ASSESSMENT OF THE STATIONARY ABUNDANCE OF ZANTHOXYLUM ZANTHOXYLOIDES (LAM.) ZEPERNICK & TIMLER FOLLOWING THE CLIMATE GRADIENT OF BENIN (WEST AFRICA)

ABSTRACT

Z. zanthoxyloïdes is a multipurpose plant. Therefore, it is under heavy user pressure in Benin. This study assessed the availability of this species and the ecological characterization of natural habitats that currently supports it. The inventory of Z. Z. zanthoxyloïdes was carried out in 120 square 50 m x 50 m plots on mega-transets in the Lama, Wari-Maro and N'Dali classified forests and fallows that surround them. Individuals of Z. zanthoxyloïdes were counted and breast height diameters (DBH) greater than 5 cm were measured with pi tape. The stationary abundance of the species between the three classified forests was compared with variance analyzes. The rarefaction index has also been calculated between habitats. The results show that adult and juvenile densities are significantly different between natural forest and surrounding fallow (p <0.0001). The distributions of the diameter classes showed a good fit with the Weibull distribution (p> 0.05). The density of adult Z. zanthoxyloïdes trees is higher in the Lama Classified Forest than in the other two. The study reported that fallows currently contain more young individuals than natural forests. The vulnerability of the species is therefore confirmed as previously reported by the Benin Red List. Thus, actions to assist its natural regeneration would be a necessary contribution to keep the species for present and future generations.

Key words: *Z. zanthoxyloïdes*, abundance, density, fallow, protected areas, Benin.

INTRODUCTION

In severaldeveloping countries, non-timberforestproducts (NTFPs) have long been underutilized. It wasfrom 1995 that the need to domesticatethem to increase the well-being of local populations became a major concern(Leakey *et al.*, 2005). Indeed, the information available on non-timberforestresourcesismostoften qualitative and does not bring out the quantitative data necessary to demonstrateeconomicopportunities or for social developmentand environmental management (Codjia*et al.*, 2003). AmongtheseNTFPsis Z. zanthoxyloids, whichis a multi-purposespecies. It is a plant on Benin'sredlist in the category of vulnerablespecies (Adomou*etal.,* 2011). Itsroots are heavilymarketed in Benin and evenexported (Quiroz*et al.*, 2014). To this end, itdeservesspecial attention for the implementation of conservation and domestication strategies in a context of climate change. A lot of work has been carried out to contribute to the enhancement of the species in the sub-region. However, moststudies on this plant have onlyfocused on itspharmaceutical value. Admittedly, someauthors, in this case Adomou (2011), Guendéhou (2012) and Yaoitcha (2016) have addresseditsethnobotanical and ecological aspects, but itshould be notedthat the aspects of abundance and population structure have not been elucidated. This studyaddressedboth aspects in order to have the scientific data to help make conservation decisions to ensureitssustainable use in Benin. Knowledge of the species' population structure is essential becauseitmakesit possible to measureanthropogenic pressures on population dynamics (Sinsin et al., 2004) and is a crucial step in defining a conservation and sustainable management strategy for a species (GlèlèKakaï&Sinsin, 2009;Assogbadoet al., 2010; Sinsin, 2004; Bonouet al., 2009). Thoserelated to Z. zanthoxyloides populations in Benin in general are not yetdocumented. In terms of the abundance of the species, itsknowledgeisuseful in explaining how itisinfluenced by environmental conditions and anthropogenic pressures (Jacob et al. 2010). Thus, abundanceis one of the very first pieces of information in the evaluation of the potential and availability of species(Avocevou-Ayisso, 2011). The presentstudy, whichwill document the abundance of Z. Z. zanthoxyloids in the differentclimatic zones, willallow us to betterappreciate the occurrence, the level of availability and the pressure and these data willmakeit possible to make suggestions for conservation action and sustainable exploitation. In doingso, the specieswillbeconserved for current and future generations.

MATERIAL AND METHODS

A-Material

The material for thisstudyiscomposed of biologicalmaterial and fieldtools.

1) Biologicalmaterial

It is Z. zanthoxyloides, which belongs to the Rutaceae family. It is a shrub 6 to 7 m high. The twigs are very armed with very curved and sharp prickles, claw-shaped, small or up to 1 meter long. The rachis and sometimes the midrib bear large curved spines. The leaves**(photo 1)** are alternate, compound and imparipinnatewith a petiole of 2 to 5 cm of rachis more or lesscylindrical or flattened. The stems are in the form of cylindrical fragments 3 to 5 cm in diameter**(photo 2)**.

Photo1. Leafy branch of *Z. zanthoxyloïdes*

Photo2. Stem of *Z. zanthoxyloïdes*

2) Field Tools

The materialused in thisstudyconsists of a penta decameter for the delimitation of the squares; fluorescent strip to materialize the boundaries of the squares; cutting for the opening of the sills and the making of the corner stakes; pruningshears for takingsamples; pi tape for measuringtreediameters, GPS (*Global Positionning System*) for the georeferencing of the feet of*Z. zanthoxyloïdes*and a map of Benin'sprotected areas.

3) Studyenvironment

The study area consists of the ClassifiedForests of the Lama, Wari – Maro and N'Dali **(Figure 1**)below**.**

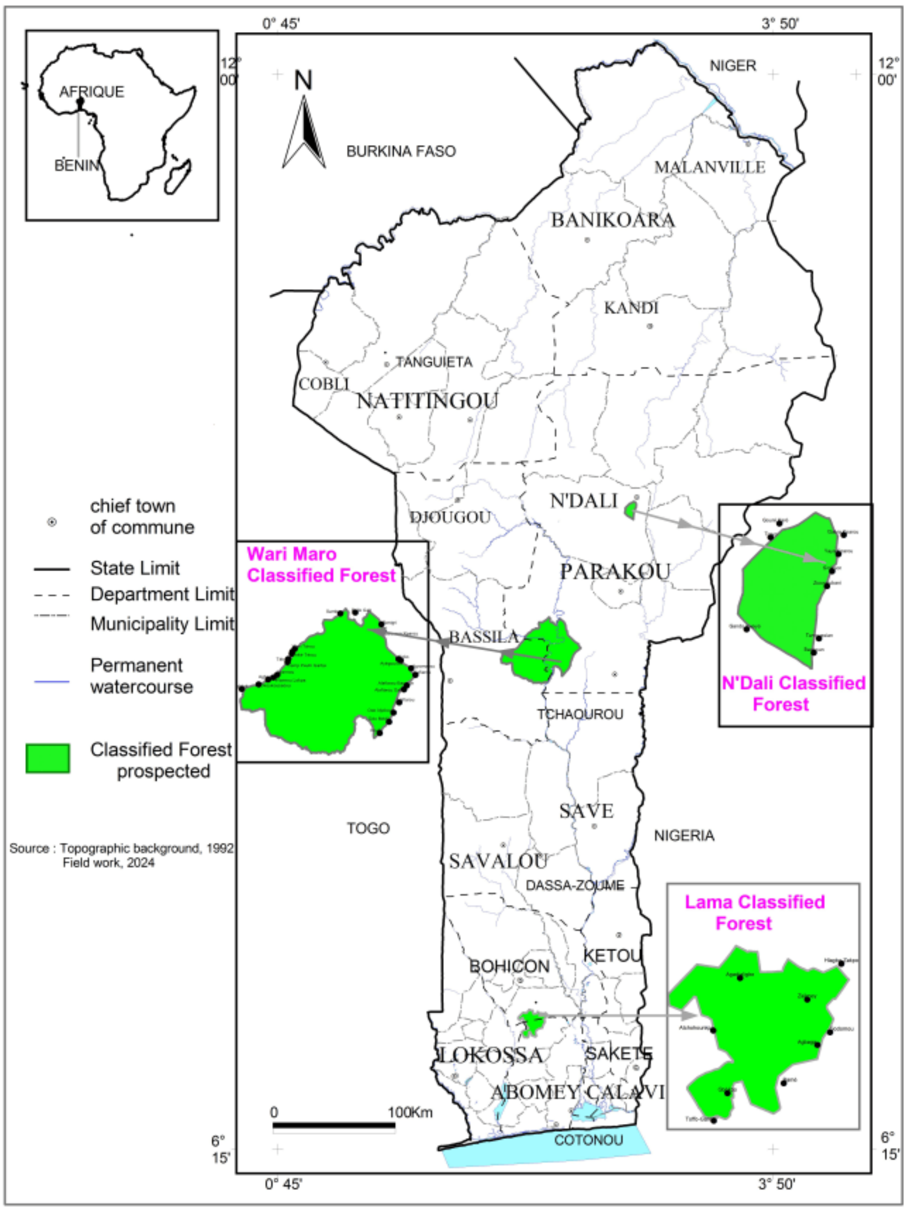

Figure 1 : Map of Benin'sprotected areas with the threeclassifiedforests

B-Sampling and data collection

The choice of its habitats was made in a reasonedway, takingintoaccount the forestsclassified in eachclimatic zone. The Lama Classified Forest in the Guinean zone, the Wari-Maro Forest in the Sudano-Guinean transition zone and the N'Dali Classified Forest in the Sudanian zone.

The sub-equatorial zone has four seasons and extendsfrom the coast to the latitude of Dan north of Abomey. It experiences 250 days of raindividedintotwoparts: the first, the longestfrom March to the end of July and the second fromSeptember to mid-November. The tworainyseasons are separated by 2 dry seasons.

The Sudano-Guinean zone has 2 seasons, one rainy and one dry, and islocated in the center of the country with 200 days of rainconcentrated in the periodfrom April to October. It extendsfrom the latitude of Dan to that of Savè. The third zone isSudanian-type with 145 days of rain. It extendsfrom the latitude of Parakou to the entirenorth of the country. It also has twoseasons, one rainy and one dry.

At the level of each habitat, the prospecting effort wasdeterminedthrough the number of plots to beinstalled by means of the formula of (Dagnelie, 1998) :

$$N = \frac{U^2{}_{1-\alpha/2}(\mathrm{CV}^2)}{\mathrm{d}^2}$$

N, Sample size wasdetermined by vegetation, $U^2_{1-\alpha/2}$=1.96 ; *CV* = coefficient of variation. The coefficient of variation wasthereforecalculated by Classified Forest and d is the margin of error (*d*=10 pour cent). Thus, the number of places is as shown in Table 1 below.

These plots werealsoinstalledrandomly by followingmega-transects orientedfromsouth to north. These are the 50 m x 50 m (2500 m2) plots indicated for structural analysis in dense forest (Salako et al. 2013). It is more convenient to use square or rectangular plots in tropical formations (Van Laar&Akça, 2007). In each plot, all Z. zanthoxyloidindividualswerecounted and the diametricmeasurementwas made at the level of individualswith a dbh ≥10 cm. Table 1 shows the distribution of plots by forest and climate zone.

Table 1: Distribution of plots by Classified Forest and by climatic zone

Climatic Zones	**Natural Formations**	**Fallow**	**Total**
Guinean zone (Classified Lama Forest)	60	19	79
Sudano-Guinean zone (Classified Forest of Wari - Maro)	20	7	27
Sudanian Zone (N'DalieClassified Forest)	10	4	14
Total	**90**	**30**	**120**

C-Data processing

The collected data wereenteredinto the Excel spreadsheet and severalecological and dendrometricparameterswerecalculated:

- **Scarcity index (***species rarity weight richness index***)**

The rare status of the specieswasdetermined by the rarefaction index calculatedaccording to the followingequation: Ri = (1- ni/N) with Ri: rarefaction index of species i, ni: number of places wherespecies i isfound and N: total number of places in the formation.

Takingintoaccountthisrelationship, if the scarcity index islessthan 80%, the speciesisconsideredpreferential, veryfrequent and abundant in the areas studied. Although the rarefaction index is more than 80%, the species is rare. A 100% rarefaction index meansthat the presence of the species has not been observedanywhere in the areas studied. Thus, the latter ishighlythreatenedwith extinction in the region.

- Stand density

N is the averagenumber of mature trees (dbh ≥ 10 cm) per hectare. It isgiven by the formula:

$$N = \frac{n}{s}$$

*n*is the total number of trees per plot and s is the area of the plot in ha. In the case of the density of Z. zanthoxyloides plants, the area consideredisequal to 1 ha.

- Structural characterizationof Z. zanthoxyloides

Individuals of Z. zanthoxyloidweregroupedinto classes with a diameter of 5 cm. Thus, the densities of trees by diameter classes weredetermined. The densities of adults (dbh ≥ 15) and juveniles (10≤ dbh<15) are comparedbetween the threeForestsClassifiedwithinnatural formations and fallowwith the nonparametric Mann Whitney test because the data do not follow a normal distribution. This statisticalanalysiswasperformedwith the R software. The diameter distribution classes werefitted to the theoretical 3-parameter Weibull distribution (a, b and c) using the densityfunction (f) expressed as a function of the diameter (x) according to the formula :

$$f(x) = \frac{c}{b}\left(\frac{a-b}{b}\right)^{c-1} exp\left[-\left(\frac{x-a}{b}\right)^{c}\right]$$

where: b= scale or size parameter; a=position parameter; c= shapeparameter. The threshold of the parameter a wasconsideredwith a=10cm to adjust the class size of the species. The analysiswasdone in R using the packages (Mass, Survival and Fitdistrplus) to test the observed distribution compared to that of Weibull.

RESULTS

Abundanceof Z. zanthoxyloides

Table 2:Densities and Indices of Z. zanthoxyloidscarcity by climatic zone and by foreststudied.

Climate Zone	Densities(pieds/ha)	Rarefaction Indices
Guinean (Classified Lama Forest)	1,2	RI<80%
Sudano-Guinean (Wari-MaroClassified Forest)	0,24	RI>80%

Sudanian (N'Dali Classified Forest)	0,1	RI>80%

The density of Z. zanthoxyloidessubjectsdecreasesfrom the Guinean zone (FC de la Lama) to the Sudanian zone (FC de N'dali) and the scarcity index also shows that the speciesisabundant in the Guinean zone and increasingly rare as weevolvetowards the Sudanian zone. This resultissimilar to that of (Romain GlèlèKakaï et al, 2011) whoworked on the ecological adaptation of Vitellariaparadoxafollowing the climatic gradient in Benin.

Within the Llama FC where the speciesisabundant, itappearsthatjuveniles are found more in fallowthanadults (P-value< 0.0001) whileadults have been at the same time more represented in natural formations than in fallow (P-value< 0.0001).

The diameter structures of Z. zanthoxyloids in the twodifferent plant formations of the Central Core of the Classified Lama Forest are shown in **Figure 2.**

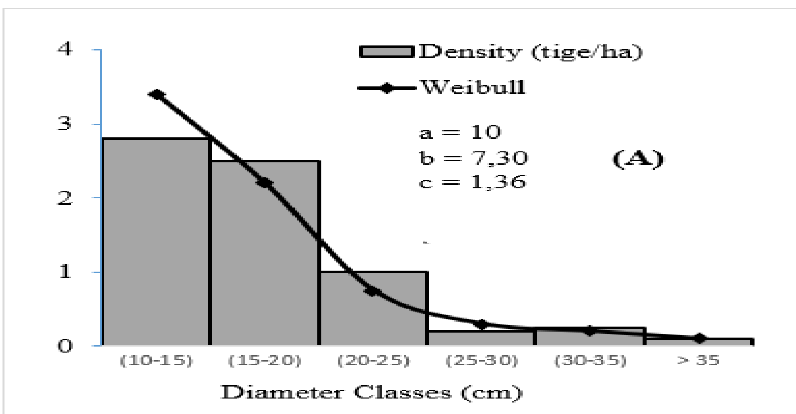

Figure2 : Structure in diameter of Z. zanthoxyloides in the classifiedforest of the Lama (A)

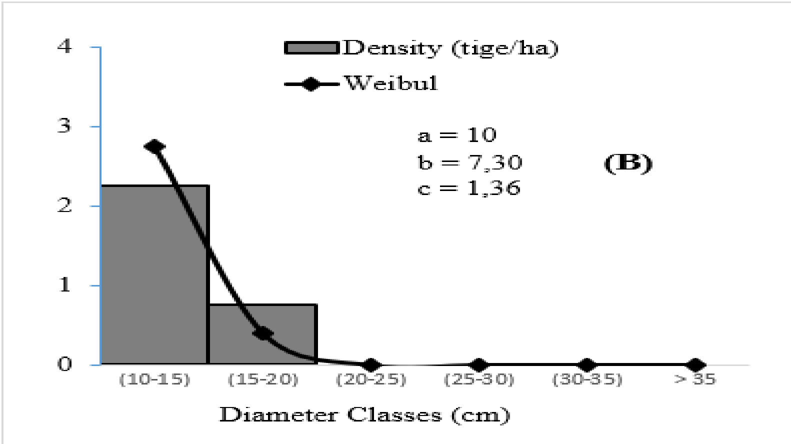

Figure 3 : Structure in diameter of Z. zanthoxyloides in the surroundingfallow land (B)

In both habitats, the Weibullshapeparameter (c) isbetween 1 and3.6. Thus, the distribution by diameter class of the individualsgenerallyindicates a non-Gaussianappearanceeverywhere and presents a leftasymmetry (1<*c* < 3,6) Characteristic of stands with a relative predominance of young or smalldiameterindividuals. Regardless of the type of habitat, individualsbetween 10 and 15 cm in diameter are the mostabundant. There are nearly 3 plants per hectare in the natural formation and more than 2 plants per hectare in fallows. At fallow land, the diameter of this plant hardlyexceeds 20 cm, whileitreaches 35 cm in the forest.

Moreover, in the otherforests (Wari-Maro and N'dali), no Zanthoxylumzanthoxyloides plants have been found. However, the investigations made it possible to findtwoisolated plants in a fallow land located in the district of Manigri, a locality not far from the classifiedforest of Wari-Maro.

DISCUSSION

Abundanceof Z. zanthoxyloides

The results of thisstudyshowedthat the density of Z. zanthoxyloidessebecomesrarer as the distance from the coastincreases. This resultissimilar to that of Yaoitcha (2015), whoshowedthat the speciesislessabundant in the mostaridclimates. A recentstudyhadalreadymentionedthatthisspeciesisthreatenedwith extinction already at the height of Glazoué-Savè-Ouèssè, in the Sudano-Guinean zone (Ehinnou-Koutchika*et al.*, 2014).

It istherefore not surprising to report the information we have had in thisstudy on thisspecies in the twoclimatic zones of Central and Northern Benin. The scarcity of adult plants in fallow land in the prospected areas couldbeexplained by the anthropogenic pressure exerted on the species. Indeed, apartfromitsmedicinal values (Queiroz et al., 2006), the speciesisused for otherpurposessuch as carbonization, woodenergy, sculpture, etc. (Pote *et al.*, 2006;Furukawa*et al.*, 2011). Bossokpi (2003) hadreportedthat Z. zanthoxyloidesis a species of pre-forestsavannahs and coastalthickets;Adesina (2005) alsoreported in southwestern Nigeria that the speciesis more abundant in savannah and dry forest, soitwould not have been otherwise at ourstudy sites if adult plants were not regularlycollected. The proof of thisisthatjuvenile and young plants are fairlywellrepresented in fallows, a signthatnaturalregenerationisoccurringrelativelywell.

In fallow land, direct access to light allowsseedlings to establish and develop. Fallow land and open plant formations therefore have a high conservation potential if specific management actions are carried out onthisyoung population of the species (Houéhanou*et al*., 2013).

Population structural characteristic of Z. zanthoxyloides

The distributions in diameter by plant formation at the level of the Llama FC generallyindicate a non-normal appearance, i.e. they do not present a Gaussianappearance and therefore lead to the conclusion that the regularity of the Z. zanthoxyloides structure is not assured. This leftasymmetryhad been reported on different tropical species by variousstudiessuch as Cassou et al. (1997) hadreported on the African population of palm trees in Burkina Faso, Kperkouma et al. (2005) on the Shea butter trees of Donfelgou in Togo, Bonouet al. (2009) on the populations of Afzeliaafricana in Benin. However, ithad been mentioned by authorsthatsomespecieswith a bell-shaped distribution withinsmall patches mightexhibit an inverted J-shapewhen the patches are larger(Pulido*et al.*,2001). The scale of a classifiedforestcouldtherefore have played a role in the adjustmentobtainedwith the Weibull distribution. The densityfunction (f) of the diameter (x) required for the dendrometricstudy of the speciesisjustified by itsefficiency. According to (Bonou, 2009), the use of the Weibull distribution probabilitydensityfunctionisbecomingincreasinglyuniversal to model the diameter distributions of homogeneous and uneven-agedforest stands.

As far as the N'Dali Classified Forest isconcerned, the speciesis absent as alreadyreported in a previousstudy (Djagouni et al., 2010). The observation isidentical to whatisobserved in the FC of Wari-Maro.

Anthropogenic pressures and destruction of Z. zanthoxyloidespopulations

This plant isconstantlycut down during the establishment of agricultural areas in the south as well as in northern Benin. For the agricultural production of foodcropssuch as maize, forests are graduallycleared by ploughingwith a gradualuprootingthat first takesintoaccount the lessrobuststumps in order to betterensure the availability of nutrients and the aeration of the soillayers(Bajwa, 2014). Generally, afterfarmers have worked the land, the roots of Z. zanthoxyloides are recovered by thosewhowant to sellthem. Otherwise, the rootsbecome a nuisance and are used as fuel. All this not onlyreduces the extent of the species' populations but alsoreduces the potential for itsregeneration on wastelands. But itis good to note that the studiesof Quiroz*et al.* (2014) in Benin report that the roots of the speciesweresoldcheaper on the market (1.15 USD/kg) comparé aux racines des plantes en général (2.21 USD/kg). This shouldreduce the pressure a little, at least from the point of view of collections for commercial purposes. Botha et al. (2007) arguedthatpriceis not the best indicator of the availability of a medicinalherb.

CONCLUSION

The distributionof*Z. zanthoxyloïdes*is more confined in the Guinean zone of Benin and benefitsfrom a more favorale protection situation in the Classified Lama Forest. The decrease in mature trees in fallow and anthropogenic areas recommendsthatdevelopment actions becarried out to ensureitscurrent and future availability. In addition, propagation actions by cuttingssuccessfullytried by the sameauthors are a recommended avenue.Wesuggest, however, thatfurtherstudies are needed to makeavailablemaps of the current and past distribution of thisspecies to guide conservation actions.

REFERENCES

Adesina, S. K. (2005). The Nigerian Zanthoxylum; chemical and biological values. *African Journal of Traditional, Complementary and Alternative Medicines*, *2*(3), 282-301.

Adomou A. C., Agbani O. P., Sinsin, B., 2011. Plantes. 21-46. *Protection de la Nature en Afrique de l'Ouest : Liste Rouge pour le Bénin. International Institute of Tropical Agriculture Ibadan Nigeria*

Assogbadjo A. E., GlèlèKakaï R. L., Sinsin B., Dieter P., (2010). Structure of *Anogeissusleiocarpa*Guill., Perr. natural stands in relation to anthropogenic pressure within Wari-Maro Forest Reserve in Benin. *African Journal Ecology* 48 (3) : 644–653.

Avossèvou-Ayisso, C., Avohou, T.H., Oumorou, M., Dossou, G., Sinsin , B., 2011.Ethnobotany of Pentadesmabutyraceain Benin : A quantitative approach.*Ethnobotany Research & Applications 9, 151-166.*

Bajwa A. A., 2014. Sustainable weed management in conservation agriculture. Crop Protection, 65: 105-113. doi: 10.1016/j.cropo.2014.07.014

Botha, J. Witkowski, E.T.F., Shackleton, C. M, 2007. Factors influencing prices of medicinal plants traded in the Lowveld, South Africa. Int. J. SustnainableDev . World 14,450-469 .

Bonou, W., GlèlèKakaı¨, R., Assogbadjo, A.E., Fonton, H.N., Sinsin, B., 2009. Characterisation of Afzeliaafricana sm. Habitat in the lama forest reserve of Benin. Forest Ecology and Management 258, 1084–1092.

Bossokpi, I. (2003). Study of the biologicalactivities of FagarazanthoxyloidesThesis, Faculty of Medicine, Pharmacy and Odontostomatology, University of Bamako, Mali.

Cassou J. and Depomier D., 1997. “In Announcement: Tri-Party Meeting on Agroforestry,” Sikasso, Burkina Faso.

Codjia, J. T. C., Assogbadjo, A. E., &Ekué, M. R. M. (2003). Diversity and valorization

local level of forest plant food resources in Benin. Cahiersagricultures, 12(5), 321-331.

Dagnelie, P., 1998. Theoretical and applied statistics, vol. 2. De Boeck and Larcier, Belgium, Paris.

Djagoun, S. C. A. M., GlèlèKakaï, R., Konnon, D., Sewade, C., Kouton, M., Bonou, W., ... &Fandohan, B. (2010). Potential of food and medicinal forest plant resources of the classified forest of OuéméSupérieur and N’Dali in Northern Benin. Fruits, Vegetable and Cereal Science and Biotechnology, 4(1), 47-54

Furukawa T., Fujiwara K., Kiboi S. K., ChaloMutiso P. B., 2011. Threshold change in forest understory vegetation as a result of selective fuelwood extraction in Nairobi, Kenya. *Forest Ecology and Management*. 262, 962–969.

Gaoue, O. G., Ticktin, T., 2007. Patterns of harvesting foliage and bark from the multipurpose tree Khayasenegalensis in Benin: variation across ecological regions and its impacts on population structure. *Biological Conservation*. 137, 424–436.

GlèlèKakaï, R., Sinsin, B., 2009. Structural description of two Isoberlinia dominated vegetation types in the Wari –Forest Reserve (Benin). *South Africa Journal of Botany 75, 43-51*

GlèlèKakaï, R., Akpona, T. J. D., Assogbadjo, A. E., Gaoué, O. G., Chakeredza, S., Gnangle, P. C., ... &Sinsin, B. (2011). Ecological adaptation of the shea butter tree (Vitellariaparadoxa CF Gaertn.) along climatic gradient in Bénin, West Africa.*African journal of ecology*, *49*(4), 440-449.

Guendehou F. J., 2012. Ecological evaluation and use of Zanthoxylumzanthoxyloideswartern. (Rutacecae) in Lama Forest Reserve. Thesis of Master, Faculty of Agronomic Sciences, University of Abomey-Calavi, Benin. 60 p

Houehanou T. D., Assogbadjo A. E., GlèlèKakaï R. Kyndt T., M., Sinsin B., 2013a. How far a protection area contributes to conserve habitat species composition and population structure of endangerd African tree species. *EcologicalComplexity*. 13, 60-68.

Husch B., Beers T., Kershaw J., 2003. Forest Mensuration, 4th ed. Ronald Press Company, London in Africa. SRP, Exeter, London. Shahabuddin, G., Prasad, S., 2004. Assessing ecological sustainability of non-timber forest produce extraction: the Indian scenario. *Conservation and Society*. 2, 235–250.

IUCN, 2008. List of tropical Woods Used and Sold for Woodturning and their Endangerment Status. http://www.bradturnsgreen.com/Wood%20Status%20List.pdf.

Jacob, T., & Gardes, L. (2010). Propositions relatives au développement des connaissances de la population de dugongs de Nouvelle-Calédonie. Période, 2012, 33.

Kperkouma. W., Sinsin. B., K. Guelly, Kokou. K andAkpagana. K. , “Typologie et Structure des Parcs Agroforestiers Dans la Prefecture de Donfelgou,” *Sécheresse*, Vol. 1, No. 3, 2005, p. 8.

Leakey R. R., Tchoundjeu Z., Schreckenberg K., Shackleton S. E., Shackleton, C. M., 2005. Agroforestry tree products (AFTPs): targeting poverty reduction and enhanced livelihoods. *International Journal of Agricultural Sustainability*, *3*(1): 1-23.

Pote J., Shackleton C., Cocks M., Lubke R., 2006. Fuelwood harvesting and selection in Valley Thicket, South Africa. *Journal of Arid Environments*. 67, 270–287.

Pulido, F. J., Dı́az, M., & de Trucios, S. J. H. (2001). Size structure and regeneration ofSpanish holm oak Quercus ilex forests and dehesas: effects of agroforestry use on their longterm sustainability. *Forest Ecology and Management*, *146*(1-3), 1-13.

Queiroz, E. F., Hay, A.-E., Chaaib, F., van Diemen, D., Diallo, D., and Hostettmann, K. (2006). New and bioactive aromatic compounds from Zanthoxylum zanthoxyloides. *Planta Medica* **72**, 746-750.

Queiroz D., Towns A., Legba S. I., Swier J., Brière S. Sosef M., van Andel T., 2014. Quantitafying the domestic market in herbal medicine in Benin, West Africa. *Journal of ethnopharmacology*. 151, 1100-1108

Rondeux J., 1999. Measuringforest stands. Gembloux agronomic presses, 2nd ed. Gembloux, 521 p.

Salako V. K., GlèlèKakaï R., Assogbadjo A. E., Fandohan B., Houinato M. & Palm R., 2003. Efficiency of inventory plots patterns in the quantitative analysis of vegetation: case study oftropical woodland and dense forest in Benin. Southern forests 75 (3): 137-143

Sinsin B., EyogMatig O., Assogbadjo A. E., Gaoué O. G., Sinadouwirou T., 2004. Dendrometric characteristics as indicators of pressure of Afzeliaafricana Sm. Dynamic changes in trees found in different climatic zones of Benin. *Biodiversity and conservation*. 13, 1555-1570.

Van Laar A. &Akça A. 2007. Forest mensuration. Springer, Dordrecht. 383 p.

Yaoitcha A., 2016. Biologie de la conservation des plantes ligneuses médicinales au Bénin : Diversité, Vulnérabilité et Priorisation. Thèse de doctorat de l'UAC. 177 p.