Rev. Ivoir. Sci. Technol., 37 (2021) 155 - 167
ISSN 1813-3290, http://www.revist.ci

INFLUENCE OF *ANACARDIUM OCCIDENTALE* L. CANOPY LENGTH ON SOIL FERTILITY AND *ARACHIS HYPOGAEA* L. YIELD IN TOUBACOUTA, SENEGAL

Elhadji FAYE [1], Mamadou BOIRO [1], Cheikh Oumar SAMB [2,4*], Bothié KOITA [3], Moussa DIENG [2] et Samba Arona Ndiaye SAMBA [4]

[1] Alioune DIOP University, Higher Institute of Agricultural and Rural Training, Bambey, Senegal (ADU-HIART), PO 54, Bambey, Senegal
[2] Senegalese Institut of Agricultural Research, National Center of Forestry Research (SIAR-NCFR), PO 2312, Dakar, Senegal
[3] Agricultural Research Center (ARC), PO 3120, Djibelor, Ziguinchor, Senegal
[4] Iba Der THIAM University, National Higher School of Agriculture (IDTU-NHSA), PO A296, Thies, Senegal

(reçu le 09 Avril 2021 ; accepté le 12 Juin 2021)

* Correspondance, e-mail : *omarsamb2004@yahoo.fr*

ABSTRACT

In Senegal, the agricultural production system is dominated by rainfed crops and tree-crop association is an alternative for sustainable production. The introduction of a high value- species into the agricultural space should be one of the solutions to ensure diversified and sustainable agricultural production. The cashew tree, which occupies an important place in the Senegalese agricultural sector, could also be one of the species with high agroforestry potential, but little is known about this potential. In this study we are investigating the influence of cashew tree (*Anacardium occidentale* L.) canopy length on soil fertility and peanut (*Arachis hypogaea* L.) yield in the Toubacouta zone in Senegal. For this purpose, 6 m, 9 m and 12 m canopy length cashew trees were selected, and then peanut seeds were sown in concentric rows following the tree canopy with 40 cm spacing between rows and between patches and an uncovered control. An univariate analysis was performed with STATISTIX 8.1. The results show a significant effect of canopy length on soil parameters and peanut yield. The best yield performance was found in cashew trees with a canopy length of 6 m (676.51 kg^{-1}). These results show that the cashew-peanut association is only possible at a younger age with 100 trees ha^{-1} plantation density. Beyond this threshold, silvicultural interventions would be necessary to optimize peanut production.

Keywords : *Senegal, Anacardium occidentale L., Arachis hypogaea L., peanut, canopy, agroforestry.*

RÉSUMÉ

Influence de la largeur du houppier de l'anacardier (*Anacardium occidentale* L.) sur la fertilité des sols et le rendement de l'arachide (*Arachis hypogaea* L.) Toubacouta, Sénégal

Au Sénégal, le système de production agricole est dominé par les cultures pluviales et l'association arbre-culture est une alternative pour une production durable. L'introduction d'espèces à grande valeur ajoutée dans l'espace agricole devrait être l'une des solutions pour assurer une production agricole diversifiée et durable. L'anacardier, qui occupe une place importante dans le secteur agricole sénégalais pourrait faire partie des espèces à fort potentiel agroforestier mais très peu évalué. L'objectif de ce travail est d'étudier l'influence de la largeur du houppier de l'anacardier (*Anacardium occidentale* L.) sur la fertilité des sols et le rendement de l'arachide (*Arachis hypogaea* L.), Toubacouta, Sénégal. Pour ce faire, des anacardiers de 6 m, 9 m et 12 m de houppier ont été sélectionnés, puis les graines d'arachide ont été semées suivant des lignes concentriques épousant la couronne de l'arbre avec des écartements de 40 cm entre les lignes et entre les poquets et un témoin hors couvert. Une analyse univariée a été effectuée avec STATISTIX 8.1. Les résultats montrent un effet significatif de la largeur de la couronne sur les paramètres du sol et du rendement de l'arachide. Les meilleures performances de rendement ont été relevées chez les anacardiers ayant une largeur de 6 m de houppier (676,51 kg^{-1}). Ces résultats attestent que l'association anacardier et arachide n'est possible qu'au jeune âge pour une plantation de 100 arbres ha^{-1}. Au-delà de ce seuil, des interventions sylvicoles seraient nécessaires pour optimiser la production de l'arachide.

Mots-clés : *Sénégal, Anacardium occidentale L., Arachis hypogaea L., arachide, canopy, agroforesterie.*

I - INTRODUCTION

For several decades, Sahelian countries were facing continuous environment deterioration resulting in increasingly acute food deficit zones [1]. The continuous decline in agricultural production observed in recent years in Africa, particularly in West Africa, results from a combination of several factors including population growth, repeated droughts and poor natural resources management [1]. Senegal, a Sahelian country covers an area of 196,712 km^2 and has 13,508, 715 inhabitants where 2/3 belong to arid and semi-arid zones [2 ANSD, 2014]. Its economy is mainly based on agriculture [3, 4]. About 60 % of rural population live in the Groundnut Basin which occupies 1/3 of the total area and produces 75 % of peanut (*Arachis hypogaea*) and 80 % of millet (+) and sorghum (*Sorghum vulgare*) [5, 6]. In this area, crops have been associated with trees, for generations, in a parkland system defines as planted or naturally originated trees dominated by woody plants, of even-aged tendency and integrated into agricultural fields, with a relatively low density of trees per hectare [7]. In Senegal, parklands seem to result from a continuous selection, carried out by rural populations on original natural vegetation, of one or more species whose functions are known and appreciated by users [6]. Today, the projection by 2025 gives a total population of Senegal of 19,347,750 inhabitants [8]. This demographic growth implies an increase in food needs, especially in cereals and cash crops, which are both the basis of food and a source of income for the populations. Agricultural production system in Senegal is dominated by rainfall crops. The agriculture sector contributes to 16.7 % of the Gross Domestic Product (GDP) [8] where peanut crop contributes to 20 % of the total [9]. Among all the crops, peanut, occupies a prominent place in the development of the agricultural sector; it contributed 60 % to agricultural GDP at Independence [10, 11]. A cash crop grown by 70 % of the population provides 35 % of agricultural income in rural areas [12, 13]. Yet, "land" which is the major production factor has become scarce, leading to space management problem and soil fertility issue. Agriculture in the twentieth century has sterilized one (01) billion ha of cultivable land, or almost 25 % of the land on our planet [14].

It also officially recognizes the sterilization of at least 225,000 ha of land each year with fertilizers (NPK), pesticides (fungicides, insecticides) and poorly managed organic waste. To tackle this problem, agroforestry is considered as a viable alternative for raising the level of soil fertility and improving crop yields to reduce food deficit which, in turn, enable the communities to be met their needs. According to International Center for Research in Agroforestry (ICRAF), agroforestry refers to all land use systems in which perennial woody plants are deliberately associated with crops or animal production in the form of a spatial or spatial arrangement [15 - 17]. In Africa, cashew tree is found in most countries from Senegal to Congo Kinshasa [18]. Cashew tree boomed from 1995 onwards, particularly in Groundnut Basin (Fatick) and Casamance (Kolda, Sédhiou, Ziguinchor). Cashew plantations have experienced an evolutionary dynamic and mark the agrarian landscape of Senegal [19]. According to these authors, this increase is due to the promotion of cashew cultivation by the State of Senegal through projects, programs and financial spinoffs from the sale of the nut. However, species such as *Acacia nilotica*, *Adansonia digitata*, *Balanites aegyptiaca*, *Zizyphus mauritiana* and even *Guiera senegalensis* have potential to improve yield when they are combined with crops [6]. Our interest was focused on *Anacardium occidentale* L. because of its higher value but also the remaining available information for its impact on crops. However, to improve rural populations' incomes and increase agricultural production in a sustainable way, it is important to promote an agro-forestry system capable of meeting these objectives. Consequently, the impact of species on peanut culture (*Arachis hypogaea*) and soils should be known to better guarantee land use system productivity with application of standard spacing or methods of appropriate management. The objective is to study the influence of *Anacardium occidentale* L. canopy length on soil fertility and *Arachis hypogaea* L. yield in Toubacouta / Senegal.

II - METHODOLOGY

II-1. Site presentation

The study was carried out at Keur Alioune Gueye in the commune of Toubacouta (13 ° 46'N and 16 ° 28'W), Foundiougne department, Fatick region. It covers an area of 170 km^2 and has 34,957 inhabitants spread over 51 villages. Population is mainly composed of Manding, Wolof, Serere and some Fulani and Bambara families. Area has a Sudano-Sahelian climate with a dry season from October to June and a rainy season from july to september. It is also influenced by maritime climate on coastal part of Foundiougne and Fatick departments. Average annual rainfall has fluctuated between 400 and 800 mm isohyets for the past decade [8]. Vegetation is fairly abundant and is composed of three strata: herbaceous, shrubby and parkland [20]. Main crops are based on cereals millet and maize. Sorghum and cotton are not grown. In addition to cereals, they cultivate cowpea, peanuts, watermelon and red sorrel. Market gardening is practiced mainly by women and young people in lowlands during dry season.

II-2. Experimental device

A 1.5 ha cashew plantation with variable canopy length has been identified and selected at Keur Aliou Gueye. Plantation was divided into three (03) blocks of 0.5 ha. In each block, three (03) trees of cashew of 6 m, 9 m and 12 m canopy were selected and a control plot (excluding cashew tree canopy). For each category of canopy length, three trees were chosen, for a total of 9 trees. The control was also repeated 3 times. Trees are 10 m apart. This makes a total of 12 experimental units. After this inventory, samples of 100 g of soil were taken before and post-harvest at a depth of 0 - 40 cm. Samples were numbered, labeled and then transferred for analysis to the CNRA soil laboratory of Bambey. Physico-chemical analysis focused on following parameters: pH_water, electrical conductivity (CE), assimilable phosphorus (P / ASS), Total carbon (C / TOTAL), Total nitrogen (N / TOTAL), organic matter (MO), Carbon / nitrogen (C / N), Clays (%), oils (%), Sand (%), Texture. Peanut was sown under and without cover. 73-33 variety was used for its agromorphological qualities and the quality of its seeds. Peanut seeds were sown on 04 July 2017 at a rate of three per plot in concentric lines following the shape of tree canopy. Lines and pockets are equidistant from 40 cm too.

Photo 1 : *Cashew-peanut association*

Concerning the control plots, the same sowing technique was applied with the same densities. After each rain, soil moisture was assessed. The measurements were made at 2/3 of the radius from the trunk. A 0.1 liter pot was used and then pushed into ground. The soil in the pot was weighed using a CAMRY needle scale and then put in bags.

II-3. Phenological measurements of peanuts

Peanut weight growth is studied by random sampling of 5 feet by treatment at R/2 of canopy length. Height measurements were made using a double decimeter on 30th, 45th and 60th day after sowing. Fresh biomass was assessed using a Super Samson Salter scale. Yield has been evaluated in relation to the cultivated area and is expressed in Kilogram ($kg.ha^{-1}$) or in Ton ($t.ha^{-1}$). The total number of pods and full pods were counted. The average weight of full pod was measured using a CAMRY precision needle scale. Yield was calculated by multiplying its different components such as number of plants, number of pods and number of seeds per pod and brought to the hectare. The collected feet are dried and then weighed to estimate the biomass.

III - RESULTS

III-1. Effects of treatments on peanut growth and development

III-1-1. Growth

Figure 1 presents the evolution of the height of peanut depending on canopy length of cashew trees. We can observe that until the 60th day after emergence, peanut growth continues a rapid weight growth phase (linear phase). This weight growth is much faster under cashew tree cover, especially with 12 m crown followed by those of 9 m and 6 m. On the 60th day after emergence, the treatment with a canopy length of 12 m provides a height of 64.86 % greater than the control. However, there is no difference in the height of the 12 m and 9 m canopy length. The maximum growth (43 cm) of peanut is obtained on the two treatments (12 m and 9 m), on the 60th day after emergence. The height is 28.33 cm under cashew of 6 m canopy length and 15.11 cm for control.

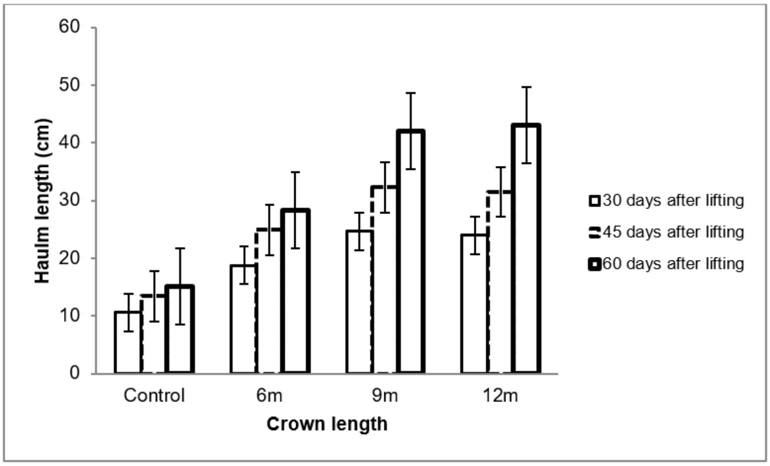

Figure 1 : *Evolution of groundnut plants height according to cashew tree canopy length*

III-1-2. Analysis of yield parameters

Analysis of variance shows a significant difference (P = 0.0003) in the canopy length on the total number of pods. The control recorded the largest number (27.1) followed respectively by cashew trees of 6 m canopy length (26.8); 9 m (15.5) and 12 m (7.6). The significance test shows that the number of full pods from the control is not different from that of cashew in 6 m canopy length. However, the number of pods varies depending on canopy length of cashew trees. The control recorded the highest values (13.6) followed by cashew trees of 6 m crown (11.6); 9 m (7.3) and those 12 m (1). The analysis of variance shows a highly significant effect of canopy length of cashew tree on the weight of full pods (P < 0.0001). Indeed, we see that the weight of pods of 6 m canopy cashew tree, have almost doubled compared to the control. However, there is a drastic drop in the weight of pods respectively with the 12 and 9 m canopy ***(Table 1)***. Analysis of variance shows a variation in yield depending on treatments. The best performance was found in cashew trees with a canopy length of 6 m (676.51 kg ha^{-1}), followed respectively by the control (399.58 kg ha^{-1}), 9 m and 12 m canopy length respectively 196.15 kg ha^{-1} and 3 kg ha^{-1}.

Table 1 : *Yield parameters according to cashew three canopy length*

Canopy length	Total number of pods	Number of full pods	Weight of a full pod	Yield (kg ha^{-1})
control	$27{,}1^{a}$	$13{,}6^{a}$	$2{,}28^{ab}$	$399{,}58^{b}$
6 m	$26{,}8^{a}$	$11{,}6^{a}$	$3{,}3^{a}$	$676{,}51^{a}$
9 m	$15{,}5^{ab}$	$7{,}3^{ab}$	$1{,}78^{b}$	$196{,}15^{c}$
12 m	$7{,}6^{b}$	$1{,}0^{b}$	$0{,}2^{c}$	3^{d}
F	6,42	8,79	10,19	10,19
P	0,0003	0,0001	0,0001	0,0001

III-1-3. Fresh biomass

Analysis of variance revealed a significant difference between the treatments on the fresh biomass production (P = 0.0064; F = 4.21). For fresh biomass, the control gave the best values (284.25 kg ha^{-1}). However, a decrease in fresh peanut biomass was observed according to the canopy length of cashew trees. The best results were obtained with a 6 m canopy length (223.95 kg ha^{-1}), followed by 9 m (203.25 kg ha^{-1}) and 12 m canopy length (176.25 kg ha^{-1}) ***(Figure 2)***.

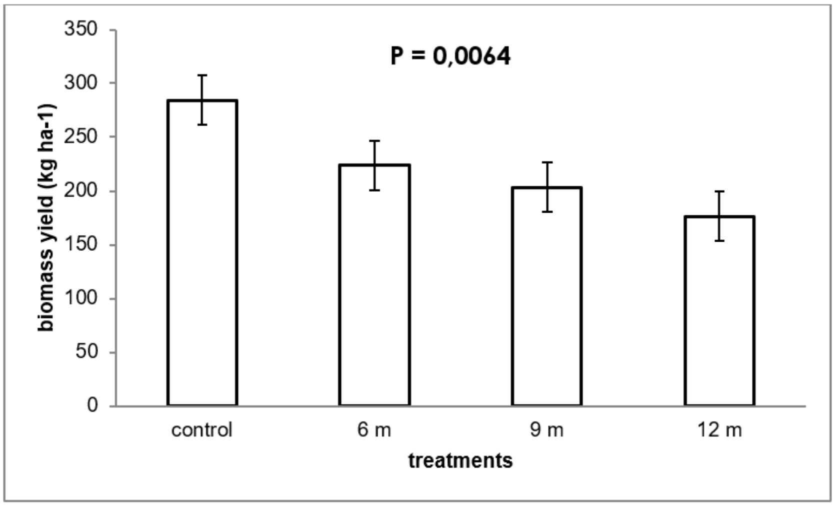

Figure 2 : *Variation in biomass yield according to canopy length of cashew tree*

III-2. Effects of treatments on physicochemical characteristics of soils

The rapid mineralization of organic matter is explained by the CEC low values. The acid character of soil lies in the leaching of the alkali (K, Na) and alkaline-earth cations (Ca^{2+}, Mg^{2+}) cations by the abundant drainage flow. It results in a low pH (< 7). This acidity is observed before sowing, especially on treatments (9 and 12 m cashew tree). This low fertility must be qualified using pH, organic matter, Ca^{2+}, Mg^{2+}, K / Mg, CEC meq / 100g and T %.

III-2-1. pH

Soils analysis of the control and under cashew with a 6 m canopy length shows a neutral pH (6.6 and 6.4 respectively). Under cashew trees of 9 m and 12 m canopy length, the pH is slightly acidic (5.8 and 5.4 respectively) before sowing. After the harvests, the pH is found to be neutral and varies according to the treatments (6.4 to 6.8) ***(Table 2)***.

III-2-2. Organic matter

Before sowing, the treatments are too poor in organic matter. However, a very high organic matter content was observed after harvesting for all treatments (2.08 to 3.7), except for cashew trees with a 6 m canopy length, which is poor (1.4) ***(Table 2)***.

III-2-3. Ca^{2+}, Mg^{2+}

Low values of Ca^{2+} and Mg^{2+} are acceptable but may reduce P assimilation. Mg^{2+} values are higher after harvest. Amounts of Ca^{2+} are variable ***(Table 2)***.

III-2-4. K / Mg

Analysis of the K / Mg ratio attests to the possibility of a low K deficiency in the soil in various treatments. The values of K and Na are almost similar before sowing and after harvesting following treatments ***(Table 2)***.

III-2-5. CEC meq / 100g

Analysis of the results shows a low soil CEC for treatments (control and 6 m crown length), medium (9 m canopy length) and high (12 m canopy length), before sowing. After harvesting, we note that the CEC values are low in all treatments ***(Table 2)***.

III-2-6. T%

The results show a low level of saturation for the control. However, the level of saturation is insufficient for other treatments before sowing. After harvesting, the saturation level for control and 9 m canopy length is insufficient but low in 6 m and 12 m canopy length ***(Table 2)***.

Table 2 : *Physicochemical characteristics of soil according to the treatments*

Period	**Before sewing**				**After harvesting**			
Treatments	Out of cover	Under cover			Out of cover	Under cover		
Characteristics	control	6 m	9 m	12 m	control	6 m	9 m	12 m
pH eau 1/ 2,5	6,6	6,4	5,8	5,4	6,4	6,6	6,4	6,8
CE 1/ 10 µs/Cm	10	11	12	39	9	15	9	16
Carbone %	1,08	0,93	0,69	0,56	1,37	0,82	2,15	1,21
Matière organique %	1,86	1,60	1,18	0,96	2,37	1,41	3,71	2,08
N %	0,11	0,1	0,08	0,07	0,14	0,09	0,21	0,12
C/N	9,6	9,3	8,7	8,2	9,9	9	10,5	9,7
Ca meq/100g	1,72	1,5	0,97	1,05	1,42	1,2	1,8	1,12
Mg meq/100g	0,3	0,07	0,37	0,75	0,6	0,9	0,9	0,75
Na meq/100g	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02
K meq/100g	0,006	0,004	0,007	0,01	0,006	0,01	0,004	0,008
P ppm	2	2	3	6	3	2	2	3
S meq/100g	2,04	1,59	1,37	1,82	2,04	2,12	2,72	1,90
CEC meq/100g	5	7	12	16	7	5	7	4
T %	42	23	11	12	28	45	41	54
PSE %	0,21	0,18	0,1	0,05	0,14	0,26	0,26	0,57
Sable grossier %	0,04	0,01	0,06	0,626	0,02	0,02	0,01	0,07
Sable moyen %	0,71	0,41	0,78	1,15	0,44	0,63	0,62	1,1
Sable fin %	24,74	22,58	24,08	20,46	22,45	26,04	23,03	25,38
Sable très fin %	26,49	26,04	26,76	20,52	25,99	27,4	26,11	27,02
Limon grossier %	27,95	28,57	29,02	23,75	28,54	27,07	28,32	27,56
Limon fin %	15,98	17,81	15,37	18,72	16,87	13,95	16,52	14,36
Argile %	4,09	4,58	3,93	14,77	5,69	4,89	5,39	4,51

IV - DISCUSSION

In the agrarian space more often we tend to associate species with high added value and annual crops to diversify production and sources of income in order to limit the risks of bad harvest linked to climatic change. According to [21, 22] the advantages of associating annual crops with trees, can include food security for households, the income generated from the sale of the two products, weed control and the best use of cultivated resources. The results of our study show that peanut-cashew association has shown significant differences for growth and yield parameters.

IV-1. Growth

Indeed, the strong growth in height of those peanut plants is related to cashew canopy length. That means there is competition for light between cashew trees and peanut plants. On the other hand, this result can be linked to the good development of the cashew canopy (especially at the level of the 9 m and 12 m canopy length). The canopy high density created a strong shade which was particularly at the origin of the strong growth in height for peanut plants. The depressive role of shade on the photosynthetic activity of certain plants has been demonstrated by [23]. These results are similar to those of [24]. Indeed according to these authors, several herbaceous species and cultivated plants modify their growth pattern under different qualities and quantities of light. The significant production of fresh biomass recorded in the control can be explained by a lack of canopy shade of cashew trees, so these plants have more access to ambient air, optimal humidity and light to make photosynthesis allowing them a good development or a good gynophorization of peanut culture. Our results corroborate those of [6] who found that biomass of the haulms was higher outside the canopy with unpruned trees of *Cordyla pinnata*. However, the lowest biomass harvests are noted when the peanuts are grown under cashew trees of 12 m, 9 m and 6 m canopy length. These results indicate that tree canopy length has a depressive effect on the growth and leaf development of peanut crop. However research by [25] shows that the association of trees and crops allows the production of more biomass per hectare. By combining cover crops and agroforestry, biomass production can be doubled. The tree-crop combination is more productive than an agriculture-forest rotation. When agroforestry is compared to a crop rotation with crops on one side and trees on the other, biomass production is 10-60 % higher [26]. These differences could be related to differences in tree planting density. Our planting density was 100 cashew trees ha^{-1}. A low planting density is recommended in agrisilviculture, of 30 to 80 trees ha^{-1} [27].

IV-2. Yield

The study found a significant effect of cashew canopy length on yield parameters: the total number of pods, the number of full pods and the weight of the full pods. The weight of full pods almost doubled when peanut is associated with the 6 m canopy, compared to the control. This result was predictable from the start of the experiment. In fact, throughout the monitoring period, growth parameters (height, leaf biomass and gynophorization) were always significant compared to those married by cashew trees at 9 m and 12 m canopy length. This result is to be compared with less significant development of 6 m canopy length of cashew trees which was observed in the site. This is due to the fact that these cashew trees canopy are not yet well developed and therefore the cover is not dense enough to limit access to light for peanut. This is proven by small values of canopy diameter measured at the start of the experiment. The best yields were found in the 6 m canopy length cashew tree. Likewise [28] found that the cultural association is very favorable and beneficial to the different plants present when cashew tree is still young (aged less than 5-6 years). But also these results are similar to those of [29]. An analysis of cashew sector in Benin [28] concluded that depending on the distances between cashew trees, the duration of association or cohabitation with annual crops is more or less long. When the spacing between trees is around 10 m and the average duration of cultural association is 6 to 7 years and also depends on the speed of vegetative development of cashew tree.

However, there is a decrease in the total number of pods depending on evolution of canopy length of cashew. On the other hand, this result can be linked to a greater development in a 9 and 12 m canopy length of cashew trees. As a result, the strong shade of these canopies created a competition for light between peanut-cashew resulting in height growth and the lack of good gynophorization resulting in low pod production of peanut plants. Several authors have shown that shade of certain species has a depressive effect on yield of certain crops [30 - 34]. The trees have an impact on the intercrop yield, especially when they have reached their adult size and their crowns are developed. In recent years, the crop yield has been reduced by up to 15-20 % [25]. Crop yields drop significantly when crop luminosity falls below 60 % of incident radiation, which corresponds to 50 trees ha^{-1} of 15 m height [26]. For a plantation of 100 individual hectares, beyond 6 m canopy length peanut crop was more sensitive to the depressive effect of shading cashew than to its beneficial effect on soil fertility. However, to allow good tree growth and have the least impact on crop yield, the inter-row width should be at least twice the height of the tree at maturity [27]. The presence of trees can protect crops from yield losses due to climatic accidents. Indeed, their buffering capacity in the face of extreme temperatures and rainfall is increasingly recognized by [35].

V - CONCLUSION

The present study reveals cashew-peanut association is indeed possible. The best peanut yields were found under cashew trees with a 6 m canopy length in a plantation of 100 individuals per hectare. Beyond this threshold, peanut yields drop drastically. This decline is thought to be linked to ecological factors (soil acidity and lack of light). Therefore, silvicultural interventions should be interesting to allow peanut crop to fulfill its physiological functions. In addition, research on association *A. occidentale* / crops should be extended to other speculations cultivated by producers in Toubacouta area, taking into account peasant practices such as cereal / legume rotation.

REFERENCES

[1] - CSAO/OCDE, "Crise alimentaire et nutritionnelle, analyses et réponses", Maps & Facts, N° 3 (2020)

[2] - ANSD," Recensement général de la population et de l'habitat, de l'agriculture et de l'élevage" (2020), section Ressources. Repéré à http://www.ansd.sn/ressources/RGPHAE-2013/ressources/doc/pdf/12.pdf

[3] - MAAF, Les politiques agricoles à travers le monde quelques exemples", (2014), www.agriculture.gouv.fr ; www.alimentation.gouv.fr, fiches 8 pages

[4] - ANSD, "Situation économique et sociale du Sénégal 2017-2018", (2020). https://www.ansd.sn/ressources/publications/9-SES-2017-2018_Agriculture.pdf

[5] - AFRENA, (1990)

[6] - S. A. N. SAMBA, "*approche expérimentale en agroforesterie"*, (1999)

[7] - M. BAUMER, ''Bois *et Forêts des Tropiques*'', (1994)

[8] - ANSD, ''*Enquête Démographique et de la Santé Continue au Sénégal*'', (2012)

[9] - A. KOUADIO, "Prévision de la production nationale d'arachide au Sénégal à partir du modèle agrométéorologique AMS et du NDVI", Université de Liege, Gembloux Faculté universitaire des sciences agronomiques, des Interuniversitaires en Gestion des Risques Naturels, (2007) 54

[10] - M. GAYE, '*'Le secteur arachidier du Sénégal face à son destin : du mal de l'étatisation au remède de la privatisation*'', OXFAM, Dakar, (2009)

[11] - A. DIAGNE '*'La commercialisation de L'arachide au Sénégal: enjeux, contraintes et perspectives pour l'obtention du diplôme de Master 2 professionnel en économie rurale et politiques agricoles*'', (2014)

[12] - K. NOBA, A. NGOM, M. GUEYE, C. BASSENE, M. KANE, I. DIOP, F. NDOYE, M. S. MBAYE, A. KANE, A. T. BA, "L'arachideau Sénégal : état des lieux, contraintes et perspectives pour la relance de la filière"Oilseeds and fats Crops and Lipids, (2014)

[13] - ISRA/BAME, "Etude sur les interprofessions au Sénégal", (2008)

[14] - FAO, ''Les *ruralités en mouvement en Afrique de l'Ouest*'', (2007)

[15] - E. TORQUEBIAU, "L'agroforesterie : des arbres et des champs". Paris : L'Harmattan, 156 p. (Biologie, écologie, agronomie) ISBN 978-2-296-03434-1, (2007)
[16] - X. HAMONT, C. DUPRAZ, F. LIAGRE, "L'agroforesterie : Outil de séquestration du carbone en agriculture", (2009), http://agriculture.gouv.fr/IMG/pdf/L_agroforesterie_Outil_de_Sequestration_du_Carbone_en_Agriculture_version_15 0dpi.pdf
[17] - C. DUPRAZ et F. LIAGRE, "Agroforesterie : Des arbres et des cultures", Editions France Agricole 2ième édition, (2011) 432 p.
[18] - L. HAENDLER, ''*Fruits*'', (1970)
[19] - C. O. SAMB, E. FAYE, M. DIENG, D. SANOGO, SAN. SAMBA et B. KOITA, *''Afrique science'',* (2018)
[20] - PLD, *''Plan local de Développement''*, (2009)
[21] - V. H. L. S. C. RODRIGO, *''Field Crops Resources''*, (2001)
[22] - K. O. F. F. B. OPOKU-AMEYAW, *''Agri. Sci.''*, (2003)
[23] - C. E. MESSIER, *''Can. J. For. Res.*'', (1988)
[24] - J. E. HODDINOT, *''Can. J. Bot''*, (1982)
[25] - METIER, " L'EST AGRICOLE ET VITICOLE", Vol. 1, N° 1 (2013)
[26] - F. LIAGRE, G. FREYSSINEL, J. P. SARTHOU, C. DUPRAZ, R. SAUVAIRE, M. SANDINONE, M. FREYSSINEL, "Produire avec les arbres pour une agriculture différente", AGROFORESTERIE, Edition France agricole, Montpellier, 1-20 (2007)
[27] - D. ORI and B. CAMILLE, "Comment Produire de La Biomasse En Agroforesterie ?", (2012)
[28] - I. BALOUGOUN, A. SAIDOU, E. L. AHOTON, L. G. AMADJI, C. B. AHOHUENDO, I. B. ADEBO, S. BABATOUNDE, D. CHOUGOUROU, H. ADOUKONOU-SAGBADJA et A. AHANCHEDE, *''Agronomie Africaine''*, (2009)
[29] - C. O. SAMB, *''thèse de doctorat unique pour obtenir le grade de docteur de l'université de Thiès, Ecole Doctorale Developpement Durable et Société, Formation doctorale : Sciences Agronomiques, Spécialité : Sylviculture et Aménagement*'', (2019)
[30] - A. GRUNOW, *''Relations between woody and herbaceous plants in agroforestry parklands in subsaharian africa''*, (1980)
[31] - S. SOMIRRIBA, *''Soil fertility research for maize based farming systems in Malawi and Zimbabwe,* édité par Stepeh R Waddington, Herbert K. Murwira, John DT. Kumwenda, Danisile Hikwa, Faneul Tagwira, (1988)
[32] - C. F. YAMOHA et J. R. BURLEIGH, "*Agrofor. Syst.*'', (1990)
[33] - N. S. YADAV, A. WIERZBICKI, M. AEGERTER, C. S. CASTER, L. PEREZ-GRAU, A. J. KINNEY, WDH, Ir R. B., B. SCHWEIGER, K. I. STECCA, S. M. ALLEN, M. BLACKWELL, R. S. REITER, T. J. CARLSON, S. H. RUSSELL, K. A. FELDMANN, J. PIERCE and J. BROWSE, *''Plant Physiol.*'', (1993)
[34] - G. SINGH and M. SINGH, ''*Journal of Arid Environments''*, (2007)
[35] - INRA, "Projections des émissions/absorptions de gaz à effet de serre dans les secteurs forêt et agriculture aux horizons 2010 et 2020", Rapport final, (2008)