

## VEGETATION MAPPING OF A PART OF DRY TROPICAL RAINFOREST OF SOUTHERN NIGERIA FROM LANDSAT TM

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### ABSTRACT

Vegetation in Nigeria, whether on topographical sheets or thematic maps, has generally been mapped from aerial photographs. But aerial photographs are not generally available beyond the 70s in most part of the country. Consequently, it has become difficult to assess the current ecological status of the biotic environment. The main objective of this paper therefore is to demonstrate the potentialities of Landsat TM in generating up-to-date information on the biotic environment in Nigeria. It shows the advantages and limitations of high resolution satellite imageries in mapping vegetation of the heterogenous Landscape of a developing country like Nigeria. The environmental implications of the study are highlighted.

### 1 INTRODUCTION

Vegetation mapping is one of the basic components of ecological data base of any region. Apart from providing the benchmark data for forestry planning, the information that could be generated from reliable vegetation map will also aid any programme on fuelwood energy conservation and assessment of ecological status of forest ecosystem. However, Adejuwon (1967) lamented that vegetation has continued to be inaccurately mapped in Nigeria. He contended that this is a result of faulty methods of data collection as mapping in the field is a most difficult exercise. The situation has only changed a little, more than three decades after this observation. In the same vein, Morain (1974) submitted that there seems to be no reasonable means of providing timely and accurate data for vegetation mapping using traditional approaches.

In response to this challenge, some attempts have been made to demonstrate the usefulness of aerial photographs in mapping Nigerian vegetation. For instance, Larin-Alabi (1979) examined the potentialities of air photos for studying Nigeria's tropical forests. Also, Ikhouria (1993), produced a multidecade map of a part of Southern Nigeria from air photos of 1963 and 1973.

Morris and Martin-Kaye (1973) noted that the ever increasing demands of the earth's natural resources and our corresponding concern with the preservation of the environment has encouraged the development of other more sophisticated methods of remote sensing than conventional photography. This development includes the emergence of satellite imageries such as Landsat and SLAR. But this led to the problem of appropriate spatial scale. In line with this development, the federal government in the 70s, through the Federal Department of Forestry initiated the Nigerian Radar (NIRAD) project. This employed Sidelook Airborne Radar (SLAR) to obtain Radar imagery covering the whole of the country. However, since the scale of the imagery is 1:250,000, it is more useful for small scale mapping.

The advent of high resolution satellite remote sensing, using SPOT P mode, SPOT XS and Landsat TM in the 80s, has opened up new possibilities which have not been adequately exploited by researchers and environmentalists in Nigeria. This has been due mainly to lack of the required hardware and software facilities as well as the technical know-how of digital image analysis, necessary for such studies. This paper is thus an attempt to demonstrate the application of Landsat TM to vegetation mapping in Nigeria. It shows advantages of the new technology-digital image processing over the analogue procedure that has been predominantly employed by Nigerian researchers, while mapping the country's vegetation.

## 2. STUDY AREA

The study was carried out in Ede Local Government Area of Southern Nigeria. The area has two rainfall maxima and the period of raining season varies between seven and nine months. The area was mapped as lowland rainforest by Keay (1959). However, only patches of this natural vegetation are now found in the area, as a result of the practice of shifting cultivation and peasant cash crop economy (Ekanade, 1985).

The most extensive soils in the area are *Egbeda*, *Olorunda*, *Iwo*, *Ibadan* and *Balogun* series (Smyth and Montgomery, 1962). Adejuwon (1971) opined that most of these soils could be considered as good soils with regard to the performance of biological communities on them.

## 3. METHODOLOGY

Landsat TM scene 6967 x 5965 with Worldwide Reference Number (WRN) 190/055 of 1991 was used for this study. A window with an areal coverage of 100km<sup>2</sup> was extracted from the scene. This contains 334 x 334 pixels. The coordinates of the first corner of the window are defined by X=1419 and Y=1273. The window was subjected to digital image processing using MULTISCOPE Software Package. Channels 4, 5 and 2 were chosen out of the seven channels available on Landsat TM. This selection was based on the fact that these channels are more relevant for vegetation studies. Channel 4 was loaded on the red plane, channel 5 was put on the green plane while channel 2 was loaded on the blue plane to obtain a colour composite.

Training parcels were chosen from ground control points and they were eventually assigned to six classes. Some of the training parcels were reassigned by the automated procedure. The parcels reassigned are those for which more than 50 % of their pixels were wrongly classified during the preliminary grouping (CNES, 1988).

The extent to which each of the vegetal classes differs from one another was computed prior to final classification. The result of this exercise indicates what to expect in the final mapping. The output of this procedure is shown by divergence matrix. The latter is the exact opposite of a correlation matrix although, each relationship is expressed by a value ranging from 0 to 1. A value of 0 means that there is total correlation and absolutely no (or zero) separability while a value of 1 means absolutely no (or zero) correlation and total (100 %) separability between the two classes concerned. In other words, the higher the value, the lower the correlation and the higher the separability and vice-versa.

The final mapping was done with 95 % level of confidence under the Gaussian hypothesis, using the maximum probability algorithm. In this case, we accept the normality hypothesis and consider each  $C_i$  class, averages  $M_i$  and covariance matrices  $Q_i$ . The multivariate normal statistical theory defines the probability that an observation  $X$  will occur, given that it belongs to class  $K$ , as the following function (Tatsuoka, 1971):

$$Q_k(X_i) = 2(\pi)^{-1/2} P(\pi_k)^{-1/2} X e^{-1/2(x-u_k)} \pi_k^{-1} (X-U_k) \dots \dots \dots \text{eq.(1)}$$

Where:

$Q_k(X_i)$  = Probability density value associated with observation vector  $X_i$  as evaluated for class  $K$ .

$X_i$  = Vector of measurements on  $p$  variables associated with the  $i$ th object or observation;  $i=1, 2, \dots, N$

$P$  = Number of measurement variables used to characterise each object or observation.

$U_k$  = Parametric mean vector associated with the  $K$ th class.

$\pi_k$  = Parametric  $p$  by  $p$  dispersion (variance-covariance) matrix associated with the  $k$ th class.

$X$  =  $p$ -dimensional vector.

The individual is assigned to the class for which the probability value is greatest. In an operational context, the observed means, variances and covariances are substituted using the log form of equation (1):

$$\ln[Q_k(X_i)] = -1/2 \ln(|\Sigma_k|) - 1/2 (X_i - M_k)^T D_k^{-1} (X_i - M_k) \dots \dots \dots \text{eq.}(2)$$

Where:

$M_k$  = Mean vector associated with a sample of observations belonging to the kth class; taken as an estimator of  $\mu_k$ .

$D_k$  = p by p dispersion matrix associated with a sample of observations belonging to the kth class; taken as an estimator of  $\Sigma_k$ .

A simple decision rule,  $R_1$ , can be derived from the equation (2) by estimating constants:

$R_1$ : Choose K which minimises.

$$F_1, K(X_i) = \ln(D_k) + (X_i - M_k)^T D_k^{-1} (X_i - M_k) \dots \dots \dots \text{eq.}(3)$$

## 4 RESULTS AND DISCUSSION

The results of the analysis are presented in three parts. These are the levels of divergence among the classes, the confusion matrix and output of the final supervised classification.

### 4.1 Level of Divergence

The divergence matrix (Table 1) shows the extent of separation among the vegetal classes mapped from the imagery. Table 2 which expresses the level of separability in percentages, was derived from Table 1. The former shows that tree crop/mature secondary regrowth and young secondary regrowth (C5 and C6) are the most similar classes. There is only 27.93% separation between the two classes. This result depicts the extent of similarity between the two vegetal types. The reason for this is explained later in the discussion. Apart from this high level of similarity between C5 and C6, there is generally, a high level of discrimination among the classes. This shows that generally, the variances between are much higher than variances within the classes or vegetal types.

**Table 1: Divergence Matrix of Cover Types**

|    | C1     | C2     | C3     | C4     | C5     | C6     |
|----|--------|--------|--------|--------|--------|--------|
| C1 | 0.0000 |        |        |        |        |        |
| C2 | 0.9988 | 0.0000 |        |        |        |        |
| C3 | 0.9987 | 0.8381 | 0.0000 |        |        |        |
| C4 | 0.8979 | 0.8315 | 0.8469 | 0.0000 |        |        |
| C5 | 1.0000 | 1.0000 | 0.9999 | 0.9958 | 0.0000 |        |
| C6 | 1.0000 | 0.9996 | 0.9975 | 0.9679 | 0.2793 | 0.0000 |

KEY

C1: Burnt Patches (BP)

C2: Arable Cropland/Fallow Complex (ACFC)

C3: Exposed Land/Settlement (ELS)

C4: Mixed Grassland (MG)

C5: Tree Cropland/Mature Secondary Regrowth Complex (TMSRC)

C6: Young Secondary Regrowth (YSR)

**Table 2: Separability Percentage Index of Cover Types**

|    | C1     | C2     | C3    | C4    | C5    | C6   |
|----|--------|--------|-------|-------|-------|------|
| C1 | 0.00   |        |       |       |       |      |
| C2 | 99.88  | 0.00   |       |       |       |      |
| C3 | 99.87  | 83.81  | 0.00  |       |       |      |
| C4 | 89.79  | 83.15  | 84.69 | 0.00  |       |      |
| C5 | 100.00 | 100.00 | 99.99 | 99.58 | 0.00  |      |
| C6 | 100.00 | 99.96  | 99.75 | 96.79 | 27.93 | 0.00 |

NOTE: C1-C6 are as defined in Table 1.

## 4.2 Confusion Matrix

Confusion matrix (Table 3) depicts the extent of homogeneity of the cover types. It shows that burnt patches were 90.70% homogenous. The class has 5.43% overlap with mixed grassland. This overlap could be due to the fact that method of land preparation in the area includes clearing and burning of the vegetal cover, and the Landsat scene was recorded during the period that farmers in the area usually prepare the ground for cultivation. It might also be due to the fact that mixed grassland contains some elements of burnt patches.

**Table 3: The Confusion Matrix**

|    | C1    | C2    | C3    | C4    | C5    | C6    | RJ   | TP     |
|----|-------|-------|-------|-------|-------|-------|------|--------|
| C1 | 90.70 | 0.78  | 0.00  | 5.43  | 0.00  | 0.00  | 3.10 | 100.00 |
| C2 | 0.00  | 91.30 | 4.78  | 2.61  | 0.00  | 0.00  | 1.30 | 100.00 |
| C3 | 0.00  | 4.81  | 83.17 | 7.21  | 0.00  | 0.00  | 4.81 | 100.00 |
| C4 | 4.61  | 2.52  | 6.38  | 81.83 | 0.00  | 0.24  | 4.42 | 100.00 |
| C5 | 0.00  | 0.00  | 0.00  | 0.12  | 83.42 | 15.24 | 1.22 | 100.00 |
| C6 | 0.00  | 0.00  | 0.00  | 2.55  | 37.82 | 54.01 | 5.60 | 100.00 |

NOTE: C1-C6 are as defined in Table 1.

RJ- % of rejected or unclassified pixels.

TP- Total %.

Arable cropland/fallow complex was 91.3% homogenous. The class has 4.78% confusion with exposed land/settlement and 2.61% overlap with mixed grassland. This means that some portions of this cover type has been exposed due to cultivation while grasses are growing in some parts. Exposed Land/Settlement was 83.17% homogenous. It has 7.21% overlap with mixed grassland and 4.81% confusion with cropland/fallow complex. This confusion is not abnormal as some parts of the cropland and mixed grassland in the area were exposed as a result of cultivation and grazing respectively.

Mixed grassland was 81.83% homogenous. However, elements of this cover type were found in all but one of the classes. This result confirms the classification of the study area as forest-savanna transition zone by Adejuwon (1971). Mixed grassland has 6.38% overlap with exposed land/settlement, 4.61% with burnt patches, 2.52% with cropland/fallow complex and 0.24% with young secondary regrowth. It was noted from the confusion matrix that elements of mixed grassland were not found at all in tree cropland/mature secondary regrowth while they are rarely present in young secondary regrowth, which is actually fallow at an advanced stage of succession. This result implies that it is the opening of the mature forest in the area for cultivation that encourages the growth of grass. Grass could therefore not be said to be a natural habitat of this environment. This finding confirms the submission of Adejuwon and Adesina (1988) that regressive succession is already in progress in some parts of the Tropical Rainforest belt of Nigeria. Tree cropland/mature secondary regrowth was 83.42% homogenous. It has 15.24% overlap with mixed grassland.

Class purity rating (Table 4) was derived from confusion matrix (Table 3). The former is obtained by dividing the number of pixels well classified by the total number of pixels in the class. Table 4 shows that among the vegetation types in the area, arable cropland/fallow complex and burnt patches, are the most efficiently studied class using digital image processing procedure employed. The former was classified with 91.3% precision while the latter was classified with 90.7% precision. This is due to the fact that arable cropland/fallow complex consists of young luxuriant vegetation with distinctive bright red signature while burnt patches have distinctive black signature on the original imagery prior to classification.

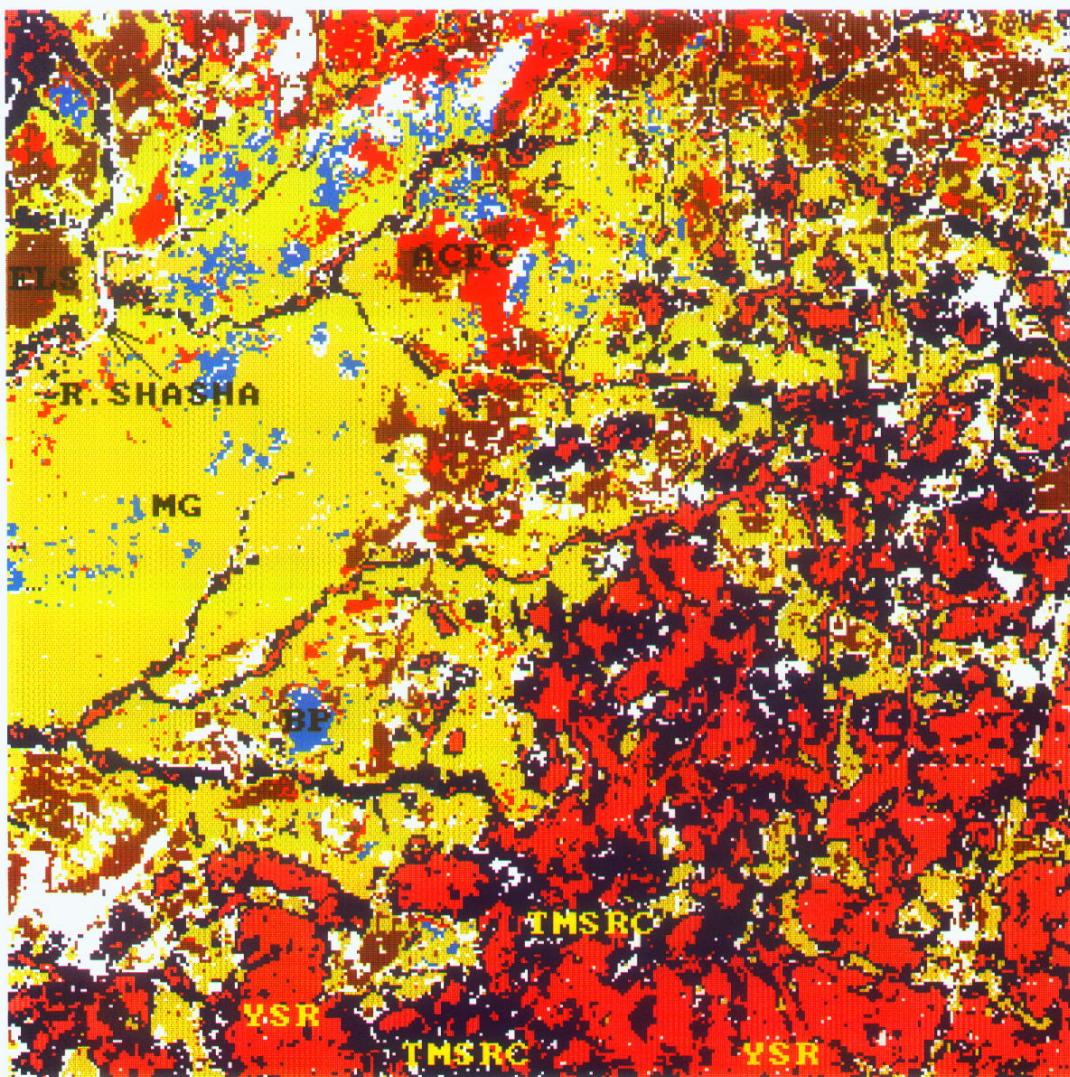
**Table 4: Class Purity Rating of Cover Types**

| Class No. | Class Content                          | % of Pixels Well Classified | % of overlapping Pixels | Purity Ratio | Purity Rating   |
|-----------|--|-----------------------------|-------------------------|--------------|-----------------|
| 1.        | Burnt Patches                          | 90.70                       | 6.21                    | 0.907        | 2 <sup>nd</sup> |
| 2.        | Arable Cropland/<br>Fallow Complex     | 91.30                       | 7.39                    | 0.913        | 1 <sup>st</sup> |
| 3.        | Exposed Land/<br>Settlement            | 83.17                       | 12.02                   | 0.832        | 4 <sup>th</sup> |
| 4.        | Mixed Grassland                        | 81.83                       | 13.75                   | 0.818        | 5 <sup>th</sup> |
| 5.        | Tree Crop/Mature<br>Secondary Regrowth | 83.42                       | 15.36                   | 0.834        | 3 <sup>rd</sup> |
| 6.        | Young Secondary<br>Regrowth            | 54.01                       | 40.39                   | 0.540        | 6 <sup>th</sup> |

Young secondary regrowth is the most difficult vegetation unit to classify. It was classified with 54.01% precision. This is probably due to the fact that the field survey showed that it constitutes the undergrowth/understorey of mature secondary regrowth in the area. In fact, in a generalised procedure, it could be merged with mature secondary regrowth to form a vegetation complex. This is what Table 2, which shows that young secondary regrowth, has only 27.93% separability from tree crop/mature secondary regrowth implies. An attempt was however made to distinguish the former from the latter and hence, its poor purity rating (54.01%). This type of problem has been noted to be common as a result of the fact that automated procedure represents transitions as boundary lines (Martin, 1959) and as such, interpretation of satellite imageries whether by analogue or digital methods is not a precise science (Nahani, 1990). This made Allan (1989) to conclude that beguiling elegant cartography can conceal high levels of error while Hobbs (1990) argued that accurate representation of terrestrial vegetation in Earth system models has been a continuing challenge. Given the nature of the landscape in Nigeria, it is necessary to amalgamate like-classes during the digital image processing in order to enhance the level of classification accuracy. This however, means that only broad rather than specific classes could be generated with a high level of reliability.

### 4.3 Automated Mapping of Vegetal Cover

Figure 1 shows the result of the final mapping. The summary of its statistics (Table 5) shows that only 43.96% of the area could be said to be under forest cover. This is the total area occupied by tree cropland/mature secondary regrowth (17.14%) and young secondary regrowth (26.82). On the other hand, 33.63% of the area was occupied by mixed grassland. This situation implies that although the climatic climax of the area is Lowland Humid Tropical Rainforest (Keay, 1959), there is now quite a keen competition between forest and savanna elements for ecological space in the area.



**Figure 1: Supervised Classification of Landsat TM of the Study Area.**  
*NOTE: Legend is as defined on Table 1.*

**Table 5: Areal Extent of Cover Types**

| Cover type               | Areal Extent (in ha) | % of Total | Cum. % |
|--------------------------|----------------------|------------|--------|
| Tree Crop/Mature         |                      |            |        |
| Secondary Regrowth       | 1714                 | 17.14      | 17.14  |
| Young Secondary Regrowth | 2682                 | 26.82      | 43.96  |
| Mixed Grassland          | 3363                 | 33.63      | 77.59  |
| Arable Cropland/Fallow   |                      |            |        |
| Complex                  | 411                  | 4.11       | 81.70  |
| Burnt Patches            | 236                  | 2.36       | 84.06  |
| Exposed Land/Settlement  | 1096                 | 10.96      | 95.02  |
| Unclassified             | 498                  | 4.98       | 100.00 |

## 5 CONCLUSION

This study has demonstrated the value of high resolution satellite imageries in vegetation mapping and analysis, especially, in a developing country like Nigeria where aerial photographs are not available on a regular basis. However, the precise classification of the vegetal types shown by the satellite imageries was hampered by the heterogenous and unplanned nature of the landscape. Nevertheless, since this is explained by confusion matrix, the accuracy of the map generated from the exercise could not be said to be in doubt (Goodchild, 1987). It is necessary, in the light of the findings of this study, for the policy makers in the country, to encourage the integration of remote sensing techniques, especially, the digital image analysis into the regular resources surveys and inventory. This will constitute a major step toward the establishment of a reliable data base on the biotic environment and capability building in forestry management in the country.

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