Plant communities, forest site identification and classification in Toffo reserve, South-Benin

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Nine plant communities in Toffo forest reserve (southern Benin) were identified by using a phytosociological approach. Within each non-pioneer plant community, site conditions and productivity levels were remarkably homogenous. The relationships between plant communities, ecological factors and plantation productivity were used to identify and map five forest sites, for which management specifications are indicated.

Chromolaera odorata plant community
Photo J. C. Ganglo.

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RÉSUMÉ

GROUPEMENTS VÉGÉTAUX, IDENTIFICATION ET CLASSEMENT DES STATIONS FORESTIÈRES DANS LA RÉSERVE DE TOFFO, SUD-BÉNIN

Des études phytosociologiques ont été faites, entre novembre 2001 et mars 2004, dans la forêt de Toffo (6° 51' - 6° 53' latitude nord et 2° 05' - 2° 10' longitude est), au Sud-Bénin (Afrique de l'Ouest), en vue d'identifier et de classer les stations forestières. L'étude de la végétation a été faite selon l'approche de la phytosociologie synusiale. Celle des sols a été réalisée en analysant deux profils pédologiques au sein de chaque groupement végétal identifié. Les paramètres topographiques tels que les pentes, les positions topographiques et l'exposition ont été notés. Par profil pédologique, deux échantillons de sol ont été prélevés dans les horizons de surface pour analyse de laboratoire. Les paramètres dendrométriques (diamètre à 1,3 m du sol et hauteur) ont été mesurés dans au moins quatre placettes de 300 m² (15 m x 20 m), au sein de chaque groupement végétal. Les études ont permis d'identifier et de décrire neuf groupements végétaux. Au sein de chaque groupement non pionnier, nous avons noté une homogénéité remarquable, aussi bien des facteurs écologiques que de la productivité des plantations. L'étude de la productivité des plantations en fonction des groupements végétaux a caractérisé trois niveaux de productivité, significativement différents au seuil de probabilité de 5 %. Les corrélations entre les groupements végétaux, les facteurs écologiques et la productivité des plantations a permis d'identifier et de cartographier cinq stations forestières pour lesquelles des recommandations d'aménagement ont été faites.

Mots-clés : phytosociologie, station forestière, groupement végétal, réserve forestière de Toffo, Bénin.

ABSTRACT

PLANT COMMUNITIES, FOREST SITE IDENTIFICATION AND CLASSIFICATION IN TOFFO RESERVE, SOUTHERN BENIN

Phytosociological surveys were carried out from November 2001 to March 2004 in Toffo forest reserve (latitude N 6° 51' - 6° 53' to longitude E 2° 05' - 2° 10') in southern Benin (West Africa), in order to identify and classify forest sites. The method used for the vegetation survey was based on the synusial approach to phytosociology. The soil survey was made by analysing two soil profiles per plant community. Topographical parameters such as slopes, positions and exposure were noted. Two soil samples from each soil profile were taken for laboratory analysis. Dendrometric parameters (height and diameter at breast height) were measured in at least four sample plots of 300 m² (15 m x 20 m) within each plant community. The study has enabled us to identify and describe nine plant communities. In the non pioneer plant communities, site conditions and forest productivity were remarkably homogenous. An analysis of plantation productivity according to plant communities has identified three levels of productivity that differ significantly at the 5% probability level. The correlations between plant communities, ecological factors and plantation productivity have enabled us to identify and map five forest sites for which we indicate management specifications.

Keywords: phytosociology, forest site, plant community, Toffo forest reserve, Benin.

RESUMEN

AGRUPACIONES VEGETALES, IDENTIFICACIÓN Y CLASIFICACIÓN DE LAS ESTACIONES EN LA RESERVA DE TOFFO, SUR DE BENÍN.

Se efectuaron estudios fitosociológicos, entre noviembre de 2001 y marzo de 2004, en el bosque de Toffo (6° 51' - 6° 53' N y 2° 05' - 2° 10' E), en el Benín meridional (África occidental) para identificar y clasificar las estaciones. El estudio de la vegetación se hizo siguiendo el enfoque de la fitosociología sinusial. El estudio de suelos se realizó analizando dos perfiles edáficos en cada agrupación vegetal identificada. Se anotaron los parámetros topográficos como pendientes, posiciones topográficas y exposición. Se tomaron dos muestras de suelo por perfil edáfico, en los horizontes superficiales, para su análisis en laboratorio. Los parámetros dendrométricos (diámetro a 1,3 m del suelo y altura) se midieron en al menos cuatro parcelas de 300 m² (15 m x 20 m), en cada agrupación vegetal. Los estudios permitieron identificar y describir nueve agrupaciones vegetales. En cada agrupación no pionera, observamos una notable homogeneidad, tanto de los factores ecológicos como de la productividad de las plantaciones. El estudio de la productividad de las plantaciones en función de las agrupaciones vegetales permitió caracterizar tres niveles de productividad, significativamente diferentes en el umbral de probabilidad del 5 %. Las correlaciones entre agrupaciones vegetales, factores ecológicos y productividad de las plantaciones permitieron identificar y cartografiar cinco estaciones y aportar recomendaciones de ordenación.

Palabras clave: fitosociología, estación, agrupación vegetal, reserva forestal de Toffo, Benín.

Introduction

Benin's natural forest resources are not extensive, covering about 2.65 million hectares according to the 2001 FAO forest inventory. These limited forest resources are vulnerable to degradation from seasonal fires, intensive grazing and extensive agriculture. Benin is currently losing some 70 000 ha of forests per year due to degradation (FAO, 2001). In the early 1940s, some reforestation was carried out by the government, and the country now has about 112 000 ha of plantations (FAO, 2001). Sustainable management of these limited forest resources is essential if the country is to continue to meet demand for forest products. Any sustainable management of forest resources must be based on the results of forest research. Research results from many authors (STEEN, COUPÉ, 1997; GANGLO, 1999 and 2005; YESSOUFOU, 2002; KLINKA *et al.*, 2003; AOUDJI, 2003; NOUMON, 2003) show that plant communities are reliable tools for forest site classification. This article describes the main results obtained in the identification and classification of forest sites in the Toffo forest reserve. Based on a study of natural undergrowth in teak plantations in Toffo forest, plant communities were identified, described and their relationships with site factors (soils, topography, geomorphology) and plantation productivity were used to identify and classify different forest sites.

Area under study

Our investigation area was Toffo forest reserve (6° 51' - 6° 53'N; 2° 05'-2° 10'E) (figure 1). This forest area has a subequatorial climate, with a long rainy season from March to July and a short rainy season from September to October. There is a long dry season from November to February and a short dry season in August (figure 2). From 1961 to 2003, mean annual rainfall of the study area was 1 030 mm, mean daily temperature was 27.5° C and relative humidity varied from 52% to 95%.

Two major soil types are found in the study area:

▪ Ferrallitic soils of the Continental Terminal geological period are found in the southern parts of the forest. In the upper horizons of these soils,

Mallotus oppositifolius and *Reissantia* plant community.
Photo J. C. Ganglo.

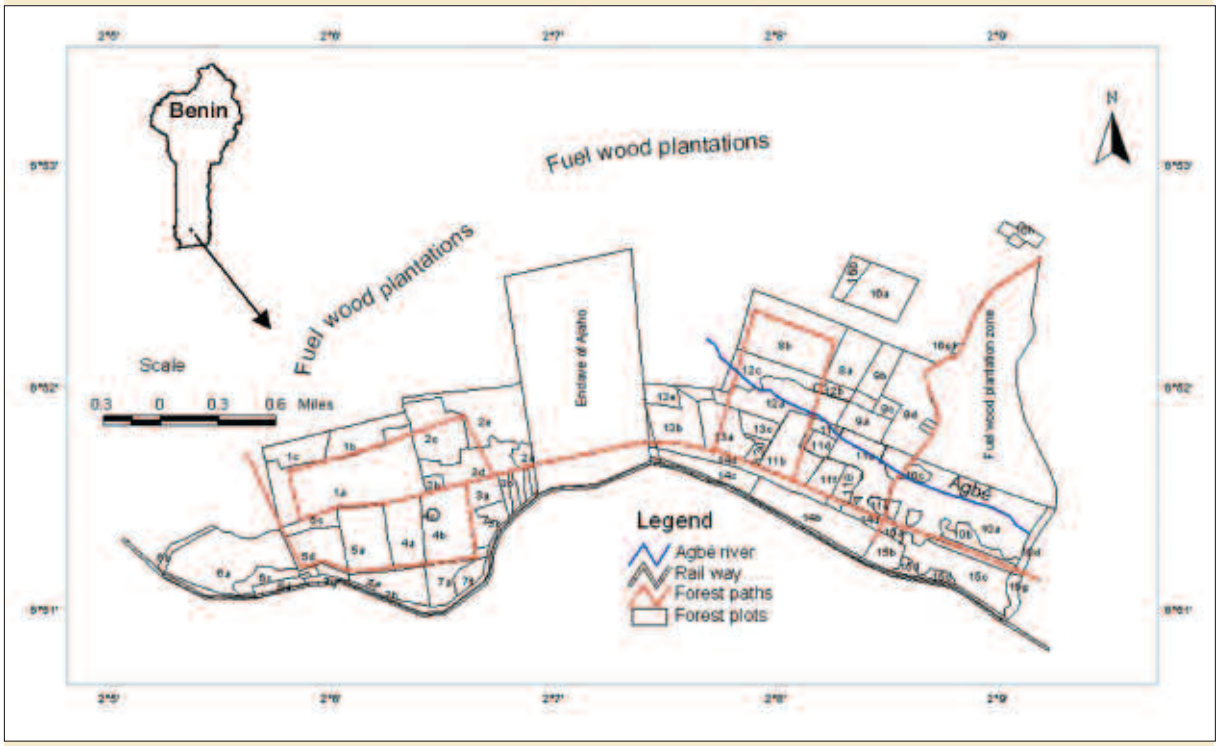

Figure 1.
Toffo forest reserve.

sand is dominant (81-95%). The soil pH varies from 6.7 to 7.7 and organic matter content from 0.5% to 8%. The C/N ratio is 10-13%. Cationic exchange capacity varies from 3 to 20 meq/100g of soil and the rate of saturation ranges from 33% to 100%.

▪ Black cotton soils ("vertisols") are found in the northern part of the forest. Clay is dominant in these profiles (59-68%). The organic matter content is higher (3-28%) than in the ferrallitic soils. The C/N ratio is also high (12-18%). The pH is 6 - 7 whereas the cationic exchange capacity varies from 19-28 meq/100g of soil with a saturation rate of 80% to 100%.

The above two soil types are separated by the muddy, swampy soil along the Agbé river (figure 1).

Spontaneous vegetation in Toffo forest varies with soil types. Ferrallitic soils typically feature shrubby *Lecaniodiscus cupanioides* communities growing on plateaux and steep slopes, while *Mallotus oppositifolius* and *Reissantia indica* communities develop on the sandier soils where breaks in the slope favour sand accumulation. Both plant communities may harbour some relic natural forest species, of which *Ceiba pentandra* and *Antiaris toxicaria* are the most common. The black cotton soils favour liana communities of *Paullinia pinnata* and *Combretum hispidu*, where the relic natural forest species *Milicia excelsa* and *Diospyros mespiliformis* are commonly found. In the river zones, the vegetation varies with the occurrence of water. We frequently recorded *Nymphaea maculata* in stagnant water and *Leersia hexandra, Alternanthera sessilis, Mitragyna inermis, Berlinia grandiflora* and others on muddy and swampy soils surrounding water points.

The Toffo forest reserve currently has 802 ha of forest plantations, mainly teak (92% of the total area). The second species in terms of the percentage of forest area covered is *Senna siamea* (about 7%). The other species, such as *Gmelina arborea, Cedrela odorata* and others, cover about 1% of the forest. Concerning the age structure, about 50% of the plantations are less than 15 years old, while 26% are over 46 years old.

Material and methods

Phytosociological study of spontaneous vegetation

To carry out the phytosociological study, we used a 1/10000 forest map for plant community mapping and orientation in the field. A Global Positioning System (GPS) was used to record relevant points and plant community contours; a SUUNTO compass was used for field orientation.

In the study of the spontaneous vegetation, we used the synusial approach to phytosociology developed by Gillet *et al.* (1991) and Gillet (2000). A plant synusia is an elementary plant community with homogenous species composition and a dominant type of biological, morphological and adaptation strategy (Gillet *et al.*, 1991). We distinguished the following categories of synusia: annuals, low or high herbaceous perennials, shrubs, lianas and trees. The sample surfaces varied from 500 m² for the annual and

herbaceous synusia to 1 000 m² for the others. All flowering species and easily identifiable ferns were recorded in each sample. Each synusia was named for the species most frequently found and generally attached to its site conditions. Based on spatial and temporal relationships, the plant synusia were combined to describe more complex plant communities known as phytocenoses. In this article, "plant community" refers to the phytocenosis. Each plant community was named for its unifying component synusia; i.e., the one responsible for the structural unity of the plant community. We distinguished the same types of plant communities as of synusia, but spontaneous tree communities are not represented in the plantations.

Ecological factor study

The study of ecological factors involved the use of a soil drilling device to determine soil texture by touch. Soil colour was determined with the Munsell code and a machete was used to refresh soil profile horizons and take soil samples. Polyethylene containers were used to carry soil samples to the laboratory for analysis. Slopes were measured with the SUUNTO slope meter device.

Soil types were studied within each plant community, by appreciating tactile soil texture up to 50 cm in depth in at least four drill holes. In addition, at representative points of each plant community, two soil profiles 2 m in depth, 2 m in length and 1 m in width were dug for detailed soil descriptions. Topographical parameters such as slopes, topographical positions, and exposure were also noted. One soil sample was taken per profile in each of the two upper horizons for laboratory analysis. In the laboratory, phosphorus was extracted using the Bray I method: the solution used was hydrochloric acid in ammonium fluoride and the concentration was determined by means of standard curves. Soil pH was determined with a pH meter whose electrodes were immersed in a solution of 20 g of soil and 50 ml of distilled water. Soil texture was determined with the soil hydrometer method. Exchangeable cations were extracted with ammonium acetate and assayed. Carbon and organic matter were determined with the Walkley and Black method and the nitrogen content with the Kjeldalh method.

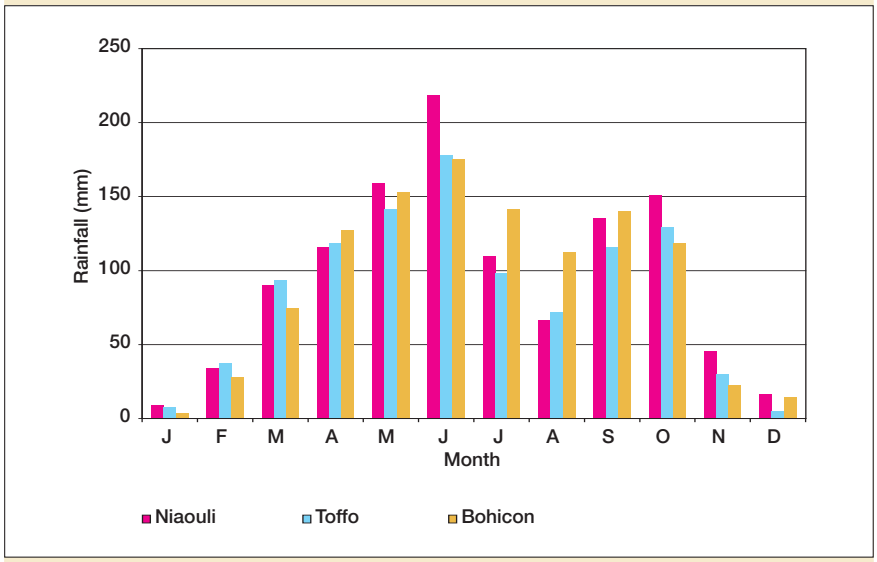

Figure 2.
Mean annual rainfall at Niaouli, Toffo and Bohicon meteorological stations (1961-2003).

Forest plantation parameter study

Dendrometric parameters (diameter and height) were measured with a tape measure and a Blum-Leiss in representative parts of each plant community. To do so, at least four rectangular 300 m² sample plots (15 m x 20 m) were assessed in each plant community. The following parameters were recorded:

- diameter at breast height (1.30 m);
- height of the two largest trees in each plot in order to calculate top height;
- height of two trees in the mean diameter class in order to calculate the mean height.

On the basis of productivity curves plotted for teak plantations in southern and central Benin (GANGLO, 1999), top heights were used to calculate the productivity indices of each plant community.

Results

Species diversity

A total of 380 species belonging to 91 families and 290 genera were identified in Toffo forest reserve. The most diversified genera were: *Combretum* (7 species); *Desmodium* and *Sida* (5 species each), *Albizia, Cassia, Cissus, Ficus, Ipomoea* and *Salacia* (4 species each); *Celosia, Corchorus, Diospyros, Euphorbia, Hibiscus, Indigofera, Ludwidgia, Panicum* and *Vernonia* (3 species each).

The number of species per synusia ranged from 2 to 130. The least diversified synusia were found in specific forest sites affected by adverse environmental conditions, such as periodic flooding and black cotton soils with low soil aeration.

Plant community diversity and ecological indicator values

A total of nine plant communities were identified in Toffo forest reserve (figure 3). Five of them were identified as understorey communities, and the other as riverside communities (table I). Apart from the *Chromolaena odorata* plant community, a pioneer community usually

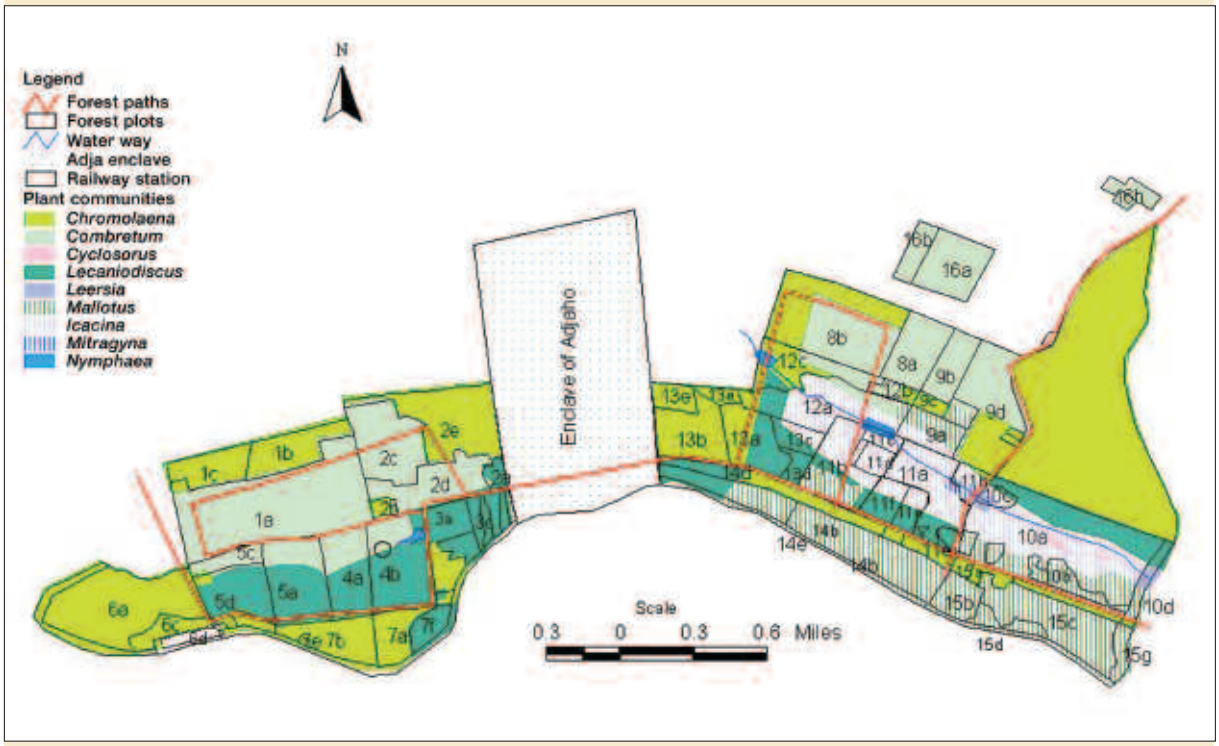

Figure 3.
Plant communities identified in Toffo forest reserve.

Cola millenii and *Icacina trichantha* plant community.
Photo J. C. Ganglo.

found under direct sunlight irrespective of soil types, the other plant communities had reliable ecological indicator values (table I). The nine plant communities are shown in the photographs.

Variation of plantation productivity in plant communities

To describe the variation in plantation productivity in plant communities, we only considered plant communities growing in forest plantations. The results are shown in table II, from which we can deduce that the *Chromolaena odorata* pioneer community has the greatest variation in productivity:

- The amplitude of productivity indices in this community is very high (16.4 m).
- The standard deviation is also considerable (5.9 m) and the variation coefficient (23.3%) is also high when compared with the values obtained for the other plant communities.

When we consider the non-pioneer plant communities in table II, we see that:
- The standard deviation values are low (2m at most).
- The variation coefficients are also low (9% at most).
- The amplitude of plantation productivity indices is 5 m at most, proving that within each non-pioneer plant community, forest productivity is homogenous.

Variation of productivity levels in plant communities

This was studied by means of variance analysis. Because of the highly variable productivity in the pioneer *Chromolaena odorata* community, only the non-pioneer undergrowth plant communities were included in this analysis. The results of the variance analysis are given in table III. The results of the mean Newman-Keuls comparison test are given in table IV. From tables III and IV, we can deduce that:
- There is a significant difference ($P < 10^{-3}$) between plant community productivity levels.
- The *Mallotus oppositifolius* and *Reissantia indica* community is the most productive; at 25.7 m, its productivity index is significantly higher than that of the other plant communities at 5% probability.

Table I.
Plant community diversity and ecological indicator values.

Plant communities	Ecological indicator values	Topographical positions
Chromolaena odorata community (pioneer community)	Mesophilic site; direct sunlight irrespective of soil types and topography.	Any position except foot of slopes with stagnant water.
Lecaniodiscus cupanioides community	Mesophilic site; leached and / or eroded ferrallitic soils usually found on slight to moderate slopes surrounding plateaux ; 81 to 91% sand in the upper soil horizons; 0.5-3% organic matter; the C/N ratio is 10-13% and the pH is 6.8-7.7; the cationic exchangeable capacity is 18-19 meq/100g of soil in the upper horizons.	Plateaux or slopes surrounding plateaux.
Mallotus oppositifolius and *Reissantia indica* community	Mesophilic site; ferrallitic or black cotton soils dominated by sand at slope rupture points; 81 to 95% sand in the upper soil horizons; 5-8% organic matter; the C/N ratio is 9-13% and the pH is 6.7-7.4; the cationic exchangeable capacity is 15-17 meq/100g of soil in the upper horizons.	Rupture points of slopes.
Paullinia pinnata and *Combretum hispidum* community	Mesophilic site; poorly drained black cotton soils; 59-68% clay in the upper soil horizons; 3-28% organic matter; the C/N ratio is 12-18% and the pH is 6-7; the cationic exchangeable capacity is 19-27 meq/100g of soil in the upper horizons.	Slightly sloping black cotton soils.
Cola millenii and *Icacina trichantha* community	Ferrallitic hydromorphic soils along waterways; 39 to 65% fine sand in the upper soil horizons; 1-10% organic matter; the C/N ratio is 11-13% and the pH is 4.5-7.6; the cationic exchangeable capacity is 19-22 meq/100g of soil in the upper horizons.	Foot of slopes along waterways but not flooded with water.
Mitragyna inermis and *Berlinia grandiflora* community	Hygrophilous site; muddy soils periodically flooded with water.	Valley flooded with water.
Cyclosorus striatus community	Hygrophilous site; swampy and marshy soils.	Valley flooded with water.
Leersia hexandra and *Alternanthera sessilis* community	Hydrophilic site; muddy river soils.	Valley flooded with water.
Nymphaea maculata community	Hydrophilic site; stagnant but shallow water.	

Table II.
Variation in plantation productivity indices within plant communities.

	Replication number	*Lecaniodiscus cupanioides* community	*Mallotus oppositifolius* and *Reissantia indica* community	*Paullinia pinnata* and *Combretum hispidum* community	*Cola millenii* and *Icacina trichantha* community	*Chromolaena odorata* community
Productivity indices (m)	1	20.0	26.1	23.4	19.0	34.9
	2	18.8	25.8	24.7	19.4	25.8
	3	18.8	26.1	24.7	16.7	18.5
	4	20.0	25.2	25.5	20.0	27.6
	5	18.1	23.2	24.1	–	25.5
	6	18.1	26.7	20.4	–	19.7
	7	23.2	27.1	21.4	–	
	8	21.5	–	–	–	
	Mean index (m)	**19.81**	**25.74**	**23.41**	**18.78**	**25.3**
	Amplitude of productivity indices (m)	5.1	3.9	4.7	3.3	16.4
	Standard deviation (m)	1.79	1.28	1.94	1.44	5.9
	Variation coefficient (%)	9.03	4.97	8.29	7.67	23.32

Table III.
Variance analysis of plantation productivity indices.

	Degree of freedom	Mean square	F	p
Factors	3	63.56614	22.96240	0.001
Error	22	2.768271	–	
total	25	66.334411	–	

- The *Paullinia pinnata* and *Combretum hispidum* community has an intermediate productivity level of 23.4 m, which also differs significantly from that of the other plant communities at 5% probability.
- The productivity levels of the *Lecaniodiscus cupanioides* / *Cola millenii* and the *Icacina trichantha* communities are respectively 19.8 m and 18.8 m. These two productivity levels are not significantly different at 5% probability.

Table IV.
Comparison between the four communities using the Newman-Keuls test.

	Community			
	Cola millenii and *Icacina trichantha* {1}	*Paullinia pinnata* and *Combretum hispidum* {2}	*Lecaniodiscus cupanioides* {3}	*Mallotus oppositifolius* and *Reissantia indica* {4}
{1}	18.77500	23.41429	19.81250	25.74286
{2}		0.000330	0.289857	0.000167
{3}			0.001201	0.023597
{4}				0.000141

Lecaniodiscus cupanioide plant community.
Photo J. C. Ganglo.

Identification of forest sites

From the above results, it may be deduced that: a) non-pioneer plant communities have reliable ecological indicator value (table II); 2) their biotopes are homogenous in terms of ecological factors (soil types and topography). Plantation productivity within each non-pioneer plant community (table III) shows very little variation: low values of standard deviation, variation coefficients and amplitude of productivity indices. We therefore deduce that the biotopes of each non-pioneer plant community can be considered as forest sites. A forest site is a forest area which is homogenous in terms of vegetation and site factors so that the same level of productivity can be expected (Maître, 1983; Delpech *et al.*, 1985).

Based on plant community productivity levels, the forest sites identified in Toffo forest reserve are as follows (figure 4):

- Site 1 is the biotope of the *Mallotus oppositifolius* and *Reissantia indica* community, the most productive in the Toffo forest reserve.
- Site 2 is the biotope of the *Paullinia pinnata* and *Combretum hispidum* community, with an intermediate productivity level.
- Site 3 is the biotope of the *Lecaniodiscus cupanioides* community; this site is among the least productive in the forest.
- Site 4 is the biotope of the *Cola millenii* and *Icacina trichantha* community; this site is also among the least productive in the forest.
- Site 5 represents the hydrophilic zones in Toffo forest.

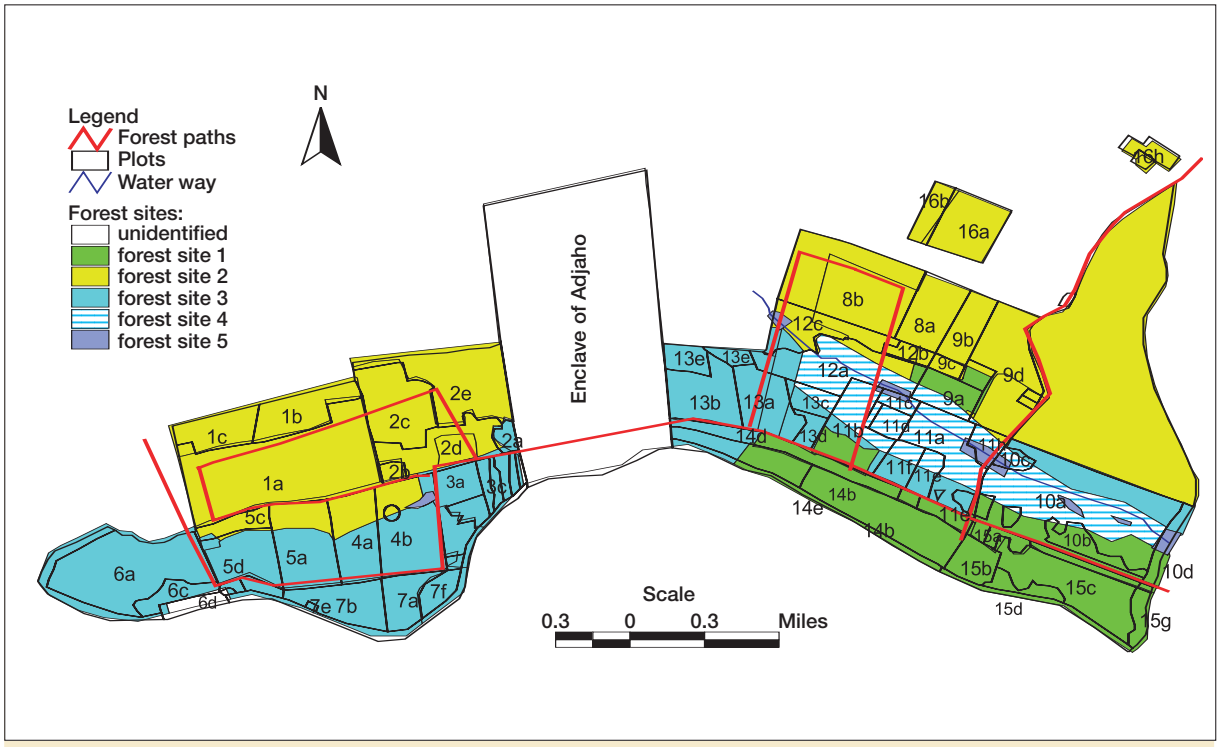

Figure 4.
Forest sites identified in Toffo forest reserve.

Discussion

Determinism of the plant communities identified

The impact of geomorphology on soil development has been underlined by Duvigneaud (1949). Our observations in Toffo forest reserve agree with his assertion, since many soil variations were observed along topographic gradients. The plant communities identified in Toffo forest are differentiated by the response of the vegetation to geomorphology. From table I, it is clear that the plant communities identified can be roughly classified according to topographical positions: the plant communities which develop on slopes and surrounding plateaux, where micro-topographical variation induces some differentiation; the plant communities observed at the foot of slopes along waterways, and those in the river valley (table I). Our results are consistent with those of many other authors. Previous phytosociological studies in the Republic of Benin confirm the dominant effects of topography and soil types in the differentiation of many plant communities (Sokpon, 1995; Ganglo, 1999 and 2005; Yessoufou, 2002; Aoudji, 2003; Noumon, 2003). In south-east Belgium, many site plant communities have been described (Tanghe, 1969; Tanghe, Duvigneaud *in:* Duvigneaud, Kestemont, 1977). The results obtained by these authors, who clearly relate the plant communities in sites to specific ecological conditions (mainly topography and soils), support the importance of ecological factors in the development of plant communities. The same observations were also made by Decocq (2000), who identified many synusia and plant communities that were dependent on topographic positions and soil types in the high Oise valley in Belgium. Previous phytosociological studies in the Republic of Benin also confirm the dominant effects of topography and soil types in the differentiation of many plant communities (Sokpon, 1995; Ganglo, 1999 and 2005; Yessoufou, 2002; Aoudji, 2003; Hessou, 2003; Noumon, 2003).

Lecaniodiscus cupanioides plant community.
Photo J. C. Ganglo.

Combretum hispidum and *Paullinia pinnata* plant community.
Photo J. C. Ganglo.

Cyclosorus striatus plant community.
Photo J. C. Ganglo.

Leersia hexandra and *Alternanthera sessilis* plant community.
Photo J. C. Ganglo.

Mithragyna inermis and *Berlinia grandiflora* plant community.
Photo J. C. Ganglo.

Nymphea maculata plant community.
Photo J. C. Ganglo.

Productivity and forest site identification

Phytosociology is a valuable and reliable tool for forest management. From our results, a non pioneer understorey plant community corresponds to a given level of forest productivity with remarkable homogeneity between ecological factors and productivity (table II). In our study, three levels of productivity were identified: *Mallotus oppositifolius* community was the most productive; the *Lecaniodiscus cupanioides* community and the *Cola millenii* and *Icacina trichantha* plant community were the least productive; the *Paullinia pinnata* and *Combretum hispidum* community is at an intermediate level of productivity. Our results agree with those of many authors who have successfully identified forest productivity levels according to plant communities. In the Ardennes, many studies on productivity and biomass have been performed at site plant community level. The is the case with the *Festuca altissima* community, which is among the most productive at Mirwart (Duvigneaud *et al.*, *in:* Divigneaud, Kestemont, 1977). Duchaufour *et al.* (1958), quoted by Pardé, Bouchon (1988) in their study of fir plantations in the Lower Vosges in France, identified many types of fir plantations corresponding to significantly different levels of productivity. In the Cariboo Forest Region in British Colombia, Steen and Coupé (1997) obtained interesting results in site classification mainly based on plant communities, distinguishing three site units (site association, site series and site type). The forest sites we identified in our study are equivalent to the Cariboo Forest site series. Ganglo (1999) also identified many levels of forest productivity depending on plant communities in the Djigbé forest (South-Benin). In the fuelwood plantations of South Lama, three levels of forest productivity depending on plant communities were also identified (Ganglo, 2005). Klinka *et al.* (2003) also developed a

site mapping method mainly based on plant communities in the Alex Fraser Research Forest in British Colombia, using a similar method to that of Steen and Coupé (1997). In the Massi and Koto forest reserves (North Lama in Central Benin) and in the Pahou forest (South Benin), different forest productivity levels have also been identified according to understorey plant communities (Yessoufou, 2002; Aoudji, 2003; Noumon, 2003). Successful identification of forest productivity is very important in forest site identification and the development of reliable forest management specifications.

Management specifications

Silvicultural practices and management activities must be based on the potentialities of the forest sites identified.

The *Mallotus oppositifolius* and *Reissantia indica* community

This is the most productive plant community, where production of high-quality timber should be considered. Apart from teak – the main species – silvicultural treatments should promote the regeneration and growth of native species usually found in the plant community: *Antiaris toxicaria, Ceiba pentandra, Triplochiton scleroxylon, Afzelia africana, Milicia excelsa.*

The *Paullinia pinnata* and *Combretum hispidum* community

This plant community has an intermediate productivity level. Its biotope consists of poorly drained black cotton soil that needs ploughing and ridging for good results. The native species in this biotope should be preserved and silvicultural treatments should promote their regeneration and growth. The most common indigenous forest species in this plant community include *Antiaris toxicaria, Diospyros mespiliformis, Pterocarpus erinaceus, Milicia excelsa.*

Young plantation developing after felling in 2002 to assist regeneration.
Photo J. C. Ganglo.

Timber processing in sub-parcel 4b in Toffo ; plantation established in 1951.
Photo J. C. Ganglo.

Logging operations in sub-parcel 4b in Toffo .
Photo J. C. Ganglo.

Conclusion

The *Lecaniodiscus cupanioides* community

This plant community is among the less productive. The site can be considered for high-quality timber production providing soil quality is improved. To achieve this, the undergrowth must be protected from fire damage to ensure abundant leaf litter. Silvicultural treatments should also promote natural regeneration and growth of the native forest species in the plant community: *Antiaris toxicaria, Ceiba pentandra, Triplochiton scleroxylon, Afzelia africana, Milicia excelsa*...

The *Cola millenii* and *Icacina trichantha* community

This plant community is also among the less productive. The windthrow rate is very high in this site (47% of teak trees affected), so that it may be unsuitable for teak production. Alternative forest species should then be considered, particularly those found naturally in the plant community: *Antiaris toxicaria, Ceiba pentandra, Cola gigantea, Sterculia tragacantha,* etc.

Hydrophilous plant communities

These are the *Mitragyna inermis* / *Berlinia grandiflora*, *Cyclosorus striatus, Leersia hexandra* / *Alternanthera sessilis* and *Nymphaea maculata* communities. In these plant communities, we recommend native forest species: *Ceiba pentandra, Cola gigantea, Sterculia tragacantha, Berlinia grandiflora, Mitragyna inermis*. Non-timber forest products can also be considered as market-garden and fruit crops.

Nine plant communities were identified in Toffo forest reserve by means of the phytosociological approach. Our study of ecological factors and forest productivity in relation to plant communities indicates that in each non-pioneer plant community, site conditions (soil, topography, etc.) and productivity levels are remarkably homogenous. Three forest productivity levels were identified: the *Mallotus oppositifolius* community is the most productive; the *Lecaniodiscus cupanioides* and *Cola millenii* / *Icacina trichantha* plant communities are the less productive, and the *Paullinia pinnata* / *Combretum hispidum* community has an intermediate level of productivity. Based on the homogeneity of site conditions and productivity levels of each non-pioneer plant community, we have identified five forest sites and drawn up appropriate management specifications.

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Teak plantation established in 1964 in sub-parcel 5b in Toffo.
Photo J. C. Ganglo.

Prehauling processed logs in sub-parcel 4b in Toffo.
Photo J. C. Ganglo.

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