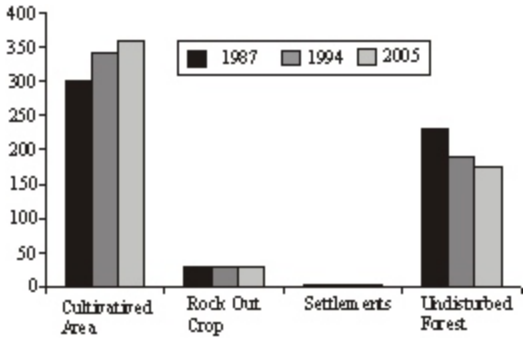

Fig. 11: Change in land use/land cover between 1987, 1994 and 2005

because, man always wants to make himself more comfortable and hence tries to use whatever is available to him within his environment and in this case the forest has been the target of man activities.

This also led to the increase in the cultivated areas and expansion of settlements. This change was very significant and this could be as a result of the increased

Plate 2: Encroachment of settlement and cultivation

Plate 3: Encroachment cultivation

Plate 4: Timber from the forest

number of settlements and the expansion of already existing ones, this is because man needs wood for various activities, the depletion of the forest is as a consequence of man need to build shelter using wood from the forest, the need to survive also leads to the felling of trees for fuel wood.

The forest has provided resources for the development of man and his environment, location of industries in the settlements may have added to other reasons or causes of the depletion of the forest, this could be in form of carpentry shops which have led to the felling of trees in the forest to make furniture of various kinds for homes and offices.

Kagoro as an economic area also have trading activities between Kagoro and Kaduna, Jos and other neighbouring towns. The larger cities come to collect trading products from the indigenes of Kagoro and one of these products is timber (Plate 4), large companies also demand classy furniture for their offices hence the movement of logs of wood. The people of Kagoro are also known for their traditional medicines and have the assorted leaves and bark of trees for this practice in the forest. Hence, the damaging of trees by peeling of the barks which if continuous will weaken the trees and expose them since their protective cover has been removed.

Also, the present energy crisis has led to the increasing demand for firewood as an alternative source of power. The firewood from the area is transported to as far as Katsina, Kano and other neighbouring states. The impact of this on the forest is significant as the surviving forest trees are being felled and used for fuel wood. Associated with this is the production of charcoal for domestic uses. A lot of trees within the forest are felled and burned to produce coal which people feel is faster in cooking, non smoky and cheaper than actual fire wood.

Environmental impact of the loss of the forest: Rao (1990) and Public Reference Bureau (2001) have itemised the danger of deforestation to the continued sustainability of the resources of the earth to include: increase in atmospheric carbon oxide (CO_2); increase albedo leading to imbalance in energy balance between the atmosphere and land; less precipitation; high temperatures and greater flooding with possibility of reducing underground recharge; soil erosion and sedimentation of river channels; loss of food medicine and fuel; declining crop yields; loss of vital soil nutrients and degradation of surrounding ecosystems; spreading of tropical diseases; reduced quantities of safe water; exacerbating climate change; and less aesthetic values and natural beauty.

Important also is the loss of biodiversity leading to loss or change in both plant species and fauna (Balmford *et al*., 1994; Abalaka and Manu, 2007).

For these reasons the forest ecosystem must be saved from total destruction by the activities of man.

CONCLUSION

The Kagoro forest like other forests worldwide is of both economic and environmental consequences. However, human encroachment by way of settlement and cultivation is threatening the existence of the forest. If the present trend continues unabated the forest may disappear in no distant time. Though the rate of disappearance is not measured in this research it is obvious that the land uses of settlement and cultivation are increasing at a significant rate. The signs of depletion of the forest are already obvious from the satellite images analysed. Subsequent analysis might reveal further deterioration. The implication of the deterioration of the forest on the environment is serious unless something urgent is done to arrest the trend.

To arrest the trend there is need to improve the energy sector of the economy particularly as it relates to the adequate provision and distribution of electricity. This would reduce the dependence on firewood and charcoal as sources of energy.

There should be strict legislation to protect the forests from undue exploitation. There is also the need for the local communities to protect their forests from undue exploitation. Active surveillance is more effective when it is community based. There are a lot of Non-Governmental Organizations (NGOs) and Community Based Organizations (CBOs) established for one form of activity or the other. But it is not common particularly at the community level to hear of an organization solely for the protection of our forests apart from the Governmental efforts which most times are not effective.

Reforestation is good option in replenishing the forests of the world but reforestation cannot bring back or correct the loss of original vegetation and species of fauna. So, it is better to leave the forest undisturbed and seek alternative sources of satisfying some of the developmental needs.

Remote sensing and GIS has provided an effective tool for monitoring changes in the environment but these tools cannot correct any anomalies in the ecosystem. It is still left for man to take steps that would check the deterioration of these natural systems.

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