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TREE DIVERSITY ANALYSIS OF A SAVANNA TYPE IN REPUBLIC OF BENIN USING REMOTE SENSING AND PLANT DIVERSITY INDICES

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Abstract

A vegetation inventory was carried out in 50 plots to analyse the biodiversity of Save Region of the republic of Benin. The aim was to show how human interventions impact the tree stands. The method of allocating plot number proportionally to the area of each stratum was adopted. This method which stems from the use of satellite data analysis was implemented using diversity indices. The main strata identified are: Gallery and dense forest (GF), Open forest (OF), Woodland savanna (WS), Tree savanna (TS) and Tree shrub savanna (TSS). Tree species diversity was analysed using plant diversity indices. From the 50 plots surveyed, a total of 63 tree species and 2,978 individual trees with DBH more than 10 cm were recorded. The mean tree population per ha is 638. The species richness varies from 24 as recorded on open forest to 52 recorded on tree savanna stratum. Analysis of tree variable correlation indicates that the strongest correlation was recorded between mean volume and basal area. In general, these plant diversity indices reveal the high heterogeneity existing among plots of different strata and the human impact on these tree stands.

Key words: *Forest inventory, tree species diversity, satellite data, stratum, savanna.*

Résumé

Un inventaire de la végétation a été réalisé sur 50 placeaux pour analyser la biodiversité de la Région de Savè en République du Bénin. Le but de cette étude est de montrer comment les interventions humaines ont des impacts sur les formations végétales. La méthodologie adoptée a consisté à allouer des placeaux proportionnellement à chaque strate. Cette méthode qui est basée sur l'analyse des données satellitaires, a été mise en place en utilisant des indices de végétation. Les strates principales identifiées sont les suivantes: Galerie forestière (GF), Forêt claire (OF), Savane Boisée (WS), Savane Arborée (TS) et Savane Arbustive (TSS). La diversité des espèces ligneuses a été analysée en utilisant des indices de la diversité biologique. Des 50 placeaux inventoriés, un total de 63 espèces et 2,978 arbres avec un diamètre à hauteur de poitrine (DBH) plus que 10 centimètre a été enregistré. La moyenne d'arbres par ha est 638. La richesse spécifique varie de 24 (forêt claire) à 52 (savane boisée). L'analyse de la corrélation entre les différentes variables indique qu'il existe une plus forte corrélation entre le volume moyen et la surface terrière. D'une manière générale, l'analyse des indices de la biodiversité révèle une forte hétérogénéité entre les différentes strates d'une part, l'impact de l'action de l'homme sur ces formations naturelles d'autre part.

Introduction

Benin Republic is located in the 'Dahomey gap', which is a break of the West African rain forest belt between Nigeria and Ghana. This gap which results from oceanographic, topographic and climatic interactions has generated essentially the drier types of guineo-congolian forest belt in southern – eastern Ghana, southern Togo and parts of southern Benin. As a result, vegetation in Benin is typical for humid savanna conditions. The main cover types are natural vegetation which varies from pockets of natural forests to herbaceous savanna (Jenik, 1994; Adjanohoun, 1968).

The greatest impetus for forest destruction in Benin as well as in most of African countries as stated by Ehui *et al*. (1990) is due to increasing demand for wood and cropland pressure from agriculture fuels by rapid population growth combined with traditional agricultural practices such as shifting cultivation. The rapid changes in land use have led to the destruction and fragmentation of natural tree stands. Bourreau and Sylla (1989) estimated that more than 100, 000 ha of natural vegetation is annually destroyed due to anthropogenic activities. As concluded by Turner *et al*. (1990), the demand for forest resources will continue to increase as long as they remain the basis for development, while the balance between population, resources, environment and development will become more and more distorted.

Despite this situation, very few assessments of land use cover changes have been undertaken in Benin. Although the floristic composition and plant community densities of forest and savanna types have been studied, the current state of knowledge about species and ecosystems is far from being complete. Detailed knowledge about the ecology of plants, floristic composition and diversity of plant communities that would be the obvious first step in understanding and conserving them is still incomplete or lacking. To tackle the decline of biodiversity and to formulate policies, reliable estimates on the state and change of these forest resources are needed. In this regard, a vegetation inventory could provide useful information on the plant diversity, the importance of growing stock available and other useful information on the tree stand which can be of great importance to improve the knowledge of the land use/cover change processes (Allen & Barnes, 1985).

Despite many methodologies developed to estimate vegetation composition, there is still a knowledge gap to be filled on the methodologies. Most of them are either physical based or transect oriented. Use of remote sensing for spatial analysis and vegetation indices have been tested as an improved means to characterise savanna type vegetation (Natta, 2000; Anderson *et al.,* 1976). Remotely sensed data and geographical information system which deal with spatial data have considerable utility in acquiring vital data information especially on vegetation. They have a great potential in providing accurate information that can be used for plant community management and monitoring activities. On the other hand, some plant indices have been successfully used to investigate the structure, the floristic composition variation and the spatial distribution of tree species across savanna vegetation types (Kokou *et al.*, 2000; Tente, 2000).

For a complete analysis of the savanna type vegetation, there is a need to fill the loopholes found in methodologies used by the past and to develop an integrated approach that links harmoniously different "tools" such as remote sensing, field measurements, and vegetation indices to increase our knowledge and understanding of the savanna type vegetation in a study area located in the central region of the Benin Republic characterised by an increasing severe human pressure.

This paper investigates both the floristic composition variation and the spatial distribution of the tree species in savanna vegetation type using plant diversity index with a view to documenting the impact of human interventions on the tree stands.

Materials and Methods

Study area

The study area is located in the central part of Benin Republic (Fig. 1). It lies between latitudes 8°00' N and 9°00' N and its longitudes vary from 1°E to 3°40'E. The study area is bounded by Oueme river in its western part and Nigeria frontier in the east by Okpara river. Its surface area covers an area of 580, 900 ha. Administratively, the study area is included in the Department of Collines. With a total population estimated in 1998 at 140,434 inhabitants of which 49.6% are male, this study area is composed of three districts: Save in the south, Ouesse in the middle and part of Tchaourou in the north. According to Adam and Boko (1983), the study area belongs to the subsudanian transition agroecological zone. The climate is intermediate between guinean congolian and sudano-guinea climate. The temperature with an annual average estimated at 28°C, fluctuates from 25°C to 30°C. The rainfall pattern is fairly monomodal. The mean annual rainfall recorded from 1964 – 1997 at Save synoptic meteorological station, fluctuated from 1000 mm to 1100 mm with a mean of around 1052 mm per annum. The stream network indicates that the study area is well drained by many streams of the two Rivers Okpara and Oueme which are used respectively as west and eastern borders of this study area. According to Igue (2000), the soils are relatively well drained, very shallow to shallow gravely and stony with sandy to clayed-sandy texture in some parts. These soils are highly favourable for savanna vegetation type and for annual and perennial crops. The vegetation is typical of humid savanna conditions. The main cover types vary from pockets of mature forests to herbaceous savanna. It consists of woodland savanna as well as riparian or gallery forest along the rivers and the streams.

Methodology

A stratified random sampling design was adopted for the inventory of the study area. This method allocates a plot number proportionally to the area of each stratum (Kent and Coker, 1994; Skole and Tucker, 1993). The method was implemented using a multiphase procedure. Stratification, the first phase is performed through satellite image analysis. The second step is the sampling itself based on legend units obtained from mapping. With this method, the following activities were undertaken in sequential steps: mapping and stratification, field survey, data arrangement and wood volume estimation.

Classification and identification of the five strata

Through Landsat TM image interpretation, the land cover patterns were analysed. A full scene of Landsat TM of 12/11/99 covering the study area was analysed. A total of 40 points selected from a 1:200, 000 topographic map and well distributed within the Landsat image were used to ensure geometric correction and to create image map. The total RMS (root mean square) error was estimated at 0.52. Image processing was performed using ERDAS IMAGE 8.3. Histogram stretching technique was used for more contrast, while edge enhancement filter technique well known as Laplacian or non-directional filtering was performed for local enhancement of the image map. Edge enhancement was carried out by a process called spatial filtering, performed pixel-by-pixel transformation of the satellite image (Foras & Sgouras, 1999; Lillesand & Kiefer, 1994). A preliminary box classification was introduced to guide this visual interpretation. Applying visual interpretation of the image map, tonal, pattern and texture differences of the imagery were considered and taken into account in order to identify and classify the different vegetation classes. During the process of image interpretation, the smallest mapping unit that could be interpreted and delineated with accurate discrimination among classes from satellite imagery was a square of 5 mm side or a circle with 2.8 mm radius. This represents an area of 25 ha for the final map edited at the scale of 1/100, 000.

From this analysis, 5 strata were identified. They include: Gallery and dense forest (GF), Open forest (OF), Wooded savanna (WS), Tree savanna (TS) and Tree shrub savanna (TSS). With regard to land cover and process identification, this method of classification yielded very good results as it enables vegetation strata discrimination with an overall accuracy estimated at 82%.

Determination of plot number, size and location.

The determination of the plot number was calculated using the following equation (JICA, 2000).

$$\mathbf{n} = \frac{(\mathbf{t} \cdot \mathbf{Cv})^2}{\mathbf{E}^2} \cdot \mathbf{S} \qquad \mathbf{(1)}$$

In which
n is plot number
t value from t-distribution table
Cv : variation coefficient
E : estimated error
S: security rate

With $\mathbf{Cv} = \frac{\sigma}{X}$ and

σ = Standard deviation of pre inventory survey samples
X = Average value of pre inventory survey samples

From above, 50 plots were selected. These plots were chosen so that to be well distributed according to the importance of the strata. As recommended by most of investigations, circular plots with 0.1 ha as area and a radius of 17.84 m for the plot centre were adopted (Reynolds, 1969; JICA, 2000; Magurran, 1988). The exact location of plots was determined before the fieldwork on the vegetation map. Allocation of plots per stratum is presented in Table 1. In order to avoid local influence, plots were located at least 500 m from the road and more than 2 km from any village. The precision in the localization of ground control points and the selected plots was obtained using a Magellan 15 GPS which allows a 15 m-precision.

Data collection and recording

Within each sample plot a complete observation was made and data were recorded in a relevee sheet. Tree diameters were measured at a standard reference point usually referred to as breast height defined as the height of 1.37 m from the ground line. This measurement is conventionally adopted for forest inventory. In order to take into account small diameter of trees, the inventory was extended to small trees with at least 10cm as DBH (diameter at breast height). Using a BLOOM LEIS device, Tree height (TH) was measured as total height, from the ground line to the top of the tallest point on the tree. Total height is usually measured in meters.

Tree species diversity analysis

To analyse tree species diversity, plant diversity indices were used. According to Bonham (1976) they are expressed as follows: Using data collected from the fieldwork, estimation of tree volume was made. Based on data collected on the two main stand factors, DBH (diameter at breast height) and (T) total height, some tree species parameters were calculated. They include:

- Single tree Volume (Vi)

$$Vi = \frac{H\pi D^2}{4}\pi \times cf \qquad (2)$$

Vi: volume of a tree (m^3)
D: diameter at breast height (cm)
H: Total height of the tree (m)
Cf: form factor =0.33.
(Value used by Forest Directorate of Benin)
∏ = 3.14

Calculation of Vi for individual tree is done after formula given by JICA (2000)

- Estimate of stand volume

Using the formula derived from stratified sampling method, the overall stand volume is estimated as follows:

$$X = \sum X_i \cdot V_i$$

Where X = overall average (m^3 /ha) **(3)**
X_i = Average value of each stratum (m^3 /ha)

- Standard Error of overall average

$$S_{\bar{x}} = \sqrt{\frac{1}{N^2}\sum \left\{ N_i \left(N_i - n_i\right) \bullet \frac{S_i^2}{n_i} \right\}} \qquad (4)$$

$S_{\bar{x}}$ **= Standard Deviation**
N = Size of population
N_i = Size population of each stratum
n_i = Size of sample of each stratum
S_i = Sample distribution of each stratum

- Confidence Interval of Overall Stand Volume: $\mathbf{N}\left(\bar{X} \pm t \bullet S_{\bar{x}}\right)$ **(5)**

- Basal area (G)

The cross section area of a tree at breast height is referred to as its basal area. The basal area (G) is calculated from diameter at breast height by assuming a circular cross section. (G) is usually expressed in m^2/ha as follows:

$$\mathbf{G = \prod . \sum D^2/4} \qquad \mathbf{(6)}$$

Where D = diameter at breast height (m)
∏ = 3.14
G = the total basal area of a given plot.

- The Species richness (N_0): which represents the total numbers of species recorded on a specific area.
- The Shannon Weiner diversity index (H^I) well known and widely used as index to compare diversity of different types of vegetation. According to Magurran (1988) and Yayi (1998), this index is said to be useful for comparison of sample diversities because it provides reliable information theory and concept that information of a sample or community can be measured in a similar way to the information contained within the message. This index is expressed as follows: $H^I = -\sum_{i=1}^{n} pi \log(pi)$ **(7)**

  Where pi is the proportional abundance of i^{th} tree species = (n_i /N)

  Where n_i is the abundance of the i^{th} tree species and N = $\sum n_i$ is the total abundance in a vegetation type (or a sample)

  In practice pi = $\frac{qi}{Q}$ qi is the frequency (i) and

  Q= $\sum_{i=1}^{n} qi$ the total sum of qi **(8)**

- Pielou equitability index (Eq) expressed as the ratio of the observed diversity with the maximum possible diversity for N species (Kokou *et al.*, 2000). Hence, its maximum value is 1. When the observed species have similar frequencies, Eq value becomes high. In contrast, when the ratio is likely to be equal to zero, the observed population has some dominant species and some with small number of tree species. The equation is expressed as : Eq= (I_{SH})/log N. **(9)**

- Coefficient of variation**.** The coefficient of variation is a statistics used in forest inventory to show the relative variability of tree stands surveyed. A high value indicates that the tree species is not well spread in all the plots or its frequencies vary a lot within localities. Linkage between vegetation groups within different tree stands was performed using factorial analysis.

For data analysis, STATSOFT was used in combination with Excel. Satellite Image data was analysed using ERDAS software.

Results

Tree species distribution

The results of the survey are summarized in Table 2. From 50 plots surveyed, a total of 63 tree species and 2,978 individual trees with DBH more than 10 cm were recorded. The tree mean population per ha is 638. The dominant tree species recorded were as follows: *Anogeissus leiocarpus, Burkea africana, Combretum molle, Daniellia oliveri, Khaya senegalensis, Marantes polyandra, Pterocarpus erinaceus, Terminalia avicennoides and Uapaca toboensis.*

An analysis of each vegetation type or stratum shows the following richness: Open and gallery forests are characterized by *Anogeissus leiocarpus, Daniellia oliveri, Dichrostachys cinerea, and Isoberlinia doka*. In woodland savanna where the highest tree population per ha was recorded, the most abundant species were: *Vitellaria paradoxa, Terminalia avicennoides, Pterocarpus erinaceus, Isoberlinia doka and Anogeissus leiocarpus.* On the other hand, tree savanna and shrub tree savanna are dominated by *Vitellaria paradoxa, Burkea africana, Parinari curatellifolia, Pterocarpus erinaceus, Terminalia avicennoides, Combretum hypopilinum, Detarium microcarpum* and *Daniellia oliveri.* Some tree species such *as Burkea africana, Pterocarpus erinaceus* and *Anogeissus leiocarpus* are well spread and are recorded across all the vegetation types. Others like *Combretum molle* and *Tectona grandis* are present in great number only in some strata. While the overall contribution of the ten species total density is 50% (49.7%), this contribution varies from plot to plot. It is as low as 20.1% in Tree savanna and 33.3% in Gallery forest and as high as 70.3% in Woodland savanna and 82.2 in Tree shrub savanna (Table 3).

The highest number of species was recorded in tree savanna strata and the lowest in open forest and gallery forest. These data are important as they help to give a real expression and description of the characteristics of each of the strata. This permits better understanding of the importance of the wood loss associated with biomass change.

Species diversity and classification of the vegetation types

As shown in Table 4, plant communities of the study area are diverse. The diversity in plant community varies from one stratum to another. The specific richness varies from 24 as recorded for open forest to 52 recorded for tree savanna stratum. Analysis of the table also reveals that Shannon index values are similar except on open forest stratum. Its highest value, which was recorded from woodland savanna, is not significantly different from the other strata values. This indicates that species recorded have quite similar frequencies of occurrence. As far as Pielou index is concerned, its lowest value was recorded on tree savanna plots (0.30 ± 0.06 and 0.28 ± 0.10 respectively for woodland savanna and tree savanna). This means that this stratum has abundant species with similar frequency of occurrence. On the other hand, the fact that its highest value was recorded on gallery forest stratum indicates that most species recorded are scarce and not really endemic to this kind of environment. The list of species recorded confirms this statement. From what is above, Table 4 illustrates as well the heterogeneity existing among the strata.

To test the tree diversity and heterogeneity, a dendrogram was constructed, based on the presence or absence of a species in a plot. Analysis of this dendrogram as shown in Fig. 2, indicates high heterogeneity among plots of different strata. Plot grouping is clearly noticeable from 100% to 84% except Gf 22, which seems to individualize from the other plots. It is of importance to note that Gf 22 indicates plot 22 located in a Gallery forest (Gf) stratum as shown by Fig. 2. But at threshold of 84 % of resemblance, two groups can be clearly identified. The first one is composed of the following plots: Ts 11, Ts 12, Tss 23; and Tss 3 whereas the remaining plots belong to the second group. Any of these groups shows aggregation of similar plots. On the other hand, at threshold of 70% of resemblance, three groups are noticeable. The first group includes 12 plots from Gf 22 to Tss 21. The second group larger than the first one includes 27 plots. The third group with 11 plots forms an homogeneous entity. At this threshold of 70% of resemblance, any other similar plot grouping is significantly remarkable.

Correlation analysis of tree variables

Correlation analysis between tree variables was undertaken. Table 5 gives the coefficient of correlation between tree variables. From this table it appears that all tree variables were highly correlated with each other. However, the degree of correlation varies between some variables. Mean volume shows strongest correlation with mean basal area. It is followed by correlation between mean Diameter at Breast Height (DBH) and mean basal area and the couple mean volume and mean DBH. The high correlations observed between these variables can be explained by the fact that DBH is used for calculating both mean basal area and mean volume.

On the other hand, the lowest correlation is recorded between mean basal area and mean Tree Height (TH). Mean DBH shows a highly significant correlation with mean TH of 0.73. Correlation between tree population per stratum or tree density and other tree variables (DBH and TH) are relatively high. On the other hand, it is relatively small when mean volume is considered. This may be due to the fact that increasing density of a tree stand is linked with decrease of the growing stock volume. Srivasta *et al.* (1999) dealing with tree variables of a *Shorea robusta* forest in India obtained similar results and concluded that the degree of correlation of each tree variable relies on its relation.

Effect of DBH on tree volume

When DBH of trees increases, growing tree stock volume consequently increases. To show how this stock growing volume varies, three different classes of DBH i.e. (DBH $\leq$ 10cm; 10 < DBH $\leq$ 20 cm; DBH > 20 cm) were distinguished. As shown in Table 6, these different DBH classes refer to practical uses of wood. In fact, trees with DBH less than 10 cm have very few uses because for most species having this size, the wood is not yet mature. But when DBH varies from class 10 cm to class 20 cm, trees of this category can be used as poles, firewood or for other uses depending on the quality of their wood. Over 20cm, trees are considered as mature and marketable. The proportions of stock growing volume for each DBH size category identified are respectively 4.95 %, 21.65 % and 73.40 %. And the growing stock volume variations are 22.86% and 29.49% respectively when DBH varies from the first category to the second and from this latter category to the third. It was also observed that large number of small size category trees yields small proportion of the stock growing volume (Table 6). In fact, stock growing volume of 1447 trees, which account for approximately 48.58% of the tree population surveyed yield only 4.9 % of the total growing stock volume. On the other hand, 16.26 % of trees with DBH more that 20 cm account for more than 73.4 % of the total growing stock volume. As shown in Fig. 3 when total growing stock volume increases, the total number of trees decreases. The crossing point of the curves occurs when trees have at least 20 cm as DBH, which means when they are mature and marketable. This confirms the assumption that it is not the number of trees especially when they have small DBH that give potential value to a tree stand. Importance is usually given to trees with larger DBH and especially to those with good wood quality.

Analysis of some valuable species as shown in Table 7, indicates that very few have mean DBH of more than 20 cm. Among species belonging to this category are two sawn wood species: *Afzelia africana* and *Isoberlinia doka*. The other sawn wood species are important in number but they still have small DBH. Although many species have been listed, this table shows that many valuable species such as *Khaya senegalensis* and *Afzelia africana* used as sawn wood are scarce in terms of number of the species. Their volumes are respectively $0.135m^3$ and $2.802\ m^3$. This indicates that these commercial species are under pressure of demand. This situation is confirmed by the total absence of other valuable species like *Millicia excelsa* formerly well spread in this region.

In the absence of these valuable species well known as sawn wood, some species are being used as substitutes. They include *Pterocarpus erinaceus, Isoberlinia doka, Pseudrocedrela kotchii* and *Lannea acida*. Although these species exist in great number, they remain small size trees. In fact, all of them have DBH less than 20 cm. Polansky (1994) recorded *Isoberlinia* doka and *Pterocarpus erinaceus*, two well spread species of Toui-Kilibo protected forest with a mean volume of respectively 24.86 m^3 and 12.62 m^3. Comparison with data collected from the study area indicates that the mean volumes for these two species are in order 8.20 m^3 and 3.76 m^3 three times lower than those collected seven years ago from the same region. This confirms and highlights the impact of human pressure on these resources.

Discussion

With regards to the floristic composition and species richness of the study area, our results confirm the location of the study area as part of the 'Dahomey gap', which is a discontinuity of the West African rain forest belt. The tree species recorded are typical of savanna type. In fact, the mean tree density is estimated at 638 trees per hectare. Apart from a few emergent species (e.g. *Isoberlinia doka, Anogeissus leiocarpus* and *Ceiba pentandra)* the average tree height is 7.7m and the mean diameter at breast height is 12.7 cm. As shown in Table 3, the most abundant tree species recorded are *Daniella oliveri, Combretum molle, Burkea africana, Pterocarpus erinaceus, Terminalia avicennoides, Khaya senegalensis, Dialum guineense, Tectona grandis, Uapaca toboensis* and *Marantes polyandra*. It was observed that most of these species ranked as the most abundant, are distributed within the five strata. These species are recorded both in forest and savanna strata. On the other hand, there are marked floristic affinities among forest and savanna type strata. Apart from some dry semi-deciduous forest types such as *Khaya senegalensis, Dialum guineense*, very few typical forest species have been recorded. This confirms the great richness of savanna type vegetation and thus the complexity of their study (Skole and Tucker, 1993).

Analysis of the tree stands using vegetation indices indicates that their respective values vary from one stratum to another. From this analysis, it can be stated that the higher the specific richness of a stratum is, the lower the coefficient of variation. This also confirms the assumption that forest strata have less species than savanna strata type. Tree density of forest strata in our study area is similar to those in Toui Kilibo forest Reserve in Benin (Natta, 2000; Polansky, 1994). Moreover, forest structure is characterized by a low tree density (Reynolds, 1969). On the other hand, the phenomenon of species dominance in which one or a few species contribute to the total abundance of the tree stand may explain this situation. Dry deciduous forests resulting from edaphic conditions unfavourable for a large majority of tree species, are other factors explaining the fact that forest strata have less species than savanna strata type (Kokou *et al*., 2000).

As far as Shannon index is concerned, it was observed that quite equal values were recorded except on open forest stratum. The fact that the lowest value was recorded on forest stratum highlights the heterogeneity in the frequency of the species recorded in the two plots surveyed composing this stratum. Analysis with Pielou index indicates that the tree savanna strata where the lowest value was recorded indicates that species are abundant but with similar frequency of occurrence. On the other hand, the fact that its highest value was recorded on gallery forest stratum indicates that most species recorded are scarce and not really endemic to this kind of environment. In other words, very few tree species are endemic to a stratum. Most of species are spread in all the five strata.

From the above, it can be stated that there is a heterogeneity existing among strata and the tree stands, in general, are heterogeneous with large spatial species distribution. One of the main issues raised is that the choice of inventory techniques (i.e. minimum plot size and plot shape) has influenced the heterogeneity so far stated. According to Pardé (1961), large plots tend to minimize the variance between plots, because they are more costly to implement and to measure. Reynolds (1969) through a comparative study assumed that small plots may over estimate the coefficient of variation. On the other hand, Magurran (1988) modelled plot size and time allocation between travel and plot measurement and observed that the optimal plot size is highly correlated with the coefficient of variation and the measurement time. Field plots (50m x 10m) were established in fragment forests in Southern Togo (Kokou *et al.*, 2000). Natta (2000) used species-area curves to adopt 500m² as the optimal plot size for riverine forests in a forest survey conducted in site located closely to the study area. However, there is some reservation with regards to the accuracy and precision of the method used as the flattening of these curves is rarely achieved. If $500m^2$ plot size is largely adopted for forest tree stand, the minimum acceptable plot size for savanna type vegetation, is 0.1ha (Kenkel *et al.,* 1989; JICA, 2000).

Besides plot size, plot shape is an important feature in forest survey. A number of empirical studies have investigated the effect of plot shape on the resulting precision. Study of different types of shapes has led to conclude that circular plots minimize the perimeter to area ratio which decreases the likelihood of field crews having to make the decision about whether or not to include borderline trees in the sample. Overall, these circular plots offer more advantages than the other ones (Goldsmith and Harrison, 1976; Bonham, 1976; Reynolds, 1969). As most of investigations recommended circular plots with 0.1 ha as area and a radius of 17.84 m for the plot centre, they were applied in the present work.

Detailed analysis of the plant diversity has also revealed the disturbance of the plant communities. The forms of this disturbance are many and affect irreversibly the tree stands. Selective removal of big stems of valuable species through tree harvesting and cutting has resulted in structural simplification of dense and undisturbed stands, in canopy opening and in gaps at lower height. Systemic cutting of some tree species such as *Milicia excelsa* formerly well spread in the study area has led to the complete disappearance and the floristic richness depletion of forest and woodland strata. Other consequences resulting from tree stand disturbance include changes in hydrology of waterways associated with gallery forest, alteration of geomorphic structure. Although these later aspects are evident and important, they were however not well documented in our study. There is a need to improve the knowledge on their environmental implication.

Conclusion

Analysis presented in this paper has highlighted the importance of the ecological pattern in the study area. The detailed analysis of the plant diversity has revealed the degree of disturbance of the plant communities. In general, this study has highlighted the importance of forest inventory as an adequate means to document on the potential of the tree stands in savanna region. The method used which stems from the use of satellite data analysis, is useful and adequate as it has helped to identify the discrepancies in tree stands resulting from the influence of driving forces and to assess the plant composition and plant diversity of the tree stand. Human impact through tree harvesting, cutting, cropping etc, have been found at the centre of the change in resource use. To improve the understanding of anthropogenic factors in the process of land use/cover change, there is a need to undertake socio-economic surveys.

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Table 1: Plot allocation per stratum

Stratum	Total Number	%
Gallery forest GF	2	4
Open forest OF	2	4
Woody savannah WS	17	34
Tree savannah TS	22	44
Tree shrub savannah TSS	7	14
Total	**50**	**100**

Table 2: Summary of the structural characteristics of the vegetation types in the study area.

	Stratum					
Parameter	GF	OS	WS	TS	TSS	Total
Number of plots	2	2	17	22	7	50
Number species	32	24	47	52	38	63
Number trees/ha	550	525	786	852	473	638
Number trees/ species	4	5	28	20	16	17
Mean DBH (cm)	14.85	13.25	13	14.21	9	12.7
Mean TH (m)	9.35	10.36	7.66	8.31	5.81	7.68

GF: Gallery forest; OF: Open Sananna; WS: Woody savanna; TS: Tree savanna TSS: Tree Shrub savanna DBH: Diameter at Breast Height; TH: Total Height

Table 3: Density and distribution of ten most abundant tree species in the different vegetation types of the study area

	Stratum					
Species	GF	OF	WS	TS	TSS	Total
Burkea Africana	4	3	54	25	84	163
Combretum molle	0	0	61	13	41	115
Daniellia oliveri	5	1	74	84	59	217
Khaya senegalensis	7	1	82	0	71	153
Marantes polyandra	6	1	60	15	77	152
Pterocarpus erinaceus	4	6	107	13	58	178
Tectona grandis	0	1	102	0	0	102
Terminalia avicennoides	4	1	3	55	43	101
Dialum guineense	5	4	46	23	34	102
Uapaca toboensis	3	5	102	0	10	112
No of trees/strata	***44***	***45***	***820***	***235***	***528***	***1672***
Total population	**117**	**105**	**1101**	**1054**	**601**	**2978**

GF: Gallery forest; OF: Open Forest; WS: Woody savanna; TS: Tree savanna TSS: Tree Shrub savanna

Table 4: Summary of tree diversity indices of the vegetation types

Stratum	Parameter Specific richness **No**	Shannon Index **Ish**	Equitability Pielou index	Coefficient of variation Cv (%)	Representative species
Gallery forest	32	3.88±0.05	0.92±0.02	159	*Mytragina inermis, Anogeissus leiocarpus*
Open Forest	24	2.80±0.56	0.77±0.03	257	*Daniellia olvieri Isoberlinia doka*
Woodland Savanna	47	3.92±0.16	0.30±0.06	173	*Afzelia africana Burkea africana*
Tree savanna	52	3,76±0,16	0.28±0.10	127	*Terminalia avicenoides Detarium microcarpa*
Tree Shrub Savanna	38	3.41±0.40.	0.86±0.08	161	*Anona senegalensis Vitellaria paradoxa*

Table 5: Summary of Correlation coefficients between tree variables in the study area

Parameter	Parameter Mean TH	Mean DBH	Mean volume	Mean basal Area	Total No. of trees/stratum
Mean TH	1.0	0.7	0.7	0.6	
Mean DBH	0.7	1.0	0.9	0.9	
Mean volume	0.7	0.7	1.0	1.	
Mean Basal area	0.6	0.9	0.95	1.0	
No. Trees/ Stratum	0.8	0.8	0.6	0.7	1.00

TH: Total Height; DBH: Diameter at Breast Height; No: Number

Table 6: Effect of DBH on tree volume

VOLUME	V1 (m^3)	V2 (m^3)	V3 (m^3)
Width	DBH ≤ 10 cm	10 < DBH ≤ 20 cm	DBH > 20 cm
TOTAL	10.4	45.6	154.6
% Total volume	4.9	21.6	73.4
Mean volume (m^3)	0.007	0.044	0.319
Number of trees	1447	1047	484
% Number of trees	48.58	35.15	16.26

Table 7: Characteristics of some valuable tree species

Species	Mean DBH (cm)	Mean TH (m)	Volume (m^3)	Coefficient of variation
Pterocarpus erinaceus	15.5	8.7	18.8	57.9
Afzelia africana	22.5	7.7	2.8	83.7
Isoberlinia doka	19.9	12.2	41.0	55.7
Burkea africana	16.6	9.4	20.0	52.6
Lophira lanceolata	12.4	8.5	1.4	44.7
Anogeissus leiocarpus	14.4	12.4	34.4	66.2
Pseudrocedrela kotchii	9.3	6.4	1.0	57.6
Terminalia laxiflora	10.6	6.4	0.1	56.1
Parkia biglobosa	24.5	10.5	2.3	69.9
Prosopis africana	14.9	9.3	2.8	70.8
Lannea acida	16.6	8.4	7.5	62.8
Khaya senegalensis	18.5	7.5	0.1	119.1
Vitellaria paradoxa	15.8	7.2	17.4	48.7

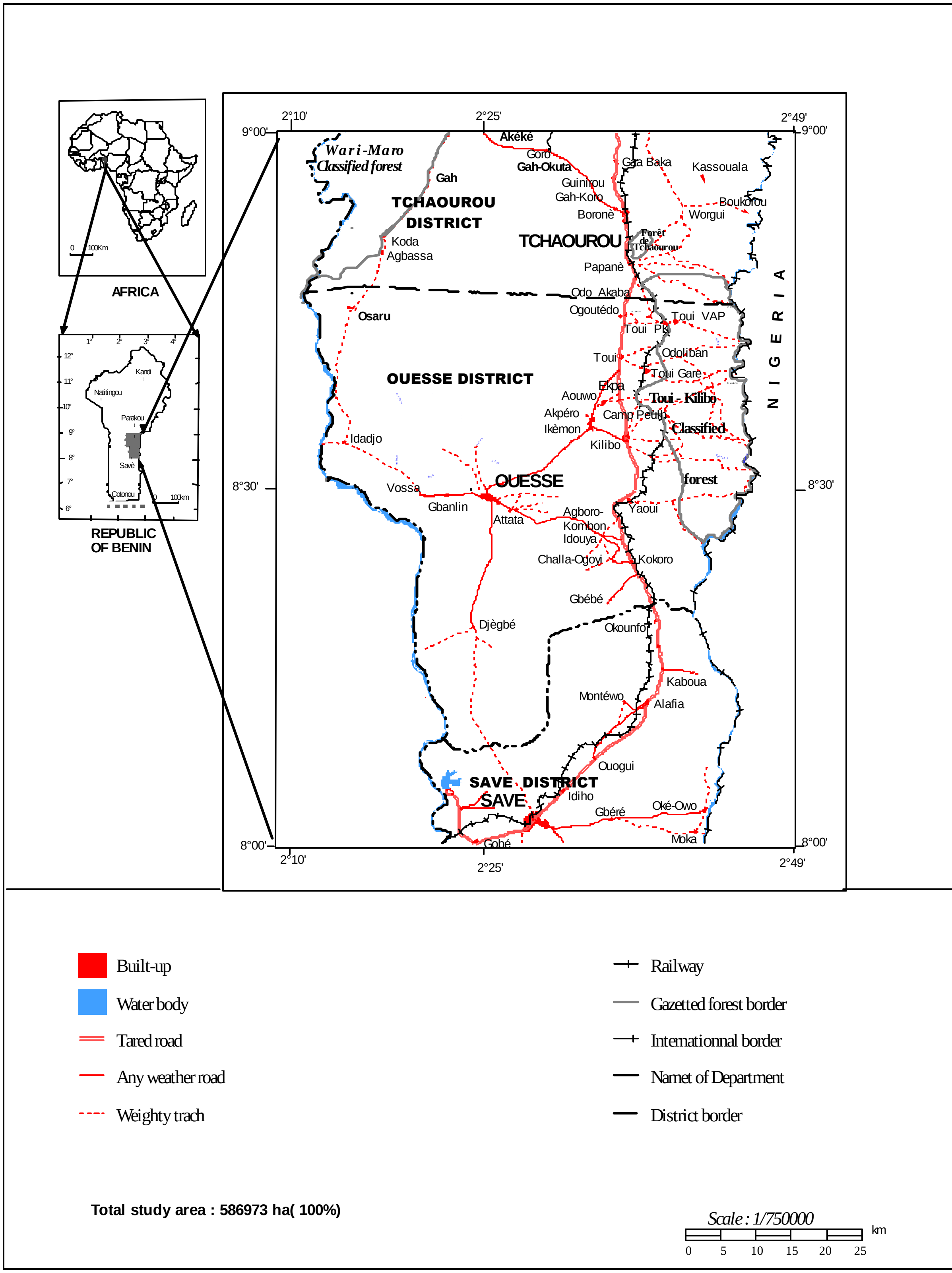
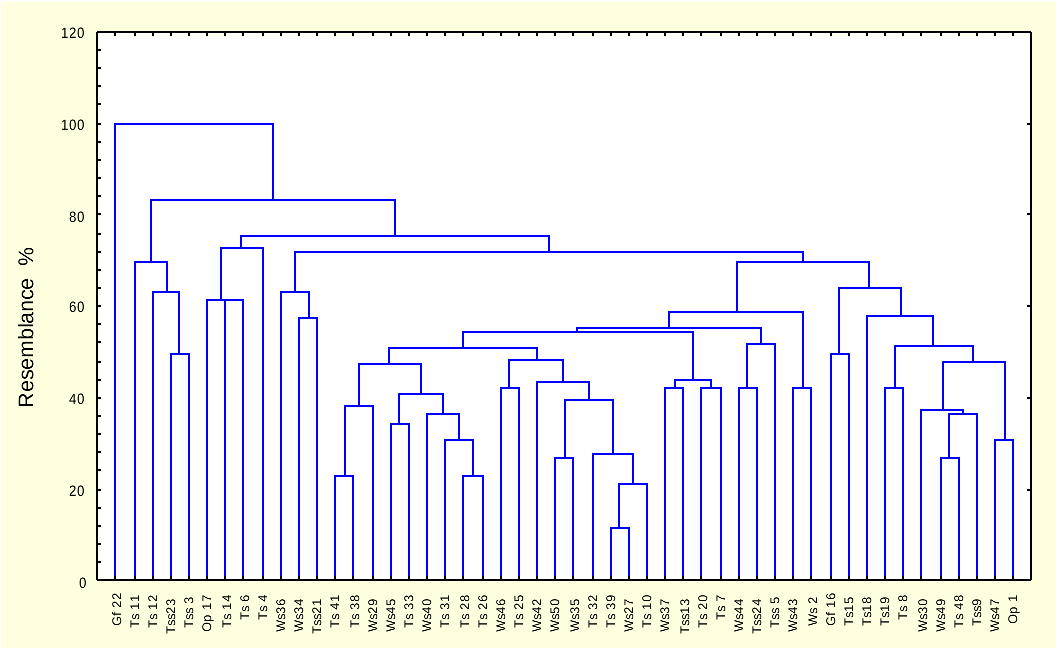


Figure 1: The study area



Gf : Gallery forest ; Of : Open forest ; Ws : Woody savannah ; Ts: Tree savannah;
Tss: Tree shrub savannah Gf 45: Plot45 belonging to Gallery forest stratum

Figure 2: Tree variable dendrogram

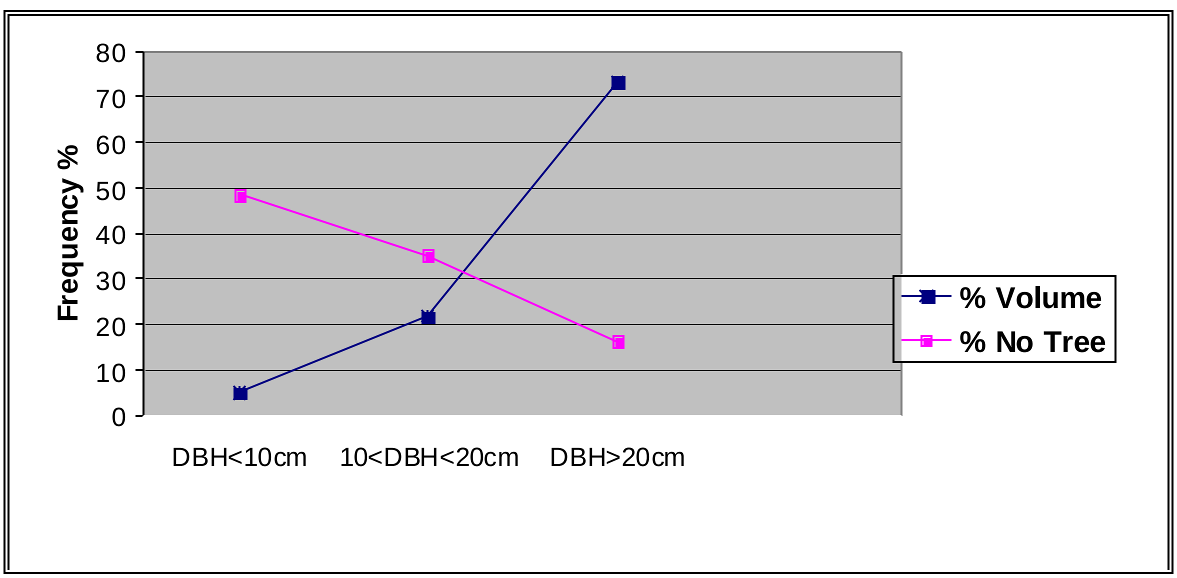


Figure 3: Comparative evolution of volume and No of trees in tree stand