AN ASSESSMENT OF SPATIO-TEMPORAL VARIABILITIES OF DEFORESTATION FOR SUSTAINABLE FORESTRY DEVELOPMENT: A CASE STUDY OF AFAKA FOREST RESERVE

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Key words: Forest, Human, Deforestation, Spatio-temporal, Sustainability.

ABSTRACT

Afaka Forest Reserve was established in 1954 as an experimental plantation site to increase the productivity and arrest the deterioration and desertification of the semi-arid zone of the Northern Guinea Savannah of Nigeria. But human influence has been identified as a critical factor militating against the realization of these noble objectives.

To monitor this trend, therefore, Remote sensing image sequences of aerial photographs of 1962 (B-W); Landsat MSS of 1970; Landsat TM of 1987; and SPOT (XS) of 1994, complemented with Geographical Information System (GIS) were used to map the forest cover of the Reserve.

The highlights of the analyses, revealed the dynamic character of the Afaka Forest ecosystem. Four deforestation variables, namely: Exotic vegetation (EXO); Erosion sites (ERO); Area Under Cultivation (AUC); and Roads (RD), in that order of prominence, were responsible for depleting the Natural Forest (NAT), and the changes have multidirectional patterns.

The results further showed that between 1962 and 1970, natural forest decreased from its original status of 95.98% to 91.51%; between 1970-1987, it decreased from 91.51% to 84.29; and from 1987-1994, decreased further to 61.96%. By assessing and integrating these variability scenarios into a GIS for the decades investigated, a restructuring of the forest management strategies in Afaka in favour of the survival and regeneration of the natural forest was proposed.

1 INTRODUCTION

Nature has endowed man, since ages with many natural resources for the sustenance of his socio – economic needs; but since these needs are ever changing and ever on the increase, these resources are often at risk of serious depletion.

One of the most affected of these resources, appears to be the “natural forest”, which has been continuously under threats of over-exploitation by man, leading to negative changes in its status and productivity. The changes occur as human beings attempt to adjust their

seemingly endless wants and desires for food, shelter, recreation, infrastructural facilities and so on to the forest resources available to them.

The uncontrolled conversion of forest into other land cover types and uses is an internationally recognized problem (Wietske, 1998). Trees are seen as obstacle to progress and their removal viewed as the first stage in development, hence deforestation has prominently become one of the most important environmental issues since the last century.

Khadka,(1997), has observed that forest are socially, economically and environmentally important, especially tropical forest, which are at home to at least two-thirds of the world's living organisms (some three million species). They play an important role in the economy of many countries, but forest resources are at great risk because of severe exploitation. These similar observations had earlier been made by: Anderson (1995); Persson (1995); Boyd et al (1996); Foody and Curran (1994); Foody et al (1996); Gholz et al (1996); Nwadialor (2000); and Curran et al (1995).

The objective of this paper, therefore, is to investigate this phenomenon of deforestation in Nigeria as an input in national planning, with Afaka Forest Reserve as a case study, using Remote Sensing and Geographical Information System (GIS) techniques.

Afaka Forest Reserve, of areal extent (12,243.760 hectares) located on one of the watershed areas of the Kaduna Plains, was established in 1954 as an experimental plantation site to increase the productivity of the Savannah and arrest desertification and deterioration of the semi – arid environment of the Northern – Guinea Savannah of Nigeria. A major consideration for choice of location, is the occurrence of a heterogeneity of abundant, valuable, endemic/native tree species that inhabit the Afaka environment. Also, as observed by Barrera and Amujo (1971), the Reserve had been known in the past for its high potentials in biodiversity of flora and fauna.

However, human influences appear to be major factors constituting serious threats to this forest. To keep up to date with the change in the Reserve, seems to be a very difficult task for the planners and managers of this Forest because of lack of adequate tools and expertise to meet the challenge. One crucial aspect of Natural Forest – Deforestation research which deserves more investigation in Nigeria in particular, and the Tropics in general, for sustainable forestry, are the effects of landuse/land cover and forest management activities on the natural forest survival and conservation. This is a major gap this present study intends to fill by exploring an integrated approach to Remote Sensing and GIS in detecting, mapping and modelling deforestation scenario in this valuable, but vulnerable forest landscape of Kaduna State, for national planning.

Changes in the forest status over four decades (1962 – 1994) of 32 year period were investigated at each epoch (1962, 1970, 1987, and 1994); drawing primarily on available historical photographs (B-W) of 1962, and subsequent sequential satellite images of Landsat MSS (1970), Landsat TM (1987), and SPOT (XS) of 1994, respectively. The data were quantitatively interpreted and spatially analyzed by visual and computer – assisted

methods, and later integrated into a GIS for socio-economic projections in national planning through the result of the spatial modelling approach adopted.

1.1 Study Area Location

Afaka Forest Reserve is situated some 30km N-W of Kaduna township, along Kaduna – Lagos Express Highway road, and is about 12,243.760 hectares in areal extent (Fig. 1). It is geographically located between latitudes 10^0 33'N and $10^0$42'N;Longitudes 7^0 13'E and 7^0 24'E.

The vegetation cover classes consist of the following native or indigenous species of Isoberlinia doka, Monotes kerstingii, Uapaca togoensis, parinarie curatellifolia, Andropogon Pseudapricus, Hyparrhenia notolosia, Loudetia Simplex, Andropogon gayanus, Annona Sengalensis, Raphia sudanica, Oxytenanthera abyssinica. etc. Some of the exotic species include; Eucalyptus rudis, Albizzai lebbek, Cassia Siamea, Eucalyptus Cerebra, E. camaldulensis, E. Citriodora, E. Toreliana, E. tereticonis, E. multiflora, E. Saligna, E. Cloeziana, E. maculata, E. Micrantha, E. Tetradonta, E. racemosa, E. bicolor, E. pilularis, E. marginata, E. fastigata, mangifera indica, Pinus oocarpa, etc. (Barrera and Amujo, 1971).

2. DATA AND METHODOLOGY

Bearing in mind the objectives of this research, which are to detect and map the deforestation elements in Afaka for sustainable forestry development, the data sets were acquired based primarily, on suitability and availability.

They include; aerial photographs (B-W) of 1962 (1:40,000); Landsat MSS of 1970 (resolution =50m); Landsat TM of 1987 (28.5m pixel resolution); SPOT (XS) of 1994 (20m pixel resolution), topographic map of 1966 at scale (1:50,000); soil map of 1968 at scale (1:25,000 and 1:40,000). All the satellite images are at the same scale of 1:250,000..

The hardcopies of the imageries are not inserted in order to reduce the number of pages in this work. The ARCINFO and ERDAS IMAGINE packages were used for the processing of the images.

The methods employed in mapping the forest features consisted of the standard image interpretation and processing procedures (visual interpretation, image geo-referencing, image digitizing, processing, projection, data clean up, feature analysis, and integration into a GIS).

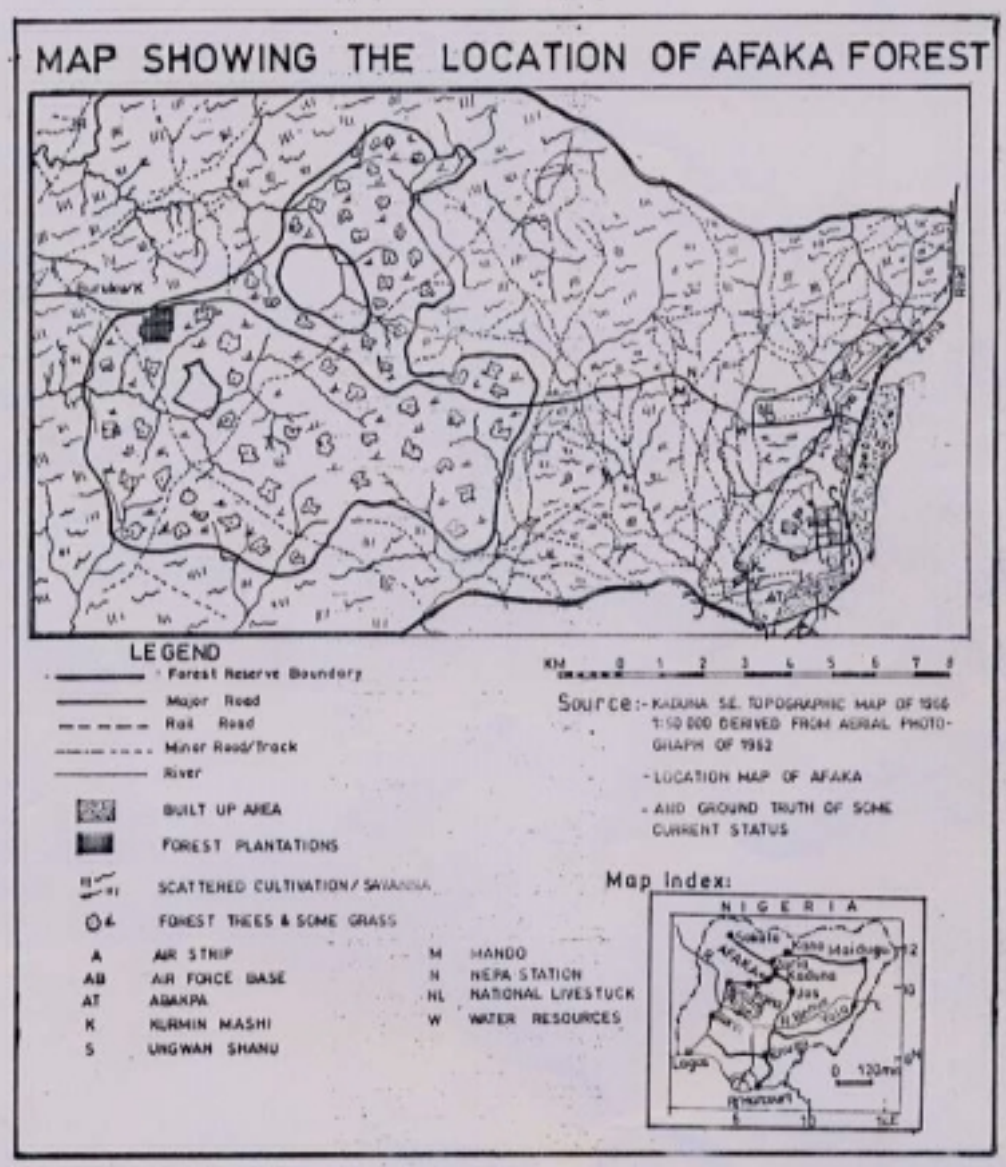

FIGURE 1:1 : LOCATION OF STUDY AREA.

3

The summary of the procedures include:

(i) Aerial photographs of 1962 were visually interpreted and later digitized to form the basic information input to the computer.
(ii) Changes in the land use/forest disturbance classes were detected using the three satellite imageries.
(iii) Interpretation was carried out on-line on these images.
(iv) Digitising of the interpretation was also carried out.
(v) Digital analyses were performed on the four sets of data (1962, 1970, 1987 and 1994) to produce among other things, areas for the different land use/forest disturbance classes.
(vi) Maps for the four decades were produced, showing the spatial distribution of the different feature types.

The deforestation variables identified and mapped are exotic vegetation (Exo); Erosion sites (ERO); Area under Cultivation (AUC); and Roads (RD).

3. RESULTS PRESENTATION AND DISCUSSIONS

3.1 Distributional Patterns of Natural Forest and the Deforestation Parameters

From the results of the interpretation analysis, Afaka Forest Reserve has been found to be under serious threats of deforestation. Therefore, the discussion that follows gives an insight, as well as an overview of the quantitative and spatio-temporal variability of the forest status of Afaka Reserve.

The results of the quantitative interpretation of the imageries are shown below, as generated from the methodology.

Table 1. Area (in hectares) of each class mapped/values of landuse/forest cover classes

IMAGERY	DECADES	AREA UNDER CULTI-VATION (AVC)	ROAD (RD)	EXOTIC-VEGE-TATION (EXO)	EROSION SITE (ERO)	NATURAL FOREST (NAT)
Photos	1962	445.280	17.137	29.307	0.00	11,752.034
L.MSS	1970	670.146	17.137	250.883	110.400	11,204.142
L.TM	1987	676.574	33.536	970.562	242.628	10,320.460
SPOT (XS	1994	591.689	33.536	2998.323	1034.173	7586.036

Source: image interpretation by the author

3.1.1. Aerial Photographs of 1962

This sub-section discusses and displays diagrammatically the interpreted airphoto results of the forest status of Afaka Forest Reserve in 1962. The maps were prepared at the same scale of 1:100,000 as shown.

The results in 1962, showed that about 445.28 hectares of the total area of the Reserve (12,243.76ha) was made up of agricultural land, which represented about 3.64%. This was

found at the extreme western and south – eastern parts (boundary) of the study area; implying that human encroachment was probably from neighbouring villages around the Reserve.

At this time, exotic vegetation constituted the experimental site, with an area of 29.31 ha; constituting only 0.24 percent. This was located at the western part of the Reserve opposite the Afaka Forest Management Office.

The Reserve was almost at its natural state with 95.98 percent being made up of natural vegetation as can be seen in Fig 3.1

There were no erosion sites in the Reserve. However, the Kaduna – Lagos road claimed about 17.137ha (0.14%) and is located almost at the middle of the study area.

3.1.2 Forest Status in 1970

The area under cultivation had disappeared during this period, from the S – E part probably, due to the policing activities of the Forest Guards. However, this feature class, increased further in the West very close to Buruku Village to about 5.40 percent.

Exotic vegetation spread further from its experimental site location to the Western boundary and a little towards the east, along the Kaduna – Tegina – Lagos road.

Erosion sites which were non-existent in 1962, started to develop in the northern part. Natural vegetation was predominant, but changed from 95.98 percent to 91.51 percent between 1962 and 1970.

Road dimension was the same as in 1962, while area under cultivation changed from 3.64% to 5.40%, concentrating in the western direction/part of the Reserve as depicted in Fig. 3.2.

3.1.3. Forest Status in 1987

During this period all the disturbance indicators increased in magnitude to the detriment of the natural forest vegetation, which decreased from 91.51% to 84.29% between 1970 and 1987. Erosion sites, which started to develop in the north in only two locations in 1970, have spread down south in multiple hot spots. Fig. 3.3 displays this development.

3.1.4. Forest Statutes 1994

During this period, area under cultivation surprisingly decreased among the other deforestation factors, from 5.53% in 1987 to 4.83% in 1994. Other disturbance variables increased during this time and natural vegetation decreased further from 84.29 percent to 61.96 percent. The overall rate of deforestation between 1962 to 1994 was computed to be about 1.06 percent annum; indicating an unhealthy condition for the natural forest, as shown in Fig. 3.4.

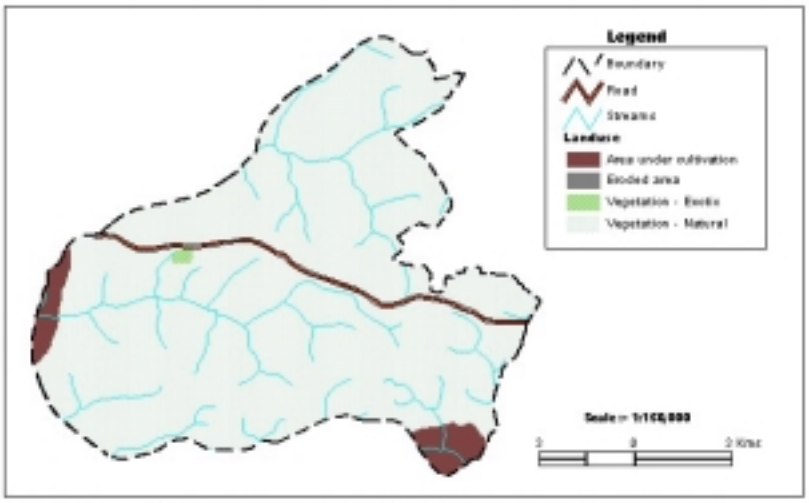

Fig: 3.1 STATUS OF AFAKA FOREST RESERVE (AERIAL PHOTO), 1962

Source : Author's Laboratory and Office Analysis

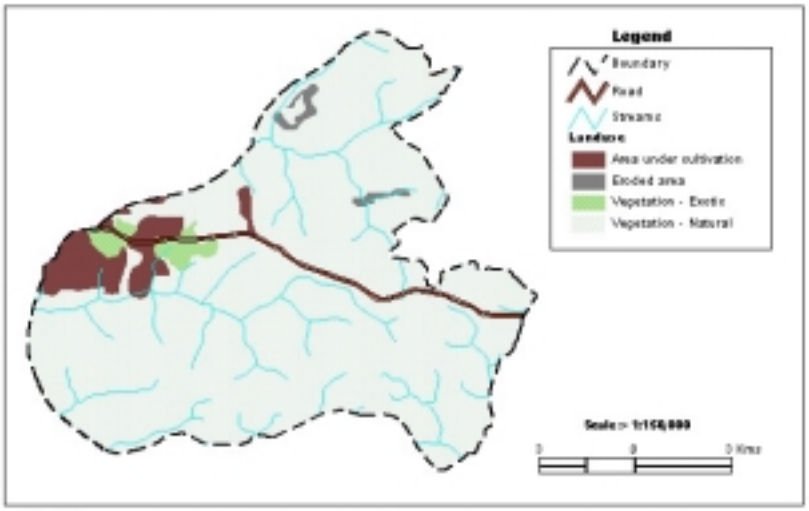

Fig: 3.2 STATUS OF AFAKA FOREST RESERVE (LANDSAT MSS), 1970

Source : Author's Laboratory and Office Analysis

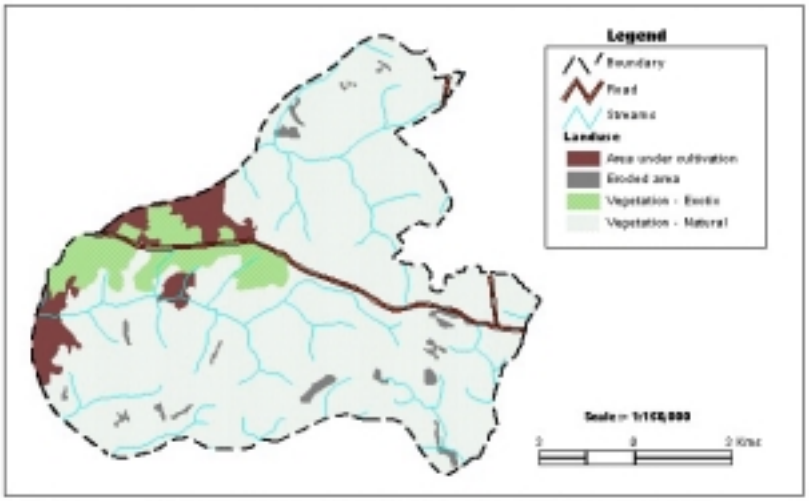

Fig: 3.3 STATUS OF AFAKA FOREST RESERVE (LANDSAT TM), 1987

Source : Author's Laboratory and Office Analysis

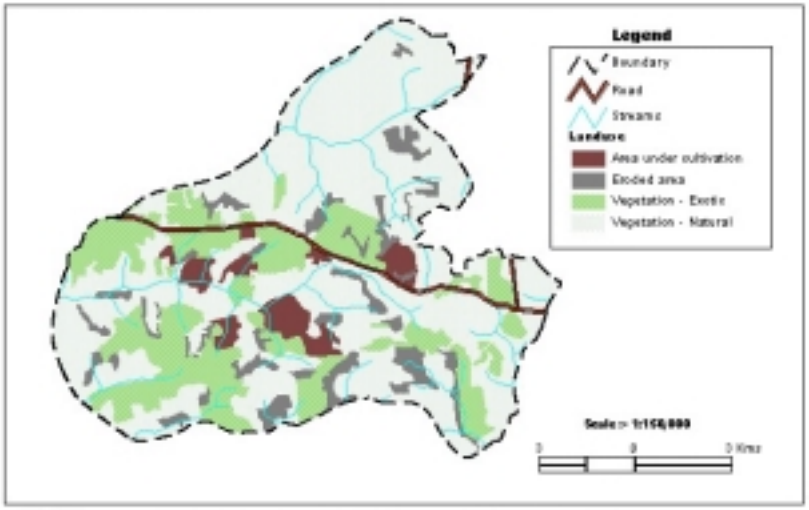

Fig: 3.4 STATUS OF AFAKA FOREST RESERVE (SPOT XS), 1994

Source : Author's Laboratory and Office Analysis

3.1.5. Composite of Natural/Disturbance Classes (1962-1994)

The overall percentage disturbance in 1962 amounted to about 4.02%; (491.726 ha) and in 1970, 1987 and 1994, increased to 8.49% (1039.618 ha) 15.71% (1923.300 ha) and 38.04% (4,657.724 ha), respectively.

The total percentage disturbance within the period of thirty –two years was 66.26 percent, which on the average, amounted to about 2.07 percent per annum. This also indicates an upsetting development for the natural forest in the Reserve, whose survival and conservation is in danger.

The integration of these feature scenarios into a GIS was aimed to articulate and organize the perception and visualization of the entire deforestation problems for proper decision-making and profferment of solutions. This condition is depicted in Fig. 3.5.

4 CONCLUSIONS AND RECOMMENDATION

The highlights of the analyses in this study have revealed the dynamic character of Afaka Forest ecosystem, while also, exposing the multi – directional change processes of deforestation in the Reserve. Exotic plantation site is the most prominent deforestation element in the Reserve, followed by ERO, AUC, and RD, respectively.

The separate composite maps generated showed Afaka Forest Reserve under serious stress of human threats, with overall rate of deforestation at 1:06 percent per annum.

The results of the spatial analyses revealed that exotic vegetation plantation, erosion, area under cultivation, and road constructions are seriously undermining the existence of the natural vegetation in Afaka Forest Reserve. The exotic afforestation/reforestation measures being initiated for improving the productivity of the Reserve have turned out to be worsening the occurrence of erosion; and hence, the degradation of the natural forest ecosystem of Afaka.

The result of the spatial variability analysis, further indicated that, between 1962 and 1970, Natural forest vegetation decreased from 95.98% to 91.51% between 1970 – 1987, it decreased from 91.51% to 84.29%; and 1987-1994, decreased further to 61.96%.

Afaka Forest had been known in the past for its potentials in biodiversity of flora and fauna. The on-going deforestation is seriously depleting the former and has sent the latter into extinction and oblivion. By comparing the present status of this Forest with its pre-disturbance condition, a restructuring of forest management strategies at Afaka was proposed. These involve the suspension of the on-going afforestation/reforestation programme; and allowing the natural forest to regenerate naturally, or the adoption of natural forest- enrichment plantation technique using endemic/native tree species that are aboriginal to the environment.

The application of the findings lies in the their adoption by the planners and managers of the Reserve in particular and other forest establishments in general; while the implications have given spatial information for the sustainable development of Afaka Forest Reserve. The sequential decrease in status of Afaka forest Reserve as revealed, may form a basis for statistical modelling of deforestation in the Reserve in subsequent contribution.

A further extension of this work could evolve an innovate philosophy on man-forest interaction based on conceptualised mathematical/physical model equations, describing and explaining the most critical determinants influencing man's decisions in forest exploitation.

A model for determining objectively the appropriate intervals of time (related to the rate of resource depletion) for remote sensing of earth features is also a unique extension of this research.

It is strongly envisaged that this aspect of spatial information would serve as a useful guide to socio-economic projections in national planning in Nigeria and Africa in the ambit of sustainable development in forestry and environmental management.

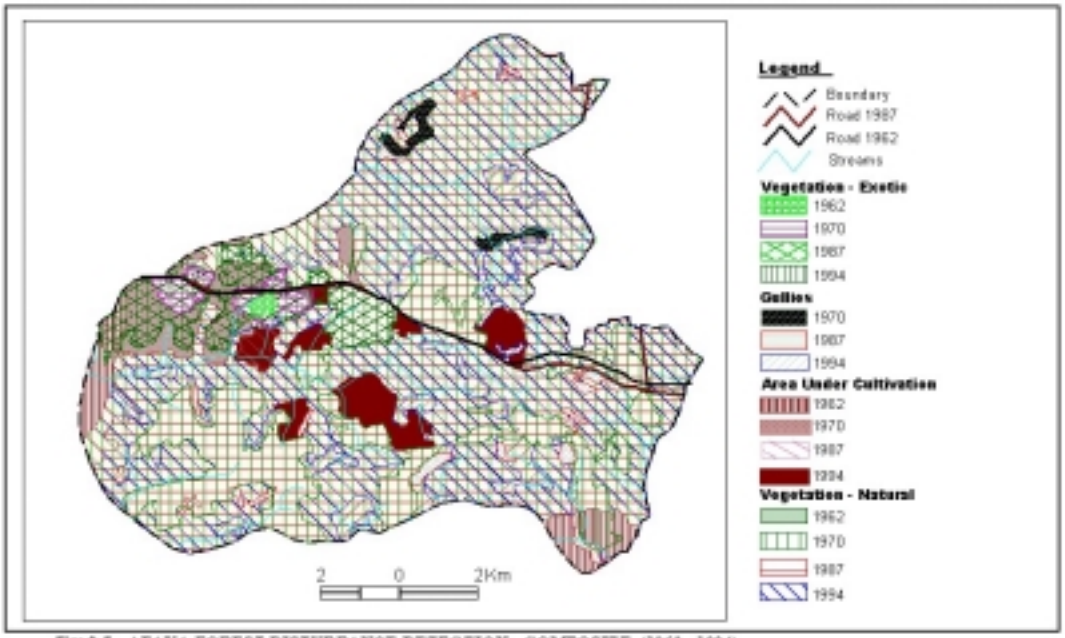

Fig: 3.0 AFAKA FOREST DISTURBANCE DETECTION : COMPOSITE (1962 - 1994)

Source: Author's Laboratory and Office Analysis

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BIOGRAPHICAL NOTES

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