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Full Length Research Paper

Status of timber species in the protected Wari-Maro forest located in the North of Benin

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Forest degradation has been worsening over the past years by the numerous populations seeking a means of living, without respecting minimum conservation rules. Converting forests into timber is another cause of deforestation. In Wari-Maro, a protected forest, timber tree species such as, *Afzelia africana, Pterocarpus erinaceus, Khaya senegalensis, Pseudocedrela kostchyi, Ceibapentanda* and *Chlorophora excels* were exploited for commercial use in Benin. The study aimed to assess the status of timber (commercial timbers) species in Wari-Maro forest in Benin. The methodology used was based on satellite images processing for identification of the vegetation types. The sampling plots were established in each type of vegetation for assessing the different timbers species listed above. The results show that *Afzelia africana* was less than three plants per hectare and the extreme classes were not represented. The same results were obtained with *Khaya senegalensis.* The results have also shown that *P. erinaceus* and *P. kostchyi* were represented in all classes with the number of plants less than 8 per hectare. The analysis has proved that these last two species were overexploited after the scarcity of *Afzelia africana* and *Khaya senegalensis.* Furthermore, *Pterocarpus erinaceus* and *Pseudocedrela kostchyi* were exported overseas.

Key words: Protected forest, Wari-Maro, timber species assessment, sampling plots, Benin.

INTRODUCTION

Since the United Nations conference on environment and development held at Rio de Janeiro in 1992, the question of sustainable management of the forests became very crucial for humanity (PNUE, 1992). The 21st century is faced with the challenges of environmental conservation, population explosion, desertification, soil erosion, pollution, other environmental threats and increased use of science and technology (Agbogidi et al. 2009; Djogbénou et al. 2010). Biodiversity is a source of anxiety because it is threatened by human activities in the world (Barbault, 1995; Bergen, 1998; Kurt et al*.,* 2003; McLaren et al*.,*2003). The World Wildlife Fund (1994) has shown that 17 million hectares of tropical forests are cleared each year, which could lead to over 60000 species disappearance within the next 30 years (World Wildlife Fund, 1994).

According to the Food and Agricultural Organization (FAO, 1985), 13,000 square kilometers of African forest disappear every year through forest clearing. Timber species exploitation is another considerable factor in forest degradation (Nyadoi, 2009; Mvogo, 2011). Forest degradation has been worsened over the past years by the numerous populations seeking a means of living, without respecting minimum conservation rules (Kokou et al. 2000; Mama et al. 2005; Alamu et al. 2011; Arouna et al. 2011; Deb et al. 2011; Glèlè et al.2011; Nacoulma et al. 2011). Therefore due to human population growth in villages and towns as well as in the nearby settlements (Rocky, 2011), the demand for forest products has increased. Plant species from natural forests are therefore exploited at much faster rate than the rate at which they are replaced through natural regeneration (Feyera and Luttge, 2001; Gérard 2004). Over decades, the primary forest product was commercial timber. Urbanized countries account for a great percentage of the world's wood consumption that increased greatly between 1950 and

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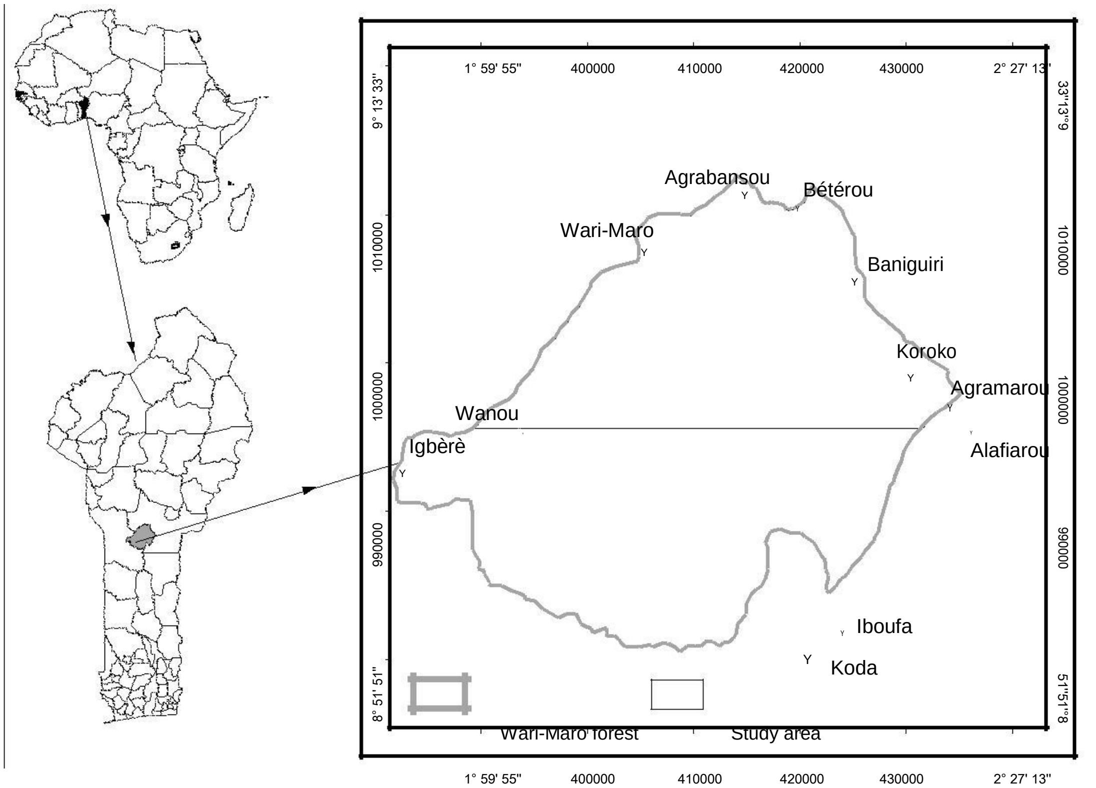


Figure 1. Location of Wari-Maro forest in Benin Republic.

1980. By 1985, 72 percent of West Africa's rainforests had been transformed into fallow lands and an additional 9% had been opened up by timber exploitation (FAO, 1985). In spite of efforts to encourage the use of lesser known timber species, the market continued to concentrate on a fraction of the available usable timber. Thus, West Africa was prone to selective harvesting practices.

In Benin, Wari-Maro forest like other protected forests of the country is destroyed by logging activities. Wari-Maro vegetation became a protected forest by Executive order n°51 /94/1964 and by Ordinance of December 10, 1955. Human activities, such as agriculture, overgrazing, rangeland exploitation and above all, exploitation of timber has contributed to forest degradation. Timber species such as, *Afzelia africana, Pterocarpus erinaceus, Khaya senegalensis, Pseudocedrela kostchyi, Ceibapentanda*and*Chlorophora excels* have been exploited for commercial use in this area. Timber extraction not only alters the structure of the forest, it influences the tree species composition by removing economically valuable species and destroying other species in the process.

An increased concern for conservation and an increased demand of timber and forest land in Africa require a sound management of the remaining forest resources (Martin, 1979; Mvogo, 2011).

The aim of this study was to assess the status of timber species in the protected Wari-Maro forest located in the North of Benin.

METHODOLOGY

Choice of the study area, satellite image analysis.

The northern part of the Wari-Maro forest has retained for a detailed study and covers 35895 ha constituting 33.4% of the total area of the forest (Figure 1). The reason for this choice is based on the fact that the forest is surrounded by increasing population and by the increase demand for fertile soils by the riparian population and their domestic consumption or for marketing, has led to their encroachment into this part of the forest.

The methodology adopted was based on satellite image processing. Using Landsat-7 ETM + (path192 rows 55) of November 28, 2006 with a spatial resolution of 30 m, the area of each type of vegetation was estimated and summarized (Table 1). It was observed that the density of assessed timber species differs from one type of vegetation to another. Based on this field observation, it is very important to first estimate the area of each type of vegetation for extrapolation purpose of these timber species. The extrapolation technique is a function of the area of type of vegetation and the sample size. Figure 2 shows the location of sample plots in each type of the vegetation or land cover (gallery forest, dense dry forest or semi-deciduous forest, woodland and tree savanna, tree and shrub savanna on rocky slopes, cultivated wooded and shrub savanna) in the Northern part of Wari-Maro forest.

Sampling and timbers species assessment

Before the establishment of the sample plots in each type of vegetation, the sampling ratio was estimated, based on the size of each type of vegetation in the forest (Table 2). A stratified sampling was used and sampling plots were allocated proportionally to size (area) of each type of vegetation.

Table 1. Sampling of the plots.

Characteristic	Vegetation type					
	Gf	**Ws**	**Tss**	**Ddf**	**Tsr**	**Cws**
Area in (ha)	2036	17148	14120	360	986	1245
Percentage (%)	5.64	47.54	39.14	1.0	2.73	3.45
Number of correspondingplots	11	44	35	2	3	4
Number of establishingplots	15	48	40	6	3	8

Source: Field investigation, February 2011. Gf, Gallery forest; Ws, woodland and tree savanna; Tss, tree and shrub savanna; Ddf, dense dry forest or semi-deciduous forest; Tsr, tree and shrub savanna on rocky slopes; Cws, cultivated wooded and shrub savanna.

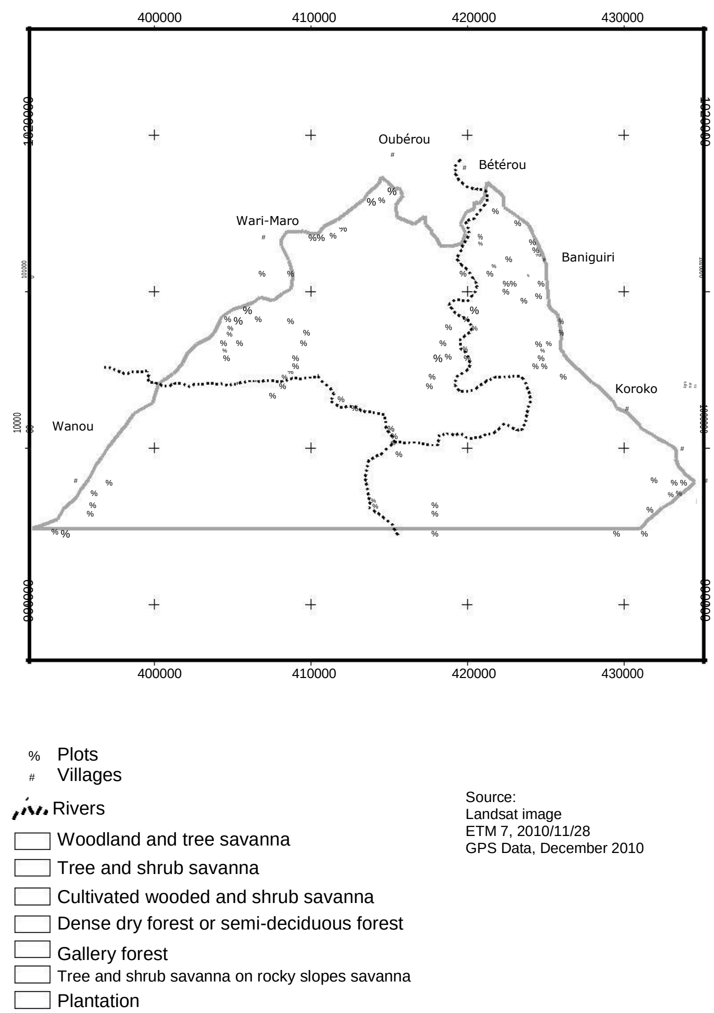


Figure 2. Location of sample plots in Wari-Maro forest.

A total of 120 sample plots were retained. The sampling ratio was 0.03% and each plot measured 30 m x 30m (900 m^2). The total inventory area was 10.8 ha, and the spatial locations of sampling plots are shown in Figure 2. The distance between consecutive sample plots was more than 100 m.

The dendrometric parameter such as diameter at breast height (DBH) of the trees was collected in the study area. A tree was taken into account for measurement when it's DBH was more than or equal to 10 cm above the ground or at 0.30 m above buttress. The purpose of this method was to estimate the commercial timbers listed previously.

Data analysis

Diameter distribution for the species was obtained by grouping trees in 10 cm interval and plotting histograms. The formula below (equations 1 and 2) was used for the estimation of basal area and

Table 2. Density of ligneous species of diameter ≥ 10cm.

Ligneous resources	Types of vegetation											
	Gf		Ddf		Ws		Tss		Tsr		Cws	
	N	%	N	%	N	%	N	%	N	%	N	%
Timberspecies	16	4.18	14	5.93	129	41.34	63	26.32	180	50.0	25	15.06
Total species	382	100	236	100	312	100	242	100	360	100	166	100

Source: Field surveys, February 2011. Gf, Gallery forest; Ws, woodland and tree savanna; Tss, tree and shrub savanna; Ddf, dense dry forest or semi-deciduous forest; Tsr, tree and shrub savanna on rocky slopes; Cws, cultivated wooded and shrub savanna.

quadratic mean diameter of timber species within the plots and the results were extrapolated to the entire vegetation type. The number of each timber species was estimated within each plot and the results were extrapolated for each type of vegetation using the sampling rate.

The basal area (G) was expressed as:

G = – (equation 1)

Where, di or DBH = diameter of the tree at 1, 30 m above the ground or at 0.3 m above buttress basal area of mean tree (g).

g = G /N with N =number of trees per hectare

Diameter of tree of the average basal area (dg) or quadratic mean diameter

—

Dg = (equation 2)

RESULTS

Density of timber species by vegetation types

The density of ligneous species was presented in Table 2. This density was related to the density of timber species and for the total species collected in each type of vegetation within Wari-Maro forest. The analysis shows that the density of timber species was important within woodland and tree savanna (Ws), and tree and shrub savanna on rocky slopes(Trs), whereas this density was very low within gallery forest(Gf), dry dense forest(Ddf) and cultivated wooded and shrub savanna (Cws). Woodland and tree savanna, and tree and shrub savanna on rocky slopes were very rich in timber species (41.3 and 50% respectively) on which *Isobernia doka* is very important because its exploitation for human use is very low. Gallery forest was poor in timber species in Wari-Maro forest. The timber species met in this type of vegetation are essentially *Khaya senegalensis.* Dry dense forest is very rich in *Anogeissus leiocarpus* species; actually very solicited for carbonization because of its high calorific power.

To have a good knowledge of the density of each timber species in the forest, the analysis has been done for each type of vegetation (Table 3). From the analysis, it is plausible to assert that except for *I. doka*, the number of stems per hectare was very low for all the timber species in each type of vegetation. *Pterocarpus erinaceus* has high capacity to colonize all types of vege-tation whereas *Khaya senegalensis* is more fre-quent in gallery forest, less frequent in woodland and absent in others*. C. excels* and *Ceibapentanda* were rare or absent in many types of vegetation*.* From field observations, their absence or rarity is due to its overexploitation by the population.

Main characteristics of the various types of vegetation

Table 4 presents the basal area of the tree population (G), basal area of the mean tree (g) and the diameter of tree of the average basal area (dg) for each vegetation type estimated. The high coefficient of variation (cv) observed in the cultivated area allows to assert that there is an important impact of anthropogenic activities in Wari-Maro forest.

Diameter distribution of main timber species in Wari-Maro forest

This analysis was a way to better understand the state of timber species in Wari-Maro forest. With the regression spread of the timber species in this forest, it is very important to describe the representation of these timber species according to their diameter and the number of stems per hectare in the forest. For this reason, the timber species which still have been exploited were

Table 3. Density of timber tree species by the type of vegetation.

Timber specie (Trees N/ha)	Types of vegetation					
	Gf	Ddf	Ws	Tss	Tsr	Cws
Isoberliniadoka	0	0	93	45	130	10
Afzeliaafricana	0	0	7	6	0	3
Pterocarpuserinaceus	2	10	17	8	40	4
Khayasenegalensis	12	0	1	0	0	0
Chlorophoraexcelsa	2	4	0	0	0	0
Ceibapentanda	0	0	0	0	10	0
Pseudocedrelakostchyi	0	0	0	11	4	8
Total	**16**	**14**	**129**	**63**	**180**	**25**

Source: Field surveys, February 2011. Gf, Gallery forest; Ws, woodland and tree savanna; Tss, tree and shrub savanna; Ddf, dense dry forest or semi-deciduous forest; Tsr, tree and shrub savanna on rocky slopes; Cws, cultivated wooded and shrub savanna.

Table 4. Main characteristics of the various types of vegetation.

Parameter	Types of vegetation					
	GF	Ddf	Ws	Tss	Tsr	Cws
	32.07	25.49	14.46	8.06	13.98	5.67
G	±14.03	± 12.1	± 5.3	± 2.63	± 3.68	± 3.62
Cv	43.76	47.5	36.62	32.65	26.32	63.86
g	0.08	0.10	0.04	0.03	0.03	0.03
dg	32.69	37.08	24.29	20.29	22.23	20.85

Source: Field surveys, February 2011. Gf, Gallery forest; Ws, woodland and tree savanna; Tss, tree and shrub savanna; Ddf, dense dry forest or semi-deciduous forest; Tsr, tree and shrub savanna on rocky slopes; Cws, cultivated wooded and shrub savanna.

analyzed. Among these species, the following can be mentioned: *Afzelia africana, Khaya senegalensis, Pterocarpus erinaceus* and *Pseudocedrela kostchyi* (Figures 3a, 3b, 3c and 3d).

A. africana was one of the most important timber species over exploited by the population of Benin Republic (Figure 4). Its diametric structure (Figure 3a) shows the absence of small diameter (10 to 20 cm) trees in the forest. The number of stems per hectare are very low (less than 3 stems/ha) for all diameters classes, and there are no trees larger than the diameter class (50 to 60 cm). The most adjustment obtained was the polynomial function (Figure 3a).

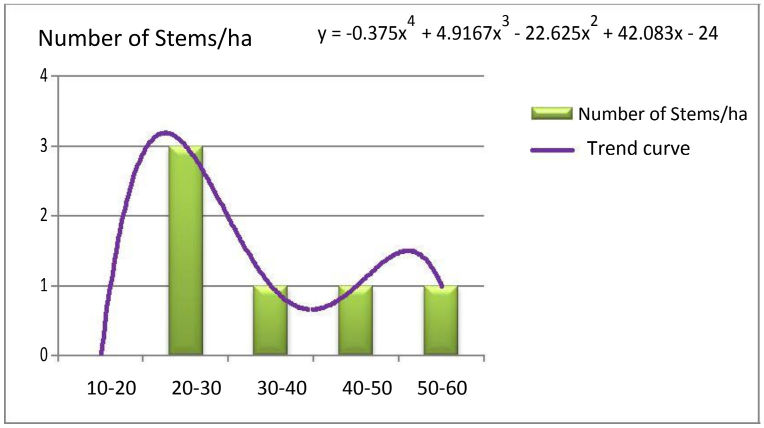
Khaya senegalensis is the second timber species used by population of Benin for industry purpose and also for exportation overseas.The diametric structure of this timber species (Figure 3b) showed less than 3 plants per hectare for the 30-40, 40-50, 50-60 and 60-70 cm diameter classes and about 4 stems per hectare in the class 70-80 cm and above class 100 cm. However, there were no stem in the small diameter classes of 10-20 and 20-30 cm. The absence of the individual of *K. senegalensis* in these classes shows that the diametric structure contributes less to the reconstitution of populating.

Pterocarpus erinaceus and *Pseudocedrela kostchyi* (Figures 3c, 3d) are actually the timber species most exploited for domestic use and for overseas exportation. It appear that *A. africana* and *K. senegalensis* are in spread regression in Wari-Maro forest and are very difficult to find. Regarding the diameter size classes the number of stems per hectare decreases from the small diameter to big diameterclasses. The adjustment function for *Pterocarpus erinaceus* is an exponential decay function expressed as $y = 6.7273e^{-0,362\mathbf{x}}$.

The same function can be used for *P. kostchyi* as well; exponential decay function (Figure 3d) expressed as $y = 8.4554e^{-0,389\mathbf{x}}$

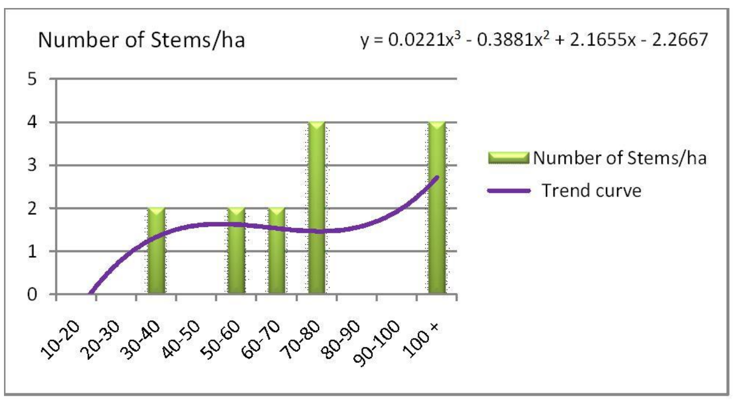
DISCUSSION

In this study, the basal area for all types of vegetation was estimated from 5.67 m^2/ ha to 32.07 m^2/ ha. Hunhyet (2000), who studied the structure and dynamic of each type of vegetation in Monts-Kouffe's forest located at the same latitude as Wari-Maro forest obtained basal area in the range of 3.87 m^2/ ha to 25.7 m^2/ ha. These similar results have shown that the two forests are over-exploited by the same riparian populations. According to Amakpa (1999), the basal area for all types of



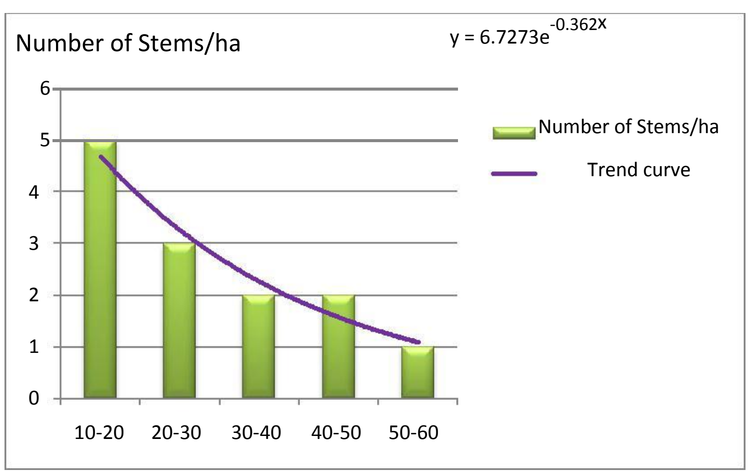
DBH size classes

Figure 3a. DBH class distribution of *Afzelia africana* in Wari-Maro forest.



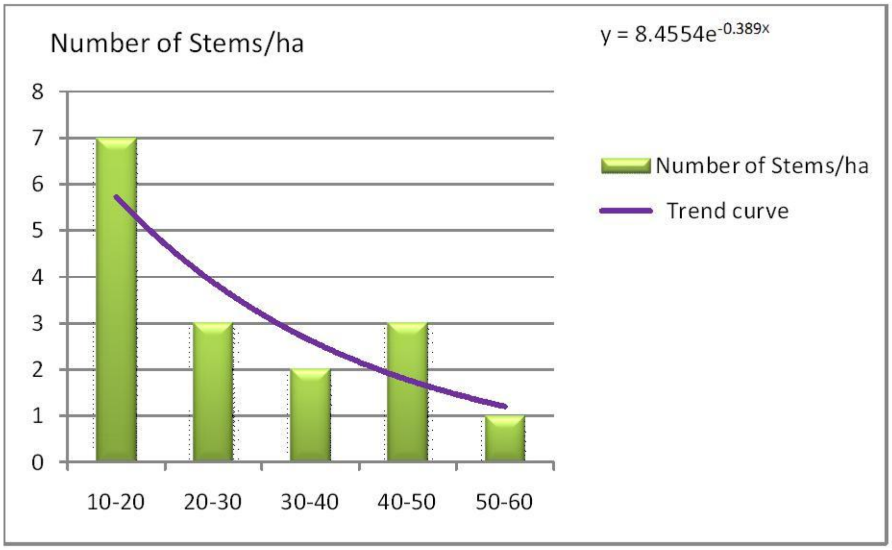
DBH size classes

Figure 3b. DBH class distribution of *Khaya senegalensis* in Wari-Maro forest.



DBH size classes

Figure 3c: DBH class distribution of *Pterocarpus erinaceus* in Wari-Maro forest.



DBH size classes

Figure 3d. DBH class distribution of *Pseudocedrela kostchyi* in Wari-Maro forest.

Figure 4. Cut of *Afzelia africana* within Wari-Maro forest.

in the 'trois rivières's forest' is estimated to be 8. 98 m^2/ ha to 32.32 m^2/ ha. These results are quite similar to those obtained in all these studies reveal that impact of human activities is areality to be taken into account for when thinking about forest management in Benin Republic.

Concerning the assessment of timber species in Wari-Maro forest, the number of stems per hectare for each type of timber species is very low. From the diametric structure obtained for these species, it appeared that *Afzelia Africana* has a dispensed distribution in Wari-Maro forest. The small class of diameter (10 to 20 cm) which contributes to the reconstitution of the populating is not present and may be an indication of poor natural regeneration. The species may become rare if over exploitation and overseas exportation continues, unless appropriate silvicultural measures are undertaken. *Khaya senegalensis* may also have a problem of natural regeneration, but it has a larger number of stems in larger diameter classes. Both species could be light demanding species. The field investigations revealed that many species such as *Pterocarpus erinaceus* and *Pseudocedrela kostchyi* were also exploited for overseas exportation. However, their diameter distribution shows good regeneration, but their exploitation is getting intensified as a consequence the scarcity of *A. africana* and *K. senegalensis.*

Conclusion

No accurate means exist to quantify the contributions of different activities to deforestation in most regions of Sub-Saharan Africa countries such as Benin. It is apparent today that there is little chance to meet domestic needs of timber species like *Ceibapentanda* and *Chlorophoraexcelsa in Wari-Maro* forest because of their overexploitation based on the field investigations and results obtained from data analysis. It can also be stated that *Afzelia africana* and *K. senegalensis* are at *risk of* extinction due *to* overexploitation. Most of the exploitation is for overseas exportation than for local consumption. This situation must question us and awaken our conscience. If this overexploitation continues, these timber species will disappear in Benin forests given that their natural regeneration is poor whereas their day-to-day exploitation continues without any policy to stop the massacre.

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