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Effect of climatic gradient and age on wood productivity in cashew-based agroforestry systems

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Abstract

Agroforestry have immense benefits for the environment and the farmer. Indeed, in an agroforestry system, the planted or preserved trees produce litter that releases after decomposition into the soil, biogenic elements as natural fertilizer suitable for cropping. But, several factors affect the biomass productivity in these systems. In this study, the wood biomass production in the cashew-based agroforestry systems was assessed following the rain fall gradient East-West and South-North in three agro ecological zones which are: the Center, the northern east and the northern west. The experimental design was a split plot with two factors associated each with three modalities as followed: young, middle age and old associated with plantation factor and south or east, central, and northern west associated with the factor rain fall gradient. Nine districts were investigated. Within each districts, tree classes of cashew plantation (8-12 years, 12-16years and 16-20years), were defined after the inventory step. Data on growth parameters were collected on twenty-seven plots with ten trees per plot, selected using the method of diagonals. Data analysis revealed that the age of plantations was significantly affected the wood productivity (total branch and stem, $p < 0.1\%$).The effect of the climatic gradient was significant ($p < 0.05$) on the stem and branch wood productivity from east to west. However, south-north climatic gradient effect was significant only on total wood productivity as well as branch wood productivity. The combined effect of the two side climatic gradients revealed that the wood productivity in cashew-based agroforestry systems is not related to associated rainfall, but plantations' age. It could be deduced that the age of the cashew trees is key factor that determines their wood productivity.

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Introduction

Agroforestry systems occupy a special place when placed in the context of agricultural integration (Griffin, 2006). They provide farming systems with many advantages including carbon sequestration (De Baets, 2007). Indeed, in an agroforestry system, the planted or preserved trees produce litter that releases after decomposition into the soil, biogenic elements as natural fertilizer suitable for cropping. In Benin, two traditional agroforestry systems were identified (Sokpon, 1994): the palm oil-based agroforestry system practiced in the southern departments of the country, and the shea tree and locust been tree – based agroforestry systems widespread in the North (Agbahungba and Depommier, 1989). Three main reasons undertake the introduction of trees in farming system: its role in the nutrient pump (Ludwig *et al*., 2004); its ability to release significant amount of organic matter from the canopy (Oelbermann *et al.,* 2005) and its best cover (Young, 1989). Cashew is a good example in the agricultural space. In Benin, the integration of cashew in farming systems started in the 1950s in the context of diversification of crops (Tandjiekpon *et al.,* 2008). Many research fields were investigated regarding cashew trees including: selection of seeds and clones for the production of improved planting material (Tandjiekpon *et al.,* 2003), developing planting techniques, inventory of the pathogenic entomofauna associated with the species (Jayaweera, 1981). As far as economic field is concerned, the analysis of the competitiveness of cashew production (Adégbola *et al.,* 2005) and the marketing system of cashew nuts (Singbo *et al*, 2004) were assessed. Akohou (2011) and Balogoun (2011) also focused their research on the inventory of cashew trees' pathogenic entomofauna in various regions of Benin. In a context where environmental changes exceptionally affect forest ecosystems (Ciais *et al.,* 2005), and where the finding of species decline, at least temporarily, is a reality (Elling *et al.,* 2009), forest productivity should be considered as a dynamic quantitative data (Bontemps *et al.,* 2005) which should be explicit dependency relationships to the environment. The current study aims to assess the influence of climate gradient and age on the wood productivity of cashew parks.

Materials and methods

Study area

The current study was carried out in the three agroecological zones suitable for cashew production in Benin (Tandjiekpon *et al.,* 2003). This study area ranges from Gogounou level (PADSE, 2003) covering the northern and central administrative departments which are: Collines department in the Central zone, Borgou department in the North East zone, and Atacora and Donga departments in the North West zone (Fig. 1).

Climatic conditions varied from one zone to another. The central zone is characterized by a Sudano-Guinean climate type with two rainy seasons covering the periods from April to July and October to November (Tandjiekpon *et al.,* 2003). The highest average annual rainfall recorded at Savè meteorological station during the period 1937 to 2000 is 1105, 2 mm. The Northern East is characterized by a Sudanian climate type with one rainy season from April to October, alternating with a dry season. The sunniest period is between December and April, with slight variations from one month to another. Annual rainfall varies from 900 to 1200 mm (INRAB, 1995). The soils of the study area are mostly tropical ferruginous soils with highly variable agronomic characteristics. Several rivers and streams feed the hydrographic network. Three types of vegetation are found: natural vegetation, anthropogenic vegetation and plantations which provide small mammals and birds with suitable habitat. The main activity in the whole study area is agriculture. It occupies more than 96% of rural households in the Northern East, and is the primary source of income for 86% of the population in the central zones and more than 50% in the Northern West. Ranching is the second economic activity after agriculture. The ranching is still not developed despite the importance of livestock and remained not fully integrated to the farming system.

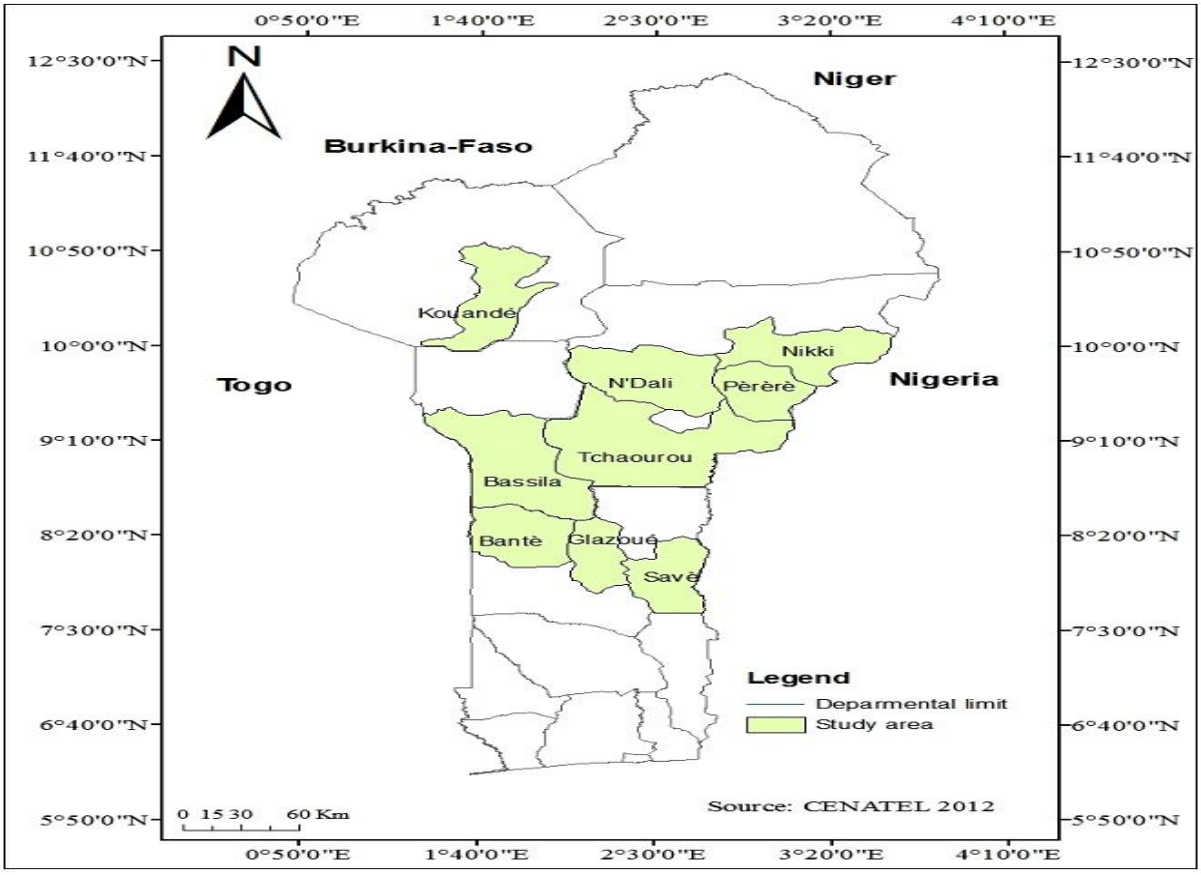

Fig. 1. Localization of study area.

The Fulani ethnic groups have to travel very far away every year, especially in the dry season, to search for pasture and water points for their cattle. This transhumance through internal border is the basis of many conflicts between herders and sedentary farmers.

Data collection and analysis

Cashew production data were collected from three agroecological zones: Center, Northeast and Northwest. In each zone, three districts were chosen on the basis of their cashew production rate. Three classes of plantations were defined which are young plantations (8-12 years), medium age plantations (12-16 years) and old plantations (16-20 years). A sample of ten trees per age class was selected making a total of 270 trees. From each tree, growth parameters such as total height, bole height, diameter at breast height, and crown diameter, were measured. We use the direct method for assessing biomass wood and Smalian formula was used to determine the volume of wood. Wood productivity was then deduced by multiplying the volume by the density wood of cashew. The total productivity in wood, branch and stem was assessed by tree.

The total biomass of wood, branches and stems of cashew plantations were assessed with the following variables such are:-Stem height (H) of 1.30m to thecutting7cm; -The circumference at breast height of the rodan the base of the branch; -The height (H) of the arm, from the base tothe7 cm. Several options can allow helping to evaluate the volume of wood from the tree such as: formula of Smalian, Newton and Simpson. Considering the tree as a series of ridges but the accuracy of each of them depends as much dendrometric calculation method used measures (Handbook of Forestry, 1989). Direct assessment of biomass wood method is the one we used and Smalian formula was used to determine the volume of wood. Wood biomass (B) was then deduced. Smalian

Formula was used because all parameters of this formula can be deduced easily.

$V = \frac{\pi}{4} * \frac{H*(C_1+C_2)^2}{4}$; $B = (V * d)$;

C1 =circumference at the base, C2 =Circumference at7cmcut, V = Volume (m^3), H = height ofstemor branch from the base tothecutting7cm and d=the volume density of the cashew tree (Kg /m3).

Data were encoded using the Excel software. Thereafter, each tree is considered as an observation, analysis of variance (ANOVA Subject-effect) test has allowed us to know the significance of the effect of the gradient, the age of the plantations on the total productivity branches and stems of cashew plantation sand to examine the differences between the parksin terms of biomass wood.

The values of F (FISHER) and P (probability that the assumption of homogeneity of effects is accepted or not), it was concluded that there wasa highly significant difference or not the threshold of probability 5% or 1 %. Outside analysis of variance was performed on multiple comparison test average follow-uptest of Newman-Keulsparks cashew following the study area and the plantation age category. This allowed us to see from south to north and east to west in the middle of study, the difference in overall productivity in wood, stems and branches is significant or not. The experimental design is showed following (Fig. 2).

Results

Influence of age and west-east climatic gradient on wood productivity of cashew plantations

Age and east-west climatic gradient were significantly affected the branches and stems wood productivity of cashew plantations (P <0.05).

Table 1. Results of the analysis of variance for the total wood productivity branch and stem according to the climate East-west and the age of the plantations.

Factors		Wood productivity of cashew trees		
	dl	Total productivity	Branch productivity	Stem productivity
Source		F	F	F
East-West gradient	2	0.09ns	3.48*	5.26**
Age	2	63.01***	33.02***	33.85***
East-West gradient*Age	4	2.23ns	0.65ns	3.71**

* *Significant difference at the 5% level*, ** *significant difference at1% level*; *** *significant difference at 0.01%*, ns =*not significant. F is the statistical value of Fischer*; df *is the degree of freedom.*

The total productivity which is the sum of the branch and stem productivity, did not differ significantly (P> 0.05) according to the climatic gradient, but varies significantly (P <0.001) depending on age. The interaction of two factors, namely east-west gradient climate and the age of the plantations, has a significant effect on rod productivity (P <0.01).

Table 2. Results of the analysis of variance for the total wood productivity branch and stem according to the climate North and South and the age of the plantations.

Factors		Wood productivity of cashew trees		
	dl	Total productivity	Branch productivity	Stem productivity
Source		F	F	F
North-south gradient	2	4.67**	4.71**	0.32ns
Age	2	74.86***	38.04***	35.61***
North-South gradient*Age	4	4.38**	1.83ns	2.82*

*:*Significant difference at the 5% level*, **: *significant difference at1% level*; ***: *significant difference at0.01%*, ns =*not significant. F is the statistical value of Fischer*; df *is the degree of freedom.*

This implies that the effect of the east-west climatic gradient on the productivity rod depends on the age of the plantation and vice versa (Table 1).

A description of effects of the different interactions was presented in Fig. 3 and 4. These figures reveal that the wood productivity of cashew branches was lower to the Center compared to the mean values that we have obtained in east or in west. But there was an opposite effect at the stems productivity that is higher at the Center. The east-west rainfall gradient between these plantations does not seem to be determining factor wood productivity.

Table 3. Results of the analysis of variance for total wood productivity branch and stem following the climate gradient and the age of the plantations.

Factors		Wood productivity of cashew trees		
	dl	Total productivity	Branch productivity	Stem productivity
Source	2	ons	ons	ons
North-south gradient	2	146.56***	74.752***	73.25***
Age	4	ons	ons	ons
North-south gradient*Age	2	ons	ons	ons

*: Significant difference at the 5% level, **: significant difference at1% level; ***: significant difference at0.01%, ns =not significant. F is the statistical value of Fischer; Df is the degree of freedom.

Influence of age and North-South climatic gradient on wood productivity of cashew plantations

Table 2 presents ANOVA results for the effects of age and the north-south climatic gradient on cashew plantations wood productivity.

This table shows that the total productivity of wood and branches varies significantly (P <0.01) according to the gradient North-South climate and the age of the plantation. Rod productivity, doesn't differ (P>0.05) according to the climatic gradient North-South, but varies significantly (P<0.001) with age. Only the effect of the interaction of the climatic gradient north-south and age on wood productivity of branch was not statistically significant (P>0.05).

Rainfaill gradient	West → East								
South	Town	BANTE			GLAZOUE			SAVE		
	Locality	Sounon 1	Sounon 2	Sounon 3	Egbessi 1	Egbessi 2	Egbessi 3	Alafia 1	Alafia 2	Alafia 3
	TP + ND	JP(10)	PM(10)	VP(10)	JP(10)	PM(10)	VP(10)	JP(10)	PM(10)	VP(10)
	Town	BASSILA			TCHAOUROU			PERERE		
	Locality	Bodi 1	Bodi 2	Bodi 3	Guinirou 1	Guinirou 2	Guinirou 3	Sonon 1	Sonon 2	Sonon 3
	TP + ND	JP(10)	PM(10)	VP(10)	JP(10)	PM(10)	VP(10)	JP(10)	PM(10)	VP(10)
	Town	KOUANDE			N'DALI			NIKKI		
	Locality	Forêt 1	Forêt 2	Forêt 3	Binassi 1	Binassi 2	Binassi 3	Worê 1	Worê 2	Worê 3
North	TP + ND	JP(10)	PM(10)	VP(10)	JP(10)	PM(10)	VP(10)	JP(10)	PM(10)	VP(10)

Fig. 2. Experimental design.

This showed that the influence of the North-South climatic gradient on total productivity and stem depends on the age of the plantation and vice versa (Table 2).

The Fig. 5 and 6 showed the mean values of branch and total productivity along the North-South climatic gradient of cashew plantations. This figures analysis revealed that the branch and the total productivity of

cashew plantations is higher in the South where the rainfall in high compared to the Central and North that enjoying lower rainfall.

This implies that the North-South climatic gradient appeared to influence the overall productivity of wood and branches of the cashew plantations. Productivity of cashew trees (total branch and stem) was positively correlated with the age of the plantation.

Influence of the combined effect of climatic gradients and age on wood productivity of cashew plantations

Table 3 presented the results of analysis of variance of the combined effect of the two climatic gradients and age on total wood productivity, branch wood productivity and stem wood productivity of the cashew plantations.

The combined effect of the two climatic gradients was no significant influence on the calculated productivity (total, stem and branch), but these productivities vary very significantly with plantation age ($P < 0.001$). Moreover, the interaction of the combined effect of climatic gradients and age wasn't significantly affected the total productivity or the productivity of the branch, as well as productivity rod. Overall, this indicates that the wood productivity of cashew plantations wasn't determined by the rainfall but depends to another factor including the age of the plantation.

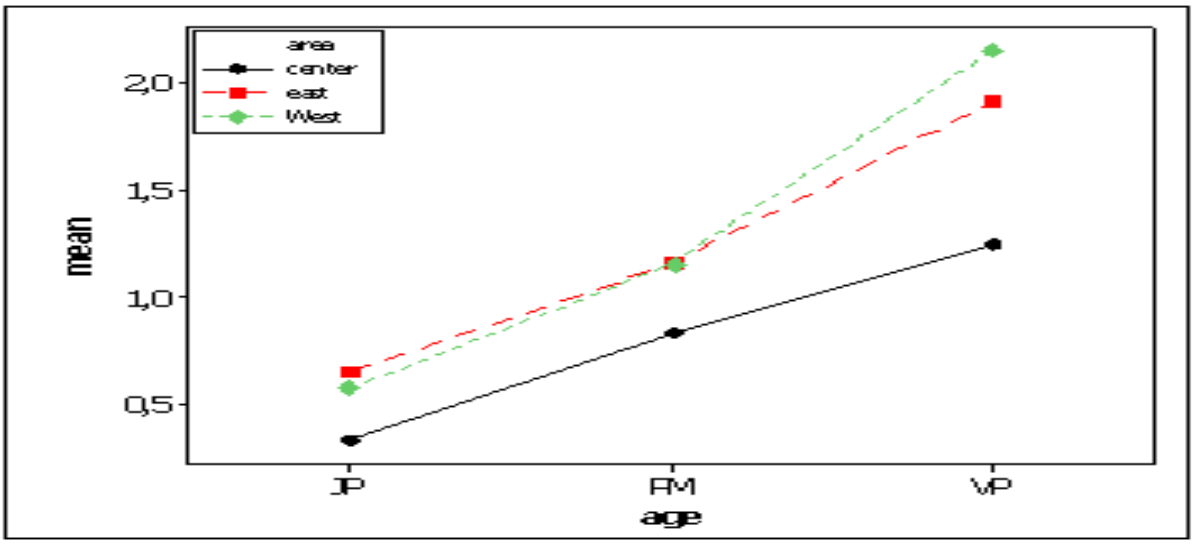

Fig. 3. Interaction Plot for branch wood productivity.

Discussion

Approach of wood productivity estimation of agroforestry systems

The wood productivity estimation of agroforestry systems based on cashew was carried out by a synchronic approach. More subtly, it means that the distribution in time at a place is equal to the spatial distribution at a given time, which allows reconstructing population dynamics and helps to evaluate the productivity, by inventorying at a given moment stands in vary states of their development. Many studies going in the same direction have used a methodology based on the synchronic approach in estimating of productivity of stands. In Mali, Coulibaly (1998), Sylla and Nouvellet (2001) used similar approaches in estimating productivity wood of forest stands. Our approach estimate of cashew wood productivity is similar with those of Glèlè Kakai (2000) and Yabi *et al.* (2013) in their study conducted on the establishment of a table of scaling respectively *Acacia auriculiformis* and *Anacardium occidentale* in Benin. Otherwise, for several authors in West and Central Africa, is the diachronic approach that looks better in the assessment of biomass wood trees of Burkina Faso (Bognounou *et al.,* 2008), Laf at northern of Cameroon (Ntoupka, 1999) Missira in

Mali (Dembele, 1996). This approach involves monitoring individual trees, requires a precise measurement protocol, possibly with rods instrumentation but proved virtually impossible in the savannas of West Africa (Poupon, 1979; Diarisso *et al.,* 2005). The diachronic approach requires repetitive measurements of the trees for a long time and can provide answers to questions such as the influence of fire, grazing and cutting on the production of stands, but is not necessarily optimal. This approach, although used for certain species of savanna West Africa (Poupon, 1979; Ichaou, 2000), today still arouses much controversy, the periodicity of the rings is not yet clear (Mariaux, 1967; Moss, 1997; Stahle *et al.,* 1999).

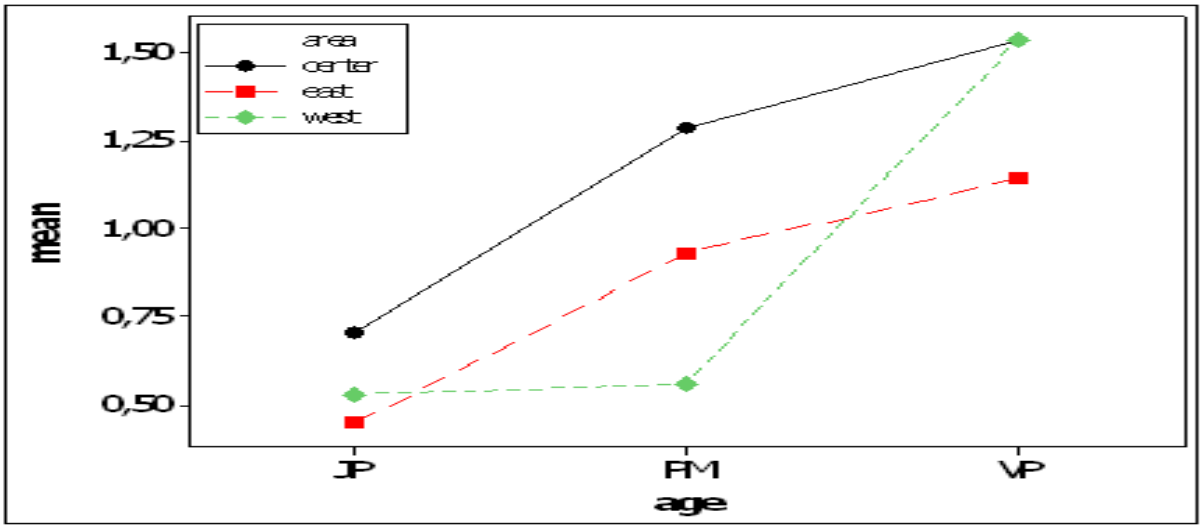

Fig. 4. Interaction Plot for stem wood productivity.

Effect of climatic gradient and age on wood productivity

The assessment of the Influence of climatic gradient and age on wood productivity in cashew based agroforestry system shows that the age of cashew plantation determines their wood productivity. The lowest productivity was observed in young plantations while the highest productivity was recorded in the old plantations.

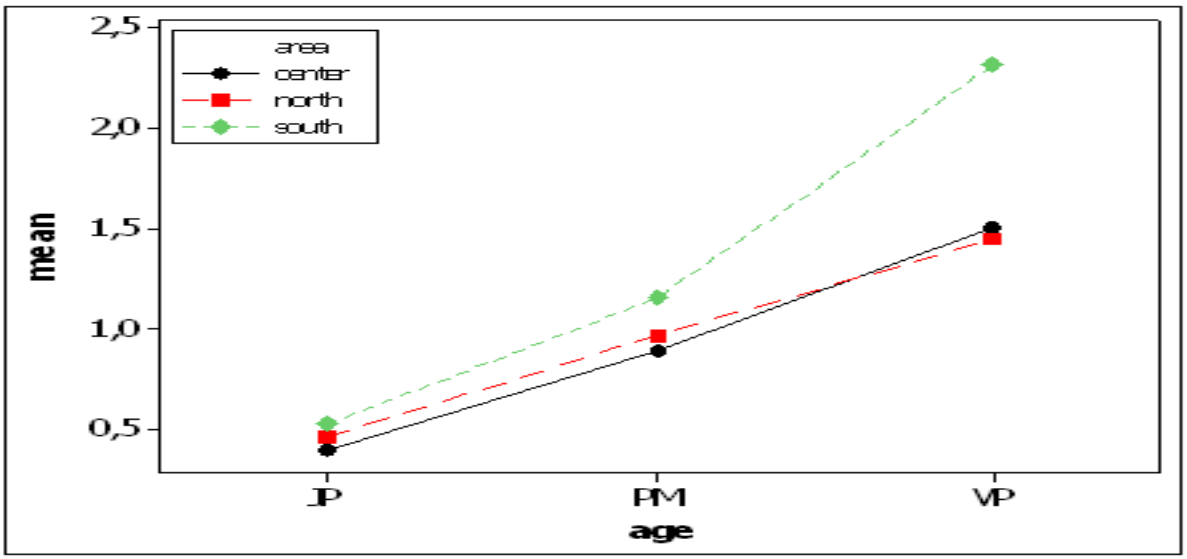

Fig. 5. Interaction Plot for branch wood productivity.

Our results are consistent with those of several authors regarding the influence of age on the trees wood productivity in general. Lemaire (2010) found that the total biomass produced by the tree increases with age. Our results also supported the work of Lieth and Whittaker (1975); Satoo (1982) who found that the standing biomass of trees increases with the age of the plant following an S curve. This result also corroborates the research of Castro *et al.* (2016) who pointed out that the age of the species is positively correlated with their wood productivity. Our work, we also share the views of Ohler (1985), in the Sahelian zone in Mali, finds that wood biomass increases with the fallow years. Kathleen *et al.* (2004) working on the difference in productivity between communities of plant species along a rainfall gradient in north of Oregon in United States arrived at similar results to ours: the highest total biomass wood is produced in wet meadows (4311 ± 289 g/m2), intermediate biomass (2236 ± 221 g/m2) was observed in communities wet meadows dominated by grasses and sedges and biomass the lowest (1403 ± 113 g/m2) was obtained in dry grasslands. Our results corroborate observations of Akouegninou (1984) cited by Sokpon, (1995) who showed that in Benin, the existence of a south-north rainfall gradient determines the distribution of forest formations.

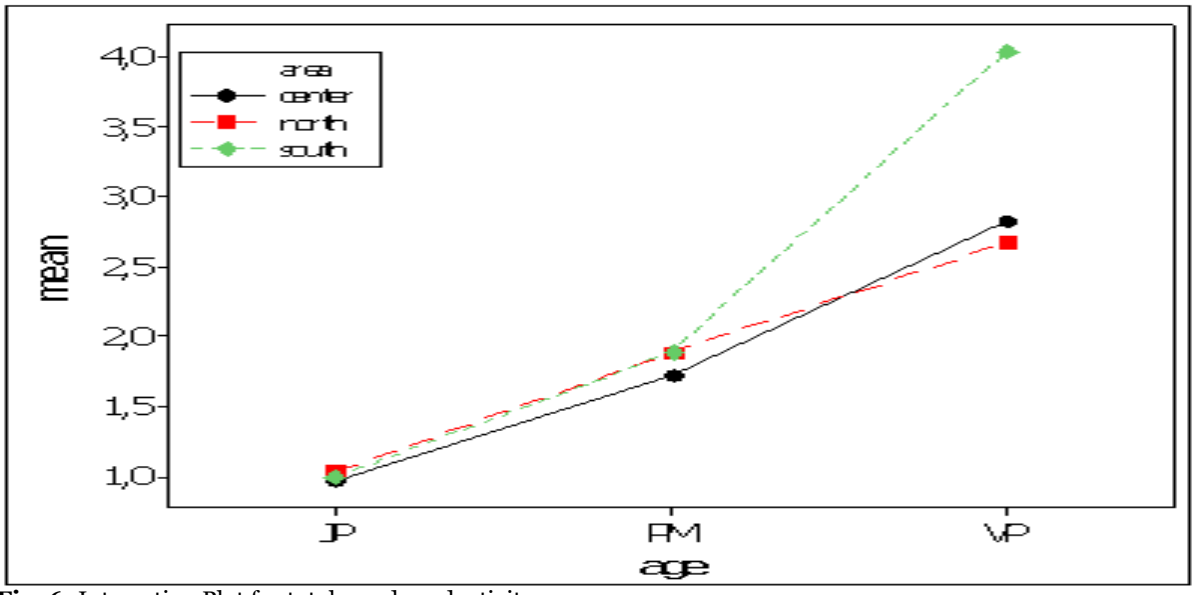

Fig. 6. Interaction Plot for total wood productivity.

The results that we find following rainfall gradient North-South, differ from those obtained following the East-West gradient where the productivity of branches or stems in the East and the West doesn't present a significant difference despite the rainfall disparity between the two areas. These results show that the influence of the gradient on the wood productivity of the cashew plantation from East to West and from South to North has a tendency rat erratic and does not reveal a clear trend. This led us to examine the combined effect of the two gradient son wood productivity in cashew plantation. The results showed that rainfall gradient in significantly influences wood productivity whatever the considered plantation age. These observations indicated that the wood productivity of agroforestry systems based on cashew depends a lot of to other ecological factors distinct of rainfall gradient. These results have although been found by several authors. Yan *et al.* (2015) indicated by theirs works that biomass increases with annual rain fall, but this relationship depends largely to other factors, particularly, to the site soil condition, to the silvicultural treatments, to the soil fertility, to the degree of plantation parasitism and factors related to degree of precision in data collection.

Conclusion

The Knowledge of factors that determining wood productivity of cashew parks in Benin is important to optimize the benefit of the coexistence of trees and annual crops in agroforestry systems. The results of this study on the determinants of timber productivity based on agroforestry systems cashew clearly showed that the age factor best expresses the productive potential of cashew wood.

Indeed, it appeared in this study that the cashew trees geographically located in the North East are those that give a best performance of total wood productivity, stems and branches. That study has shown that the wood productivity of cashew plantation is positively correlated with their age. But the analysis based on the combined effects of climatic gradient south-north and west-east has revealed insignificant influences on the productivity of cashew wood. We recommend further studies on this topic.

References

Adégbola PY, Oloukoï L, Sossou HC. 2005. Analyse de la compétitivité de la filière anacarde au Bénin. Rapport technique final, Institut National des Recherches Agricoles du Bénin, Bénin.

Agbahungba G, Depommier D. 1989. Aspects du parc à Karités-nérés (*Vitellariaparadoxa*, Geartn f. *Parkiabiglobosa*jacq. Benth) dans le sud du Borgou (Bénin). Revue Bois et Forêts des tropiques **222**, 4è trimestre.

Akouegninou A. 1984. Contribution à l'étude botanique des îlots de forêts denses humides semi-décidues en République Populaire du Bénin. Thèse Doctorat 3ème cycle écologie tropicale. Université de Bordeaux III.

Bognounou F, Savadogo M, Boussim J, Guinko S. 2008. Equations D-Estimation de la biomasse foliaire de cinq espèces ligneuses soudaniennes du Burkina Faso. Sécheresse **19 (3),** 201-205.

Bontemps JD, Vallet P, Hervé JC, Rittié D, Dupouey JL, Dhôte JF. 2005. Des hêtraies qui poussent de plus en plus vite: vers une forte diminution de leur âge d'exploitabilité? Revue Forestière Française **57,** 123-142.

Castro AFNM, Castro RVO, Carneiro ACO, Santos RC, Carvalho AMML, Trugilho PF, Melo ICNA. 2016. Correlations between age, wood quality and charcoal quality of eucalyptus clones. Revista Árvore **40 (3),** 551-560.

Ciais P, Reichstein M, Viovy N, Granier A, Ogee J, Allard V, Aubinet M, Buchmann N, Bernhofer C, Carrara A, Chevallier F, De Noblet N, Friend AD, Friedlingstein P, Grunwald T, Heinesch B, Keronen P, Knohl A, Krinner G, Loustau D, Manca G, Matteucci G, Miglietta F, Ourcival JM, Papale D, Pilegaard K, Rambal S, Seufert G, Soussana JF, Sanz MJ, Schulze ED, Vesala T, Valentini R. 2005. Europe-wide reduction in primary productivity caused by the heat and drought in 2003, Nature **437,** 529-533.

Coulibaly SM. 1998. Détermination de la productivité des jachèresdans la zone de Ouéllessébougou. Mémoire de find 'études, Université du Mali, Katibougou, p. 66.

Dembele F. 1996. Influence du feu et du pâturage sur la végétation et la biodiversité dans les jachères en zone soudanienne-nord. Cas des jeunes jachères du terroir de Missira (cercle de Kolokani), Mali. Thèse de doctorat, Université d'AixMarseille 3, France.

Diarisso D, Yossi H, Sylla ML, Ballo M, Karembe M, Picard N, Birnbaum P, Ouattara S. 2005. Rapport d'état d'avancement du projet RFO6 : mise au point d'une méthode fiable d'estimation de la productivité des formations arborées et arbustives au Mali. Rapport technique. Bamako, Mali, Institut d'économie rurale.

Elling W, Dittmar C, Pfaffelmoser K, Rötzer T. 2009. Dendroecological assessment of the complex causes of decline and recovery of the growth of silver fir (Abiesalba Mill.) in Southern Germany. Forest Ecology and Managemen**257,** 1175-1187.

GlèlèKakaï R. 2000. Etablissements-pune table de cubage de *Acacia auriculiformis* au Sud-Bénin, Mémoired' Ingénieur Agronome, FSA/UAC, Abomey-Calavi.

Griffin RM. 2006.Echinochloapolystachya management in Louisiana rice. In PhD dissertation, Dpt Agron. Env. Management, Louisiana State Univ.

HandbookofForestry.1989. Forestry Commission Handbook: Urban forestry practice.

Ichaou A. 1995. Étude de la productivité des formations forestières de broussetigrée et de broussediffuse :conséquences pour la gestion et la régénération de ces formations. Mémoire de fin de cycle ingénieur, Institut polytechnique rural de Katibougou, Mali,

INRAB. 1995. Fiches techniques sur les sols et les essences forestières. INRAB Cotonou, Bénin.

Jayaweera DMA. 1981. Medicinal Plants (indigenous and exotic) used in Ceylon. Part I. Colombo, Sri Lanka: The National Science Council of Sri Lanka, 64-65.

Lieith H. Whittaker R. 1975. Modeling the primary productivity of the biosphere.237-264 p.

Lemaire S. 2010. Système dynamique de la croissanceet du développement de Labette ravesucrière (Beta vulgaris L.). Thèse : Paris Tech.

Ludwig F, De Kroon H, Berendse F, Prins HHT. 2004. The influence of savanna trees on nutrient, water and light availability and the understorey vegetation. Plant Ecology **170**, 93–105.

Mariaux A. 1967. Les cernesdans les bois tropicaux africains, nature etpériodicité. Bois etForêts des Tropiques**113,** 3-14.

Martin D, Moss J. 1997. Age determination of Acacia tortilis (Forsk.) Hayne from northern Kenya. African Journal of Ecology **35(3),** 266-277.

Ntoupka M. 1999. Impact des perturbations anthropiques (pâturage, feu, et coupe de bois) sur la dynamique de la savanearborée en zone soudano-sahélienne du nord du Cameroun, thèse de Doctorat de l'université, Paul Valery- Montpellier III.

Ohler FMJ. 1985. The fuel wood production of wooded savanna fallows in the Sudan zone of Mali. Agroforestry Systems**3,** 15-23.

Oelberman M, Voroney RP, Gordon AM. 2005. Carbon sequestration in tropical and temperate agroforestry systems : a review with examples from Costa Rica and southern Canada. Agriculture, Ecosystems and Environment, **104(3),** 359-377.

PADSE. 2003. Diagnostic global de la filière anacarde au Bénin. MAEP/PADSE, 60.

Poupon H. 1979. Structure etdynamique de la strateligneused'une steppe sahélienne au nord du Sénégal. Thèse de doctorat, université d'Orsay-Paris 11, France.

Satoo T. 1982. Forest Biomass. Dr. W. Junk Publisher, the Hagues.

Singbo A, Savi A, Sodjinou E. 2004. Etude du système de commercialisation des noixd' anacardedans le département des Collines au Bénin. Rapport technique final.

Sokpon N. 1994.Tenure foncière propriété des ligneuxdans les systèmes agroforestiers traditionnels au Bénin. Annales Faculté des Sciences Kisangani, Numéro special 115 - 122.

Sokpon N. 1995. Recherche écologiquesur la forêt semi décidue de Pobé au Sud du Bénin Groupements végétaux, structure régénération naturelle et chute de litière. Thèse de Doctorat en Science Agronomiques, Section Interfacultaire d'Agronomie.

Stahle DW, Mushove PT, Cleaveland MK, Roig F, Haynes GA. 1999.Management implications of annual growth rings in Pterocarpus angolensis from Zimbabwe. Forest Ecology and Management, **124(2-3),** 217-229.

Sylla ML, Nouvellet Y. 2001. Détermination rapide de la productivité des formations savanicoles. Revue Malienne de Science etde Technologie, 5 (septembre) 66-77.

Tandjiékpon A, Lagbadohossou A, Hinvi J, Afonnon E. 2003. La culture de l'anacardier au Bénin :Référentiel Technique. Edition Institut National des Recherches Agricoles du Bénin.

Tandjiekpon AM. 2005. Caractérisation du système agro forestier à base d'anacardier (*Anacardium occidentale Linnaeus*) en zone de savane au Bénin. Mémoire.

Tandjiekpon AM. 2007. Appui au suivi des semenciers d'anacardier sélection nésdansl' Atacoraet la Donga pour la production de semencesa méliorées: Rapport Technique. Programme de Conservation et de Gestion des Ressources Naturelles, Mai 2007.

Whittaker RH, Woodwell GM. 1968. Dimension and production relations of trees and shrubs in Brookhaven Forest, New York Journal of Ecology **56**, 1-25.

Yabi I, Biaou FY, Dadegnon S. 2013. Diversité des espèces végétales au sein des agro-forêts à base d'anacardierdans la commune de Savalou au Benin. International Journal of biological and Chemical Sciences **7(2),** 696- 706.

Yan H, Liang C, Li Z, Liu Z, Miao B, He C, Sheng L. 2015. Impact of Precipitation Patterns on Biomass and Species Richness of Annuals in a Dry Steppe. PLoS ONE, **10(4),** https://doi.org/10.1371/journal.pone.0125300

Young A. 1989. Agroforestry for Soil Management, University of East Anglia, UK, formerly of the International Centre for Research in Agroforestry (ICRAF), Nairobi, Kenya.

Zaubin R, Suryadi R. 2002. Effect of topping, number of leaves and time of grafting on the success of cashew grafting at field conditions. Jurnal Penelitian Tanaman Industri. Résumé disponiblesur le site visité en Décembre 2017. http://agris.fao.org/