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Land cover response to changes in forest resources utilisation in South-Western Nigeria: GIS Perspective

Orimoogunje, O.O.I

Department of Geography,
Obafemi Awolowo University, Ile-Ife, Nigeria,
orimoogunje2@yahoo.comor ooorimoogunje@oauife.edu.ng

Abstract:

This study documents the extent of resource use and the level of degradation consequent upon land use with the aid of remote sensing and GIS technology. The study integrated a topographical map of 1969 and satellite imageries from Landsat MSS 1972, and Landsat TM 1991 and 2000 with ground truthing, fauna inventory and socio-economic surveys to assess changes in forest resource use and land cover in Oluwa Forest reserve, South-western Nigeria. The study area was demarcated on the map through gridding techniques which led to the selection of hundred quadrants were by adopting the table of random numbers. Digital image processing was carried out for satellite imageries. Land uses were identified and classified from the satellites imageries using ILWIS 3.4 software. Supervised classification was adopted and the maximum probability algorithm was used to classify the land covers in to the arable crop, tree crop, exotic tree plantation, dense forest and settlement/open space. Result shows that agricultural land uses which were non-existent in 1972 increased three folds from 8,176 hectares (4.43%) in 1991 to 112,172 hectares (60.72%) of the total land area in year 2000, while settlement increased by about six folds from 4932.6 hectares in 1972 to 30,911 hectares (16.73%) in the year 2000. The study concludes that the advance of remote sensing technology offers improved accuracy of environmental monitoring and analysis.

Keywords: Forest resources, land use, land cover, human activities, GIS, sustainability

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Introduction

Man's dependence on the forest is indispensable. It is therefore reasonable to assert that without the forest, man's life can be drastically affected. Forests play key roles in production and serve as food and medicine necessary for man's survival. Forest wood is useful for construction and is a major source of energy. The roots of forest trees bind the soil together and prevent erosion, landslide, etc. The forest also serves as habitat for animals and birds.

Vegetation, soils, animals, water, climate, in short, all major components of the biosphere, have been profoundly altered by human activities. The destruction of the forest cover has both direct and indirect consequences. Some of the direct effects include the reduction of timber and firewood stock, disruption of regional and global balances of carbon and reduction of genetic diversity (Salami, 1995; Dixon, 1996; Adesina, 1997). In order to preserve the original tropical rainforest in southern Nigeria some areas were designated as forest reserves especially during the colonial period. Generally, these reserves are protected by legislation against agricultural activities, human occupation and illegal logging. But the establishment of forest reserves has suffered some setbacks arising mainly from the fact that harvested trees were never replaced as originally planned. Indeed, many states have virtually abandoned the management of their forest reserves (Orimoogunje, et. al, 2009). This is threatening the survival of the remaining forests.

The purpose of converting natural vegetative cover is driven by demand for land (Walker and Homma, 1996). It was further revealed that the demand for land leads to productive land use, the dedication of the land factor to particular forms of agricultural production which use required groundcover manipulations, such as deforestation. In order to keep the forest reserves and sustain their productivity, fast growing exotic trees were introduced as components of forest reserves. In South-western Nigeria, teak (*Tectona grandis)* and gmelina (*Gmelina arborea)* are the two most widely cultivated species in forest reserves (Adesina, 1997). The growing of fast growing exotic species has been concentrated mostly in the degraded areas of the reserves. Forest exploitation has everywhere exceeded rate of regeneration (Orimoogunje, et al., 2009). The effect of land use on Nigeria's forest is that Nigeria, which in 1897 had 60 million hectares of forests and woodlands now has roughly 9.6 million hectares of forest reserves, much of which are degraded, and only 2.4 million hectares are in the forest zone – a loss of over 50 million hectares in less than 100 years (Nwoboshi, 1986). Between 1981 and 1985 closed forest was being converted at the rate of 5% per year in Nigeria (WRI, 1987). The socio-economic implications of these deforestation processes are quite disturbing. Acute shortage of both industrial

timber and fuel wood are already being experienced while deforestation is also robbing the country of numerous shrubs and herbs of food and medicinal values, as well as valuable plant genetic resources (NEST, 1991; Abe, 1995; Adesina, 1997; Orimoogunje, 2000:2005; Orimoogunje, et al., 2009). The loss of biodiversity and the genetic resources can be imagined from the list of 484 species in 112 families compiled by Gbile et al (1981) as endangered plant species.

Demand for industrial wood products has risen in developing countries along with demand for fuel-wood, the main energy source for many rural communities (FAO, 1999). Uncontrolled timber exploitation, agriculture and urbanization are the major factors responsible for the rapid drain of forest gene pool in Nigeria (Ola-Adams, 1981; Adesina, 1997; Ostrom, 1998; Orimoogunje, 1999). These tripartite evils account for a large proportion of the progressive depletion and destruction of the forest estate. The destruction of the natural forest is now apparent that there is widespread consensus for conservation and effective management to restore the ecological balance and to provide for human needs.

Land cover plays a major role in many environmental models that represent processes and connections between surface and atmospheric processes, which modify the energy balance (Shimmabukuro, et al., 2010). Changes in land cover represent significant threats to ecosystem sustainability, particularly when the naturally vegetated forms give way to human use. Ojima et al (1994) were of the opinion that such conversions reduce the availability of energy, water, and nutrients to ecosystems, facilitate the invasion of exotic species, and generally speed up natural change processes. Therefore, the purpose of this paper is to examine the potential of Geographical Information System (GIS) in assessing and monitoring forest resources utilisation for environmental sustainability; since, land cover is a key component for public decisions on ecosystems management and in the assessment of the impacts of anthropogenic actions on the equilibrium of ecosystems.

Study Area

The study area is Oluwa Forest Reserve in the South-western part of Nigeria. It lies between latitudes $6^{0}37^{1}$ and $7^{0}20^{1}$ North and longitudes $4^{0}27^{1}$ and $5^{0}05^{1}$ East. The area is part of the western plains and ranges of Nigeria with much of it lying approximately between 300 and 600 metres above the sea level (Iloeje, 1981). Most rivers and streams draining this area rise from the southern part of the study area. Notable among the rivers are Oni, Oluwa, Ominla and Owena (see Figure 1). The study area is under the influence of Koppen's Af humid tropical rain forest climate. Mean annual rainfall ranges

from 1,200mm to 1450mm and temperatures are high throughout the year with a mean of about 27^0C with an annual range of about 3^0C.

The natural vegetation of the area is the tropical rainforest characterized by emergents with multiple canopies and lianas. Some of the most commonly found trees in the area include *Melicia excelsa, Afzelia bipindensis, Antiaris africana, Brachystegia nigerica, Lophira alata, Lovoa trichiliodes, Terminalia ivorensis, T. superba, Triplochiton scleroxylon,* etc. However, the natural vegetation of the area with the exception of the areas devoted to forest reserve has now been reduced to secondary regrowth forest thickets and fallow regrowth at different stages of development or replaced by perennial and annual crops (Osunade, 1991). These perennial crops include cocoa, kola and citrus. Most of the rural settlements in the study area came into existence between 1920 and 1950 and by 1970 human colonization of the area had been completed or tending towards completion (Adejuwon, 1971).

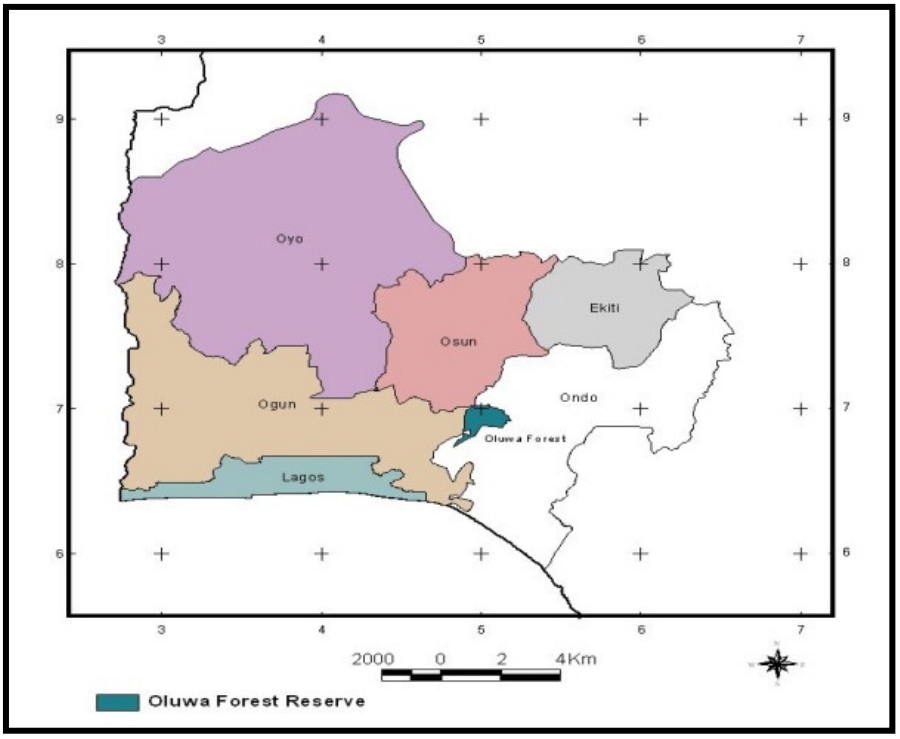

Figure 1: Map of South-western Nigeria showing Oluwa Forest Reserve

Methodology

A map of the study area was compiled from appropriate topographical map sheet and satellite imageries of that part of Nigeria. The study area was demarcated on the map and gridded into 5km x 5km squares, which gives 25 square grids out of which 10 square grids were selected using the table of random numbers. Each grid was again gridded into1km x 1km squares out of which 10 were again selected randomly. Ten quadrants of 40m x 25m were demarcated from each of the selected 1km x 1km grid for vegetation analysis. In essence, hundred quadrants were selected altogether. This quadrant falls within the range of quadrant sizes suggested by Weshoff and Maarel (1978), which has been used by Aweto (1978), Ekanade (1985), Adejuwon and Adesina (1988), Salami (1995) and Orimoogunje (2005) for vegetation sampling in the tropics. The inventory of both the floras and faunas was also compiled.

Digital image processing was carried out for the satellite imageries using Multipscope software package. Land uses were identified and classified from the Landsat imageries based on colour, texture, shape and size using the Integrated Land and Water Information Systems (ILWIS) 3.4 software. In order to minimize the different radiometric properties caused by season, which could affect the classification, the training sites were chosen at the same spatial position where there were the same land covers in different year. Training parcels were sampled based on ground survey after the contrast enhancement. The classes of training sites include: the arable crop cultivation, tree crop cultivation, exotic tree plantation, dense forest and settlement/open space. The maximum probability algorithm was used for final classification. The mathematics of the maximum likelihood decision rule, which was applied, has been explained by Tatsuoka (1971). The precision was above 90%. This shows that the classification method was reliable.

Results and Discussion

Table 1 shows the areal extent of vegetation types in the study area between 1972, 1991 and 2000 (see figures 2, and 3,). The detail of land use changes in the study area can be grouped into two, viz:

i. Land use types whose areal extent has increased; and
ii. Land use types whose areal extent has decreased.

Table 1: Areal extent of land use types in the study area between 1972 and 2000

Land use Type	1972		1991		2000	
	Areal Extent (Ha)	% of Total	Areal Extent (Ha)	% of Total	Areal Extent (Ha)	% of Total
Dense forest	130,774.00	70.79	110,826	59.99	19,383	10.49
Exotic tree plantation	49,034.40	26.54	55,683	30.14	22,276	12.06
Arable crop cultivation	-	-	2,671	1.45	56,229	30.44
Tree crop cultivation	-	-	5,505	2.97	55,943	30.28
Settlement/ open space	4,932.60	2.67	10,056	5.45	30,911	16.73
Total	184,741	100.00	184,741	100.00	184,741	100.00

Source: Landsat imagery classification

The first group includes those land use types whose areal extent has increased between 1972 and 1991 and between 1991 and 2000 (See Figure 2). The land use types whose areal extent has increased between 1972 and 1991include the exotic tree plantation from 49,034.40 hectares in 1972 to 55,683 hectares in 1991; settlement from 4,932.60 hectares in 1972 to 10,056 hectares in 1991; arable crop cultivation and tree crop cultivation from zero hectare in 1972 to 2,671 hectares and 5,505 hectares respectively. Similarly, arable crop cultivation increased from 2,671 hectares in 1991 to 56,229 hectares in 2000; tree crop cultivation from 5,505 hectares in 1991 to 55,943 hectares in 2000; and settlement / open space from 10,056 hectares in 1991 to 30,911 hectares in 2000. In sum total, these land use types have grown tremendously in areal extent in the study area.

Arable crop cultivation has shown the most spectacular growth. The areal coverage was 2,671 hectares in 1991, which increased to 56,229 hectares in 2000. This land cover unit has increased by more than 21 times its coverage in 2000. This trend may be expected because most of the people in the study area are migrant farmers looking for fertile soil. For instance, about 50% of the people interviewed were mainly arable cultivators who engaged in the cultivation of cassava, maize, cocoyam, banana and plantain. This could also be due to the fact that there is shortage of land outside the forest reserves as a result of increase in population. Land degradation through agricultural production drains the soil of its sustaining nutrients. Once the land has been exhausted it is abandoned and the cycle then continues as more forest is cleared to provide more productive agricultural land.

Tree crop cultivation has also grown by more than ten times its areal extent from 5,505 hectares in 1991 to 55,943 hectares in 2000. This was supported by the outcome of the socio-economic surveys of the study area. For instance, 75% of the people interviewed at Bagbe, Igunsin, Asewele,

Gbekelu and Ago-kabiyesi are mainly cocoa farmers while 65% of the people interviewed at Lamu, Laje and Laoso are both cocoa and plantain cultivators. The socio-economic survey also reveals that about 60% of the people at Nirowi area are taungya farmers. This has taken over a substantial part of the reserve.

The pattern of growth exhibited by the settlement class in the area is consistent with the observable pattern in many parts of the world. This pattern is influenced by many factors one of which is that the vast majority of dwellers are poor to average income earners who have no other means of survival than to settle very near their main source of sustenance. It is known that poverty is highly tied with unsustainable resources utilization and environmental degradation (Orimoogunje, et. al., 2009). Moreso, many of the farmers are non-indigenes but migrants from neighbouring states. The second land use changes in the study area are those whose extent of coverage has decreased. By 1972 dense forest had declined from 130,774 hectares to 110,826 hectares in 1991and to 19,382 hectares in 2000. This trend is consistent with what has been described for many forest reserves in Nigeria (e.g. Ola-Adams, 1981) and other parts of the world (Williams, 1990). In Nigeria, agriculture destroys many forested areas. Ola-Adams (1981) reported that approximately 2,000 hectares of the western edge of Ogbesse Forest Reserve had been cut over and replaced by permanent agriculture. Many high forests are being de-reserved for the establishment of agricultural crops. The pressure on the forest reserve is due to the fact that there is shortage of land outside the reserves. Harcourt (1992) reported that the commodity, which is generally considered to be of greatest economic value in the tropical rainforest, is timber. As a result of lumbering activities going on in the reserves, many of the valuable trees have been removed. This has led to a decline in the area of coverage by dense forest class cover. The pattern of decline exhibited by the exotic plantation class cover is consistent with the observable pattern in many parts of Southwestern Nigeria (e.g. Salami, 1995). It was revealed during the course of this study that no other plantation has been established apart from the one established between 1980 and 1996, i.e. none has been added and their products are in high demand. For example, teak is always demanded for electric pole while gmelina is mainly demanded for paper production.

The Analysis of Land Covers Change

Table 2 shows the land cover situation in the study area between 1972 and 1991. From the table, dense forest dominated other land covers being 70.79% in 1972 but dropped to 60 % in 1991. Arable crop and tree crops which are non-existent in 1972 engulfed 1.45 % and 4.42% respectively in 1991. Settlement expansion also encroached on the on land

covers by 5.45%. The significance of this is that arable and tree crops which constitute agricultural activities, and settlement expansion, were the major changes in the land covers of the study area within a period of 19 years.

Table 2: Changes in land cover in the study area between 1972 and 1991

S/N	Land cover Types	Areal Extent		% of Total		Diff. (ha)	% Decrease / Increase
		1972	1991	1972	1991		
1	Dense forest	1307.7	1108.3	70.79	60	-199.4	-746.8
2	Exotic tree	490.3	556.8	26.54	30.13	-66	252.9
3	Arable crops	0	26.7	0	1.45	26.7	101.5
4	Tree crops	0	81.7	0	4.42	4.42	310.6
5	Settlement	49.3	100.6	2.67	5.45	51.3	195.1

Source: Landsat imagery classification

Table 3: Changes in vegetal cover in the study area between 1991 and 2000

S/N	Land cover Types	Areal Extent		% of Total		Diff. (ha)	% Decrease / Increase
		1991	2000	1991	2000		
1	Dense forest	1108.3	193.8	60	10.49	-914.5	-82.52
2	Exotic tree	556.8	222.8	30.13	12.06	-334	-59.99
3	Arable crops	26.7	562.3	-30.44		562.3	100
4	Tree crops	81.7	559.4	4.42	30.28	477.7	584.7
5	Settlement	100.6	309.1	5.45	16.73	208.5	207.26

Source: Landsat TM 1991 and 2000

The data in Table 2 also reveals that the area of dense forest class has declined from 1991 to 2000, which decreased by 82.51% comparing with the situation in 1991. Its degradation rate was 9.17% per year. These results shows that the degradation of forest class has been existing in the recent years but after 2000 its degradation rates starts to increase because of demand for both minor and major forest products such as chewing sticks, rattan, timber, forest land, etc. The data in table 3 suggests that the number of exotic plantation class cover has decreased in 2000 by 60% compared to the situation in 1991. Its degradation rate was 6.7% per year. The result showed that degradation of exotic plantation has been evident in Oluwa Forest

Reserve before 1991 after which its degradation rate started to increase because of human activities such as agriculture and lumbering.

The area covered by tree crop class in 19991 has increased in 2000. Its increasing rate was 11.10% per year. The result shows that the tree crop cover is encroaching on the forest reserve land area. If this trend should continue the forest reserve may be totally taken over by this class cover. The area covered by settlement class has also increased in 2000 compared with what it was in 1991. Actually, the increasing trend of settlement class is as a result of human activities, which called for sedentariness. In addition, the dual carriage way which runs from Sagamu to Benin passes through the forest reserve.

Table 4: Land cover on the study site before human activities

Types of Vegetation	Frequency	% of Total
High thicket forest	198	56.57
Secondary regrowth	94	26.86
Mixture of trees & grasses	14	4.00
Fallow land	44	12.57
Total	350	100.00

Source: Authors Field Survey

Table 5: Purpose of farming in the study area

Reasons	Frequency	% of total
Commercial	168	48
Subsistence	102	29
Both	80	23
Total	350	100

Source: Authors field Survey

Table 6: Farming Systems in the Study Area

Farming system	Frequency	% of Total
Continuous cultivation	20	5.71
Shifting cultivation	24	6.86
Tree crops	196	56.00
Taungya system	110	31.43
Total	350	100.00

Source: Authors field Survey

Table 7: Length of fallow in the study area

Length of Fallow	Frequency	% of Total
Less than 3 years	15	4.29
3 – 6 years	14	4.00
6 – 9 years	141	40.29
9 years above	180	51.42
Total	350	100.00

Source: Authors field Survey

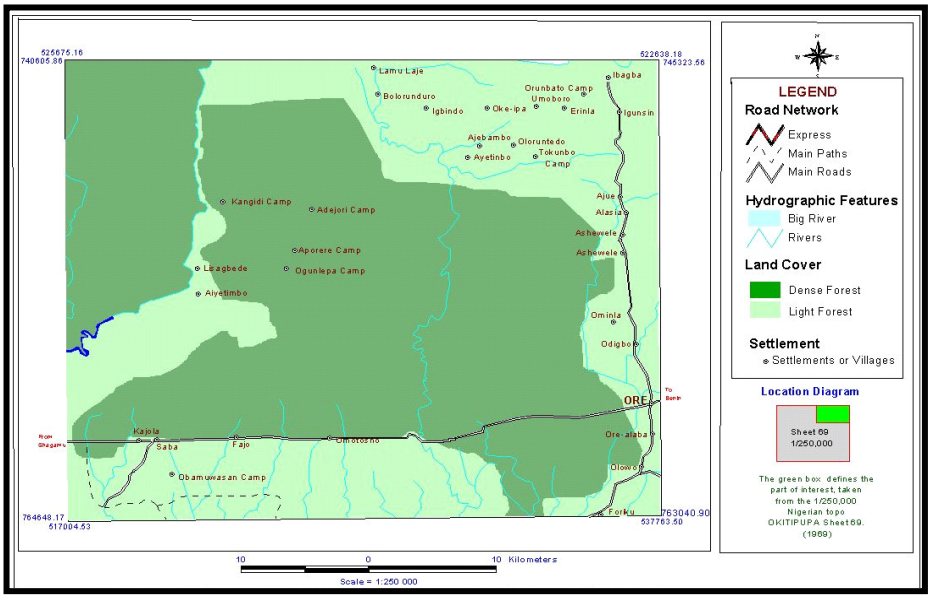

Figure 2: Land use Map of Oluwa Forest Reserve Based on Landsat MSS 1972
Source: Authors Field Survey

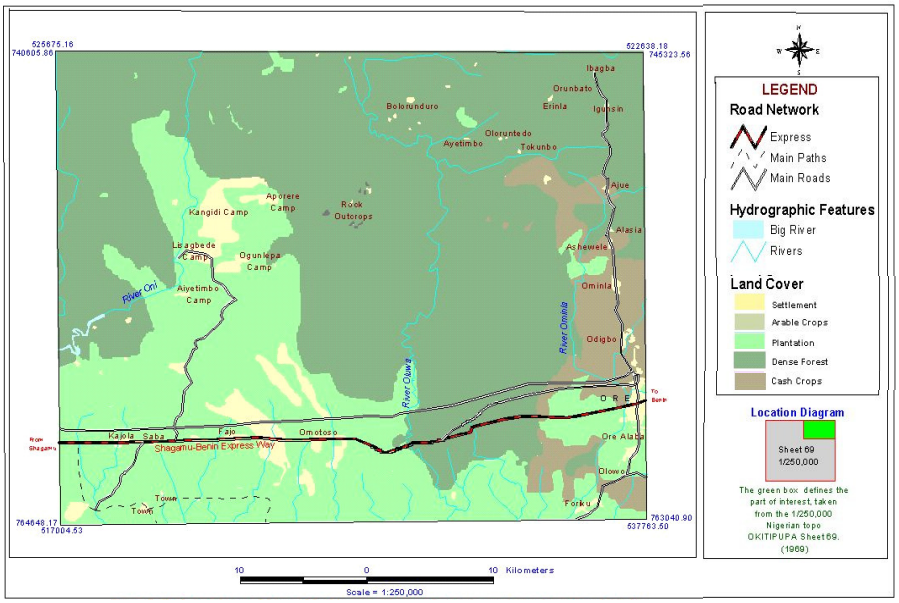

Figure 3: Land use Map of Oluwa Based on Landsat TM 1991

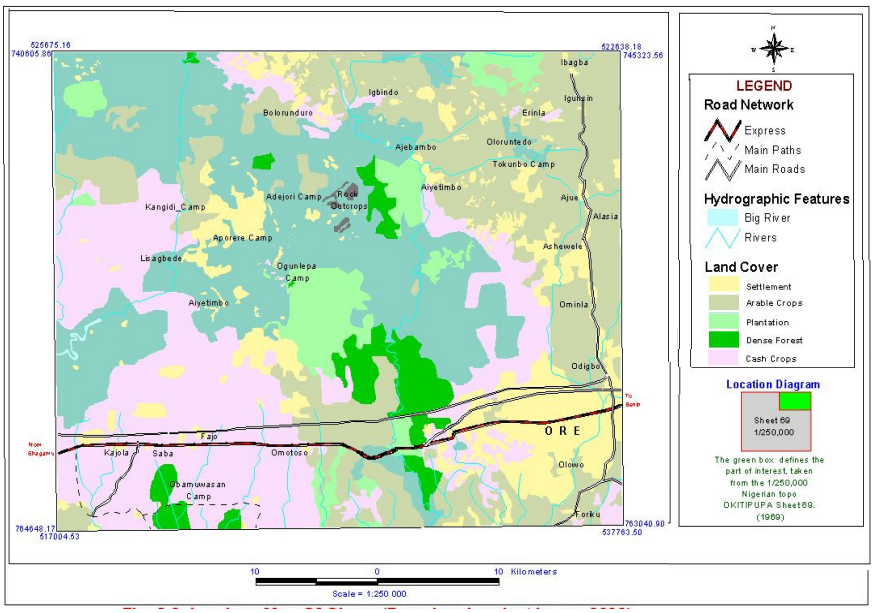

Figure 4: Land use Map of Oluwa based on Landsat TM 2000

The summary of the trend in the tables 2 and 3 below shows that the land cover in the area is experiencing serious encroachment and transformation from the original cover which is forest to man-made land covers. If the trend should continues at the rate shown in Tables, it is estimated that the reserve would have gone totally. This means that the dense forest, which covered 60% of the area in 1991, will be no more by the end of 2020. Table 4 shows that before the advent of human activities in the study area, the area has been demarcated as forest reserve and 56.57% of the farmers agreed that the area was covered with high thicket forest species while 26.86% contended that the study area has witnessed human activities that it is just a secondary regrowth and not the original vegetation. And 12.57% of the respondents revealed that the land given to them to cultivate was a fallow land that has just recovered from human occupation. Table 5 shows the reasons while the respondents cultivate the study site. 48% of the respondents engaged in farming activities for commercial purpose and majority of them engaged in cocoa and plantain cultivation. Most of these people are migrants from neighbouring states. However, 29% of the farmers engaged in farming in order to feed their immediate family and to meet their immediate needs such as financial needs. Most of these people are Ikale and other migrants from eastern Nigeria and Kogi state. The remaining farmers engaged in both in both commercial and arable farming. This shows that the major contributors to forest reserve degradation are the tree crops cultivators.

Table 6 shows that 56% of the farmers in the study area are involved in tree cropping system while 31.43% of the farmers engaged in taungya system of land cultivation. The latter farmers plant their crops mainly in between *Tectona grandis*, *Gmelina arborea* and *Nauclea diderrichii*. The forester allowed these farmers to do so because it is cheaper in that way to maintain and manage the forest reserve. Shifting and continuous cultivation is relatively low within the study area. Table 7 shows that 51.42% of the farmers adopted 9years above as fallow period while 40.29% adopted between 6 to 9 years. However 4.29% and 4% of the farmers adopted less than 3years and between 3 and 6years as fallow periods respectively. The result of the analysis shows that the length of the fallow is generally high while the average length of fallow in the study area is 6.67 years.

Ecological Implication of Land Cover Change

The analysis shows that human activities have influenced and altered land cover, and that human induced conversions and modifications have significance for the functioning of the earth system. This finding confirms the view of the World Bank (1991) that most of the tropical forests cleared each year are due to agricultural practices. It also lends credence to the hypothesis of Bilsborrow (1994) that deforestation is largely due to intensification of agriculture, involving clearing the land of trees to plant crops. Although taungya system, which was encouraged by the Forestry Department, has been noted to be similar in its appearance to forest ecosystem but its cover closure is obviously not the same as mature or high forest. The study area, which falls within the tropical rain forest, was once described as an area consisting essentially of a continuous stands of varied trees with canopies varying in height from 10 to 50 metres. It further reveals that the crowns of individual trees overlap each other and are often interlaced with lianas. This description no longer exists in state of the study area because of the human interference with the forest cover.

Also from the inventory of floras and faunas compiled from the study area through the forester there is an absence of monkey on the list and monkeys are indicators of the presence of original forest in a particular place. This shows that the natural forest is dwindling in the study area. Buffalos and antelope are also at the point of extinction in the study area. This shows that the problem of forest destruction is directly related to loss of biodiversity. This was confirmed by Shimabukuro, et al., (2010) in a study carried out in South America. According to Ola-Adams (1981) the danger of losing genetic diversity is greatest in the high forest ecosystems where there is great diversity of species and where forest destruction is more rapid. Ekanade (1991) reported that this might affect the ground surface albedo. Clayton (1958) demonstrated the possibility of a total degradation of the forest

reverting to a grassland ecosystem as a result of tree crop cultivation, which might encourage weed infestation and appearance of grasses. It is not difficult to understand therefore that changes in vegetation components over Nigeria, as elsewhere, have definite and significant specific components. Already, many plant species known to be endemic in this part of the world have become endangered or in some cases completely extinct. This fact was supported by Federal Environmental Protection Agency's (FEPA) (1992) finding that gave a list of 484 species of plants as endangered in Nigeria. This figure could be on the increase as a result of the intensification of human activities in the forest reserves. Even this study confirmed that from all the sampled plots *Melicia excelsa* was totally absent because it was in high demand by the commercial timber contractors while the forest reserve is now turning to a mono-cultural species plantation.

Conclusion

This study has shown that land cover change is an indication of forest resources degradation in the study area while the nature of the cultural substitution of the indigenous forest species has been found to be significantly affecting the species composition and the structural pattern of the vegetal cover. This is provided by different change detection techniques which were applied to monitor the changes. The study further shows that the problem of land cover change is directly related to loss of biodiversity in the study area. The study concludes that it is possible to monitor forest resources with a reasonable accuracy using satellite images because change detection techniques using temporal remote sensing data provide detailed information for detecting and assessing land cover and land use dynamics. It also offers alternatives to improve the accuracy of environmental monitoring and analysis.

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