Impact of Wari-Maro classified forest management plan implementation on the structure and specific diversity of vegetation types in Benin (West Africa)

Gildas K. S. Mensah[1], Ousséni Arouna[1&2*], Ismaïla Toko Imorou[1], Omer A. B. Thomas[1], Soufouyane Zakari[1]

[1] Laboratory of Cartography, Department of Geography and Regional Planning, Faculty of Humanities and Social Sciences. University of Abomey-Calavi. 01 BP 526 Cotonou, Benin, Email: mensahseverin1985@gmail.com

[2] School of Sciences and Techniques of Building and Road (ESTBR), National University of Sciences, Technologies, Engineering and Mathematics (UNSTIM), 03 BP 304 Abomey, Benin Abomey

Abstract— *The participatory management plan is a technical, legal and social device that joins the objectives of biodiversity conservation and the socio-economic needs of local populations. This research work aims to evaluate the impact of Wari-Maro classified forest management plan implementation on the structure and specific diversity of vegetation types. The methodological approach followed is based on the comparison of the dendrometric parameters and plant diversity parameters before and after the management plan implementation. The phytosociological and dendrometric database before the management plan was compiled with data from the forest inventory conducted by PAMF project in 2004 and others work. The forest and phytosociological inventories were carried out on the plots (70) from the forest inventory of PAMF project (2004) following the same methodological principles. The Shannon diversity index decreased from 3.35 ± 0.57 bits in 2004 to 1.98 ± 0.73 bits in 2014. The average density of dbh trees ≥ 10 cm decreased from 740.37 ± 269 , 86 stems / ha in 2004 to 184 ± 100 stems / ha in 2014. The results of the 5% sample matched t-test reveal a non-significant difference between the Shannon Diversity Index of 2004 and of 2014. On the other hand, the results of the sample t-test matched at the 5% threshold, reveal a significant difference between the average density value of 2004 and 2014 for all vegetation types except shrub savannas, fields and fallows. Most of the plant species found before the management plan are still present despite the decreased in individuals' density.*

Keywords— impact, inventories, management plan, vegetation, Wari-Maro.

I. INTRODUCTION

Forests have ecological, environmental, socio-economic and, of course, wood production functions, important not only locally but also on a global scale (Djègo, 2006). They cover 3.9 billion hectares or about one third of the world's land area. Unfortunately, the forest ecosystems are threatened by anthropogenic factors to meet the population ever-increasing needs due to the population growth (Fonton, 2006). For the conservation of the world's forest heritage, the concept of sustainable management was highlighted during the international conferences in Strasbourg (1990), Rio de Janeiro (1992), Helsinki (1993) and Kyoto (1996). Thus, sustainable forest management is the stewardship and use of forests and woodlands in a way and to an intensity so as to keep their biological diversity, productivity, regenerative capacity, vitality and ability to fulfill the current and future ecological, economic and social functions at the local, national and global levels, and that do not cause prejudice to other ecosystems (Siry et al., 2005). This is why the success and sustainability of forest management cannot be achieved without the participation of the population in the forest management process (Varughese and Ostrom 2001; Chouinard and Perron 2002; Gareau 2005, Djogbenou 2005). The forest management plan is the tool for operationalizing sustainable forest management.

Benin has experienced several generations of forest management plans. The Agoua, Monts Kouffé and Wari-Maro Forest Management Project (PAMF) has drawn up forest management plans especially the plans of the Agoua classified forest and the complex of Monts Kouffé -Wari - Maro classified forest. Several studies and research focused on the effects and impacts of these

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management plans. Djogbénou (2010) evaluated the management plans of classified forests in Benin. This evaluation highlights the quite mixed results. The management plans carried out globally are those of the classified forests of Pénéssoulou, Monts Kouffé, Wari-Maro and Agoua. The assessment of the management plans of the classified forests by Djogbénou (2010) considered globally the socio-economic and governance criteria and indicators (socio-economic benefits, the financial profitability, the running of the village committees for forests co-management, etc.). The state of forest formations is not measured diachronically from the indicators of species diversity and structure of forest formations. It is therefore appropriate to analyze the impact of successful management plans on the specific diversity and structure of vegetation types. This research has been undertaken in this perspective by considering the Wari-Maro classified forest as survey field. The objective of this research is to evaluate the impact of the management plan on the diversity and the structure of the vegetation types of Wari-Maro classified forest. The hypothesis underlying the present research predicts that the specific diversity and structure of the vegetation types of Wari-Maro classified forest improved after the implementation of the management plan.

Study area

The Wari-Maro classified forest covers an area of 111095.38 ha and is part of large protected areas in Benin. Established by the order of classification N°5194/SE of December 2nd, 1946 followed by a partial downgrading by the decree N°9190/SE of November 25th, 1955, it is located in the center of Benin, in the sudano-guinean transitional zone, between 8 ° 50 'and 9 ° 10' north latitude and 1 ° 55 'and 2 ° 25' east longitude. It is bounded on the north by the classified forest of Oueme Superieur, on the south by the classified forest of Monst-Kouffé, on the east by the national road Tchaourou-Bétérou and on the west by the Wari-Maro-Igbèrè path (Fig.1). The Wari-Maro classified forest is influenced by the subhumid tropical climate (Arouna, 2005).

II. MATERIALS AND METHODS

2.1 Materials

The material used includes:

- ✓ GPS for the location of the sites;
- ✓ ribbon 50 m long and rope roll 100 m long for the delimitation of plots;
- ✓ Forest and phytosociological inventories form ;
- ✓ SUUNTO clinometer for measuring trees height.

2.2 Phytosociological and forest inventories

Phytosociological and forest inventories were conducted in the PAMF (2004) circular plots. The selected phytosociological survey area has a radius of 5 m for the herbaceous layer and 15 m radius for the shrub and tree layers. For some particular stations such as riparian forests, adjustments were made in the size of the plots while respecting the survey area selected. These are readjustments of 15 m x 47.1 m type in order to respect the forest galleries shape. A total of 70 surveys were inventoried (Table I). The phytosociological inventory method used is the sigmatist method of Braun-Blanquet (1932) already implemented by several authors (Sinsin, 1993, Djègo, 2006, Toko Imorou, 2008, Arouna, 2012).

Table.I: Number of phytosociological and forest inventories plots by vegetation type

Vegetation types	Number of plots
Riparian forests	10
Dry forest	11
Woodlands	12
Savanna woodlands	6
Tree savannas	23
Shrub savannas	3
Fields and fallows	3
Planting	2
Total	**70**

Species identification is made either directly on the field or from specimens collected and compared with those of the National herbarium of Benin or from flora (Arbonnier 2002, Akoegninouet al 2006, de Souza 2008).

The structural data collected are: the number of each species individuals, the trees dbh ≥ 10 cm, the height of the tallest tree and the degree of opening of the tree layer. The trees dbh ≥ 10 cm is measured at 1.30 m above the ground. The dendrometric data are collected in plots with a radius of 15 m. The height of the largest tree is obtained using the SUUNTO clinometer.

2.2 Treatment of phytosociological data

2.2.1 Specific diversity

Two parameters are studied at each level:

- ✓ The Shannon Diversity Index (H)

$H = - \Sigma Pi \log_2 Pi$ (1)

Pi = (ni/N) is the relative frequency of individuals of species (i); (ni) is the number of individuals of the species (i); (N) is the total number of individuals surveyed.

This index generally varies on average from 0 to 5 bits. The high values of H reflect the favorable conditions of the environment for the installation of many species. On the other hand, low values of H reflect the adverse environmental conditions for the establishment of the species.

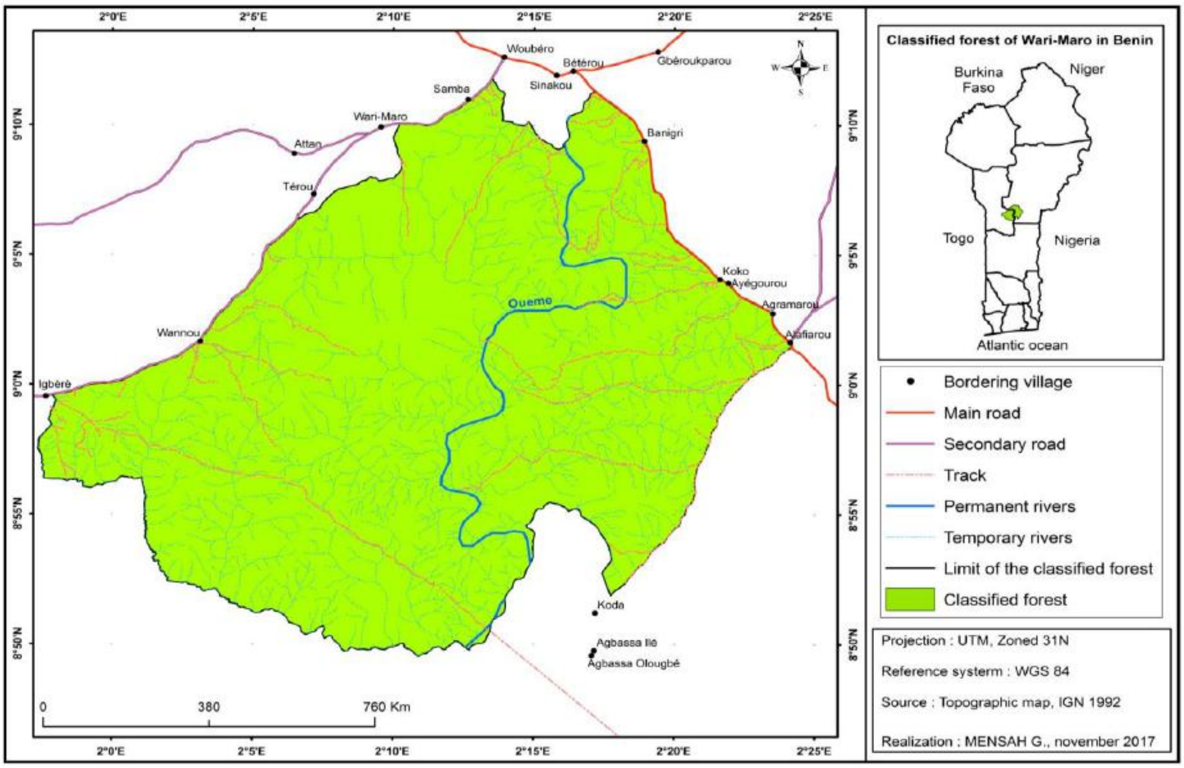

Fig.1: Geographical location of the Wari-Maro classified forest

The equitability of Pielou (E)

E = H / log2R (2)

H represents the Shannon diversity index;

log_2R is the theoretical value of the maximum diversity that can be achieved in each cluster; it corresponds to a state of equal distribution of all individuals among all the species of the group; R is the specific wealth.

This equitability varies from 0 to 1. Values close to 1 indicate a regular distribution of individuals between species. On the other hand, values close to 0 correspond to the presence of a large number of rare species or a small number of dominant species.

2.3 Treatment of the dendrometric data

Two parameters are calculated: density and average basal area.

- ✓ Density (D)

Density (D) is the number of standing trees per hectare. It is calculated according to the formula:

D = N x 10000 / S (3)

D: number of stems / ha; N: number of stems with at least 2 m height; S: inventoried area reported to the sea.

- ✓ Average basal area (Gi)

The average basal area (Gi) is the area occupied by tree trunks at breast height. It is calculated according to the formula:

$G = \Sigma \Pi d^2 / 4$ (4)

Gi is in m^2 / ha; d = diameter at 1.30 m below the ground (m); S: Inventoried area reported per hectare.

SPSS 21.0 and Minitab 14 software tested the results obtained to ensure their significance.

III. RESULTS

3.1 Specific diversity of woody species before and after the implementation of the management plan

Table II presents the diversity parameters of vegetation types before and after the implementation of the management plan of the classified forest.

From the review of Table II, it appears that the Shannon diversity index calculated for dry forests, woodlands and savannas in 2004 is higher than that recorded in 2014. On the other hand, the riparian forests, the savanna woodlands, shrub savannas and fields and fallows land recorded the highest value of the Shannon Diversity Index in 2014. The results of the paired sample t test for dry forests, woodlands, riparian forests, savanna woodlands, shrub savannas and fallow and fields at the 5% threshold, reveal a nonsignificant difference between Shannon's 2004 diversity index and that of 2014. This means that, Shannon's diversity index of these vegetation types between these two dates is almost similar.

Whereas for the tree savannas, the results of the 5% sample matched t-test reveal a significant difference between the Shannon diversity index of 2004 and that of 2014. This means that, the Shannon Diversity Index of tree savanna of 2004 is higher than that of 2014.

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The Pielou equitability calculated for all vegetation types in 2014 is greater than that of 2004. The results of the sample t test matched at the 5% threshold, reveal an insignificant difference between the 2004 Pielou equitability and that of 2014 for all vegetation types except woodlands and fields and fallow. This means that the Pielou equitability of riparian forests, dry forests, woodlands, tree savannas and shrub savannas between these two dates is almost similar. On the other hand, woodlands and fallow fields between these two dates show a difference. It should be noted that there is an equal distribution between the species in these vegetation types because all the values of Pielou equitability turn around 1.

3.2 Structural parameters of woody species before and after the implementation of the management plan

Table III presents structural parameters of vegetation types before and after the implementation of the management plan.

The examination of Table III shows that the average value of dbh woody density ≥ 10 cm calculated in 2004 for vegetation types such as riparian forests, dry forests, woodlands, savanna woodlands and tree savannas is higher than that obtained in 2014. On the other hand, shrub savannas and fields and fallow land experienced little change between these same dates. The results of the 5% matched sample t test show a significant difference between the mean density value of 2004 and that of 2014 for all vegetation types except shrub savannas, fields and fallows. This means that these vegetation types are under strong pressure between 2004 and 2014. On the other hand, shrub savannas and fields and fallows between these two dates is almost similar according the density.

The basal area of vegetation types such as dry forest, woodlands and savanna woodlands in 2004 is greater than in 2014. The results of the 5% threshold matched sample t test show a significant difference between the basal area in 2004 and in 2014 for dry forests and not significant for woodlands and savanna woddlands. This means that dry forests have experienced the greatest decrease due to logging. The basal area of woodlands and savanna woodlands between these two dates is almost similar. On the other hand, riparian forests, tree savannas, shrub savannas, fields and fallow land recorded the highest basal area values in 2014. The results of the 5% threshold matched sample t test revealed a difference between the Basal area of 2004 and that of 2014 for shrub savannas, fields and fallows and not significant for riparian forests and tree savannas. This means that the basal area of shrub savannas and fields and fallow land has increased during these years. The basal area of riparian forests and savanna woodlands between these two dates is quite similar.

Table.II: Parameters of diversity of vegetation types before and after the implementation of the forest management plan

Vegetation types	Diversity parameters (2003)				Diversity parameters (2013)					
	H'		E		H'		E		Test results	
	m	σ	m	σ	m	σ	m	σ	H'	E
FG	2	0,65	0,76	0,07	2,46	0,87	0,8	0,19	0,44	0,09
FD	3	0,59	0,81	0,09	2,59	0,51	0,87	0,04	0,18	0,13
FC	3	0,36	0,82	0,05	3,05	0,48	0,9	0,05	0,099	0,0044*
SB	3	0,39	0,86	0,06	3,33	0,28	0,91	0,04	0,46	0,18
SA	3	0,57	0,85	0,02	2,74	0,56	0,87	0,07	0,004*	0,128
Sa	3	0,17	0,90	0,03	2,91	0,71	0,94	0,01	0,07	0,001*
CJ	2	0,73	0,68	0,22	2,6	1,17	0,9	0,07	0,213	0,01

*FG: riparian forest; FD: Dry forest; FC: woodlands; SB: savanna woodlands; SA: tree savanna; Sa: shrub savanna; CJ: Fields and fallows, * significance at the 5% threshold.*

Table.III: Structural parameters of vegetation types before and after the implementation of the management plan

Vegetation types	Structural parameters (2004)				Structural parameters (2014)					
	Density (N/ha)		Basal area (m^2/ha)		Density (N/ha)		Basal area (m^2/ha)		Test results	
	m	σ	m	σ	m	σ	m	σ	D (N/ha)	G (m^2/ha)
FG	689	285,00	25	12,70	545,85	152,91	28	10,7	0,03*	0,44
FD	657	312,02	34	22,09	317,53	160,66	18	10,84	0,003*	0,05*
FC	713	9,43	15	0,71	397,13	198,02	15	5,83	0,004*	0,93
SB	655	121,54	15	3,42	436,02	155,27	13	4,65	0,001*	0,12
SA	740	269,86	10	4,37	321,56	129,97	13	6,04	0,001*	0,08
Sa	193	42,00	4	0,62	183,83	99,99	8	0,29	0,2	0,001*
CJ	188	95,85	3	0,74	216,83	77,88	9	1,72	0,284	0,003*

*FG: riparian forest; FD: Dry forest; FC: woodlands; SB: savanna woodlands; SA: tree savanna; Sa: shrub savanna; CJ: Fields and fallows, * significance at the 5% threshold*

IV. DISCUSSION

The Shannon diversity index between 2004 and 2014 varies from one vegetation type to another. The difference in value of the Shannon diversity index was noted especially in the savannas. Overall, the Shannon Diversity Index values are similar in vegetation types regardless of the year. The same is true of the values of Pielou's equitability. This is confirmed by the paired sample t test ($p < 0.05$), which indicates significant differences in the Shannon diversity index between the savanna woodlands of 2004 and 2014. For Pielou's equitability, this significant difference is noted at the level of woodlands, shrub savannas and fields and fallows. This shows that most of the plant species present in the different vegetation types in 2004 were conserved in 2014 and that the difference is more identifiable in the individuals of these species. The calculated Shannon index values are similar to those found by Biaou (1999) in the Bassila forest and Sounon Bouko *et al*. (2007) in the Wari-Maro classified forest. On the other hand, they are weaker than those obtained by Toko Imorou (2008) in the upper Ouémé catchment and Odjoubéré (2014) in the classified forest of Monts Kouffé in west-central Benin.

The average density of dbh ≥ 10 cm was higher in natural vegetation types in 2004 than in 2014. In fields and fallow and shrub savannas, the reverse trend was observed because the density passed respectfully from 188 stems / ha in 2004 to 217 stems / ha in 2014 and 193 stems / ha in 2004 to 183.83 stems / ha in 2014. These results are confirmed by the paired sample t test ($p < 0.05$) which indicates significant differences in the density of natural formations (riparian forests, dry forests, woodlands, savanna woodlands and tree savannas) between 2004 and 2014. The basal area of woodlands, dry forests and savanna woodlands in 2004 is higher than in 2014. On the other hand, fields and fallows, riparian forests, tree savannas and shrub savannas recorded higher basal area values in 2014. In this case, only the basal area of dry forests, shrub savannas and fields and fallows show significant differences between 2004 and 2014 at the 5% threshold of the matched sample t-test. The low density and basal area values of ligneous trees in 2014 reflect the impact of human activities on natural formations. These density values are lower than the value obtained by Toko Imorou (2008) in the upper Ouémé catchment. Values closer to those of this study were obtained by Wala (2004) in woodlands of northern Benin.

These analyzes indicate that logging increased after the implementation of the management plan and especially at the end of the PAMF project. This logging is practiced mainly in dry forests, woodlands and savanna woodlands. This indicates a low level of implementation of the requirements of the management plan.

V. CONCLUSION

The assessment of the impact of the implementation of the management plan is carried through the phytosociological and forest inventories. The objectives of the management plan are to significantly reduce the anthropogenic pressures on the Wari-Maro classified forest, to restore degraded areas, to contribute to the maintenance of biodiversity while advocating the sustainable exploitation of natural resources to favor local development. The diachronic analysis of the specific diversity parameters shows that the values of the Shannon diversity index do not differ overall between 2004 and 2014. Most plant species inventoried in 2004 are present in 2014.

On the other hand, Pielou's equitability shows that individuals of different species are regularly distributed.

The diachronic analysis of dendrometric data revealed a decrease in the density and basal area of trees from 2004 to 2014 despite the implementation of the Wari-Maro Classified Forest Management Plan. The number of trees has decreased even though most plant species are present.

The reconstitution of the Wari-Maro classified forest is then possible if consequent measures are taken.

Let’s mention that the fight against deforestation will only be effective if the living conditions of the neighboring populations of the Wari-Maro classified forest are improved.

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