International Journal of Research in Agricultural Sciences
Volume 8, Issue 2, ISSN (Online): 2348 – 3997

Changes in Vegetation Structure and Carbon Stock in Cashew (*Anacardium occidentale* L., Anacardiaceae) based Agro-Ecosystem after Clear Forest in the North of Cote D'Ivoire

Koffi Kouadio Arsene Dieudonne [1*], Silue Pagadjovongo Adama [2], Kouassi Konan Edouard [1, 3], Coulibaly Tioporo Naminata [1] and Koutouan-Kontchoi Milene Nadege [1, 3]
[1] Researcher, Felix Houphouet-Boigny University of Abidjan, Cote d'Ivoire.
[2] Researcher, Peleforo Gon Coulibaly University of Korhogo, Cote d'Ivoire.
[3] Lecturer, West African Science Service Center on Climate Change and Adapted Land Use / African Center of Excellence on Climate Change, Bio-diversity and Sustainable Agriculture (WASCAL / CEA-CCBAB) Cote d'Ivoire.
[*]Corresponding author email id: arsenekoffi@yahoo.com

Date of Acceptance (dd/mm/yyyy): 15/02/2021 *Date of publication: 20/03/2021*

***Abstract* – The increase in intensive agriculture combined with the problems of climate change are causing considerable degradation of natural ecosystems. Therefore, in order to ensure their protection, it is necessary to find a system that will combine environmental protection and carbon absorption. Thus, the general objective of our research is to understand the role of cashew (*Anacardium Occidentale* L., Anacardiaceae) plantations of different ages, in the mitigation of the effects of climate change, through the capture of atmospheric carbon in the north of Côte d'Ivoire (Napié in the Korhogo department). The work consisted of evaluating the carbon stock of the clear forest and cashew plantations with their sequestration dynamics at different ages. The carbon stock of the clear forest is 177.854 t/ha. While that of the cashew plantation is 8.657 t/ha, 66.304 t/ha and 193.32 t/ha respectively for plantations of 4, 10 and more than 10 years old. Our results have shown that cashew trees over 10 years old manage to recover and even exceed the rate of carbon lost after cutting down the clear forest. This study revealed that cashew farms can act as carbon sinks. These results make the species *A. Occidentale* a good candidate for reforestation, land restoration to combat climate change and land degradation.**

***Keywords* – Farm, Cashew, Reforestation, Climate Change, Napie.**

I. INTRODUCTION

Cote d'Ivoire's economy is based on agriculture with cash crops such as coffee, cocoa, rubber and oil palm in forest areas; cotton and recently cashew nuts in savannah areas. With regard to cashew nuts or 'brown gold' from the north, the first plantations in Cote d'Ivoire were introduced in the early years of 1959-60 by two state-owned companies, SATMACI and SODEFOR" [6]. However, from the 1960s onwards, this part of the country benefited from numerous agricultural development projects such as the Cotton Plan and the Cashew Plan, carried out by development companies to compensate for the agricultural imbalance between the north and the forested area of the south. This new agro-economic context has thus led to the gradual development of cashew tree plantations. Thus, Ivorian cashew nut production has undergone a remarkable evolution in recent years. It has increased from 235,000 tons in 2006 to more than 738,000 tons of raw cashew nuts in 2018 [6]. National production has more than doubled in a decade. The total area planted with cashew trees, estimated at 500,000 ha in 2006, is about 1,350,000 ha in 2018 [6]. This spectacular development of cashew plantations has been to the detriment of open forests. Today, the agricultural landscape of northern Cote d'Ivoire has been strongly shaped. Large areas of savannah and open forests are being cleared for cashew tree cultivation. This change in land use contributes to the emission of greenhouse gases such as CO_2. CO_2 is responsible for the global warming currently observed on Earth [18]. With this in mind, the 2015 Conference of the Parties (CoP21) to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris brought together 195 countries to decide on the measures to be implemented in order to limit global warming [15]. An international climate agreement, applicable to all countries, was validated by all participants, setting the objective of limiting global warming to between 1.5°C and 2°C by 2100 [7]. To this end, the agreement, which is supposed to come into force in 2020, will have to address both mitigation (the reduction of greenhouse gas emissions) and the adaptation of societies to existing and future climate change [19]. In order to mitigate climate variability and change, the international community has adopted a number of decisions such as those on reducing emissions from deforestation and forest degradation. In the global carbon balance, terrestrial ecosystems are recognized as playing an essential role, absorbing nearly 30% of the total anthropogenic CO_2 emitted [8]. It was then proven that agroforestry systems, in particular *Anacardium occidentale* L. farms, have the capacity to contribute to climate change mitigation through sequestered carbon [4]. Reported that the carbon storage potential in humid tropical agroforestry systems in Africa ranges from 29 to 53 t of carbon per ha [10]. According to the [10], forest plantations can store 10 t of above-ground biomass per ha per year. However, carbon stocks in *A. occidentale* farms have not been exhaustively studied in Cote d'Ivoire. Thus, the objective of this work is to evaluate the carbon stock stored in farms of *A. occidentale* of several ages in Napie, in the north of Cote d'Ivoire for climate change mitigation in this country.

II. Materials and Methods

2.1. *Description of the Study Area*

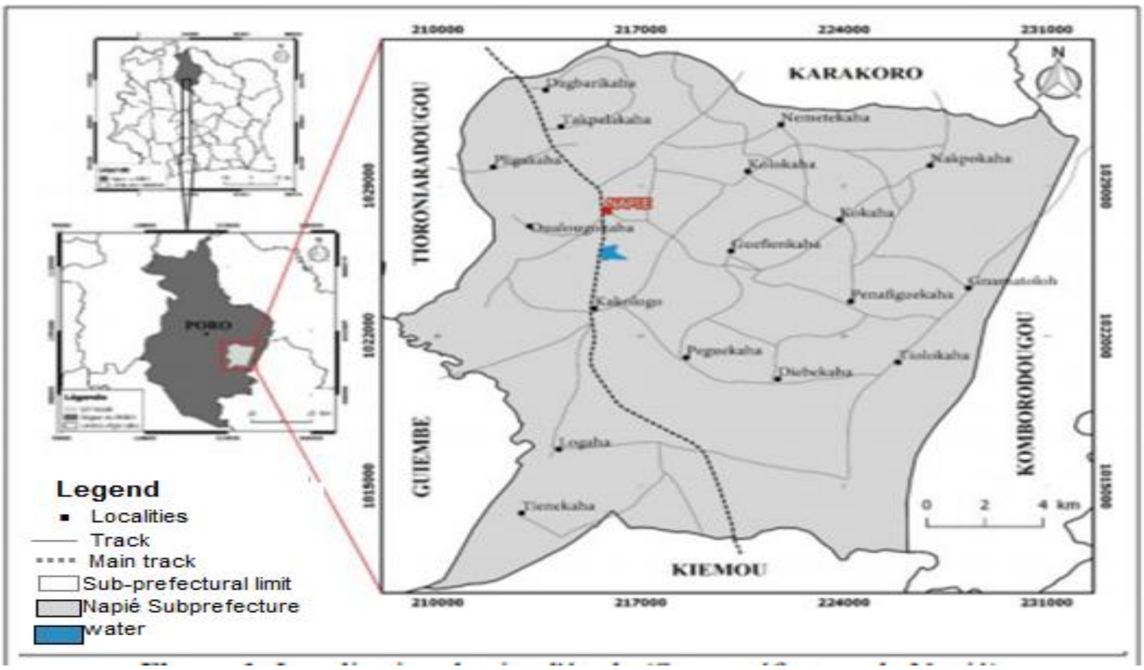

Fig. 1. Location of the study area.

The study was carried out in the Napie sub-prefecture in the Savanna District. This sub-prefecture is located in the north of the Cote d'Ivoire, 565 km from Abidjan. Today it has 5532 inhabitants. It is one of the 16 sub-prefectures of the Poro Region. It is bounded to the north by the Department of Korhogo, to the south by the Department of Niakaramandougou, to the east by the Department of Kong and to the west by the Department of

Odienne (Figure 1). The climate is described as Sudanese type with a two-season climate regime: a five-month dry season that runs from November to March and a seven-month rainy season that runs from April to October. The rainy season has a peak in rainfall in August. The annual average temperature is 26 °C. January is the driest month with less than 10 mm of rainfall. This region is characterized by an association of ferralitic soils. The vegetation of this zone is composed of savannah, open forests, fallow land and crops, especially cashew trees. The flora is dominated by species such as *Detarium microcarpum* Guill. & Perr. (Fabaceae), *Piliostigma thonningii* (Shum.) Millne-Redhead, (Fabaceae), *Anogeissus leiocarpus* (DC) Guil & Perr (Combretaceae).

2.2. *Data Collection and Sampling*

2.2.1. *Data Collection*

The surface survey method was adopted. It consisted in delimiting in the selected biotopes square plots of 50 m² (2500 m²). Within these plots, each woody individual with a Diameter at Breast Height (DBH) greater than 10 cm was identified and the diameter was measured [6], [9]; [10]. This 10 cm threshold is most commonly used for similar studies aimed at analyzing forest structure [Riera13].

2.2.2. *Data Analysis*

The data analysis focused on the evaluation of parameters such as basal area, diametric and vertical structure, estimation of above-ground biomass and carbon stocks were considered the main research parameters.

The basal area is the cross-sectional area of the trunks of all trees measured at 1.30 m above the ground [15]. It is calculated as follows: $S = \Sigma \pi D^2 / 4$, with S = basal area expressed in m² / ha, л = 3.14 and D the diameter determined from the circumference.

The distribution of individuals of species by diameter class, called diametric structure or horizontal structure, is a method of demographic study of plant populations which makes it possible to assess the capacity of a plant formation to be able to develop naturally and to measure its stability. The vertical structure of a stand is the distribution of individuals in that stand by height class. It allows to account for the stability of a stand.

We then calculated the amounts of above-ground biomass of the different individuals from the bio volume as it takes into account the parameters of the tree (density, height, diameter).

The bio volume is given by the following mathematical formula: $V = D^2 * \pi * h * 0.86 / 4$

In this formula, V represents the bio volume (m^3), h is the height of an individual in meters and D its diameter also in meters. The next step is to convert this volume of wood to dry matter biomass using the specific density constants of the wood. For this purpose, a database of timber density values for African species was consulted [5]. But for species whose specific gravity is unknown we have used the default value for tropical forests in Africa. This standard density value is 0.58g / cm^3 [5]; [14]. The above-ground biomass is given by the following mathematical formula: $AGB = V \times EF \times D\ (sp)$

V commercial volume of a tree (m^3); EF expansion factor (1.895); the formula D (SP) specific density of wood for a tree species (t / m^3). The underground biomass was estimated to be 16 p.c. of the above-ground biomass. Thus the total carbon biomass is calculated according to the following mathematical formula: - $Btot = BGV + AGV$.

The total biomass estimated from the different equations was converted into the corresponding sequestered carbon stock by multiplying it by 0.47 [7]. The values of carbon stocks found at the scale of the different sampling areas were extrapolated to the hectare.

To compare some of the calculated parameters, means comparison tests were performed. For each type of biotope, we compared the means with each other and for each habitat we have 6 plots and the means of the calculated parameters were compared with each other. Before making these comparisons the normality of the data distribution was verified by the Shapiro-Wilk test. In our case, this distribution not respecting normality even after the transformation, the Kruskall-Wallis test was chosen.

III. Results

3.1. *Vegetation Structure*

The distribution of individuals by diameter class was adjusted to a polynomial function (Figure 2). The histograms of stem distribution by diameter class show a variety of shapes. These shapes can be grouped into 3 types:

Type 1: Decreasing distribution in inverted "J" shape, in open forests. This pattern indicates that low diameter classes are better represented than large individuals.

Type 2: Bimodal distribution in cashew farms aged 4 years. The first mode is dominated by individuals with a diameter class between 20 and 30 cm while the second mode is dominated by individuals with a diameter class between 40 and 50 cm. This observed distribution of diameter classes suggests a positive asymmetrical distribution, characteristic of monospecific stands with a predominance of individuals of small diameter.

Type 3: Bell-shaped distribution in cashew farms of 10 years and older with a better representation of intermediate diameter classes compared to extreme classes. This distribution is characteristic of monospecific stands with predominantly young individuals.

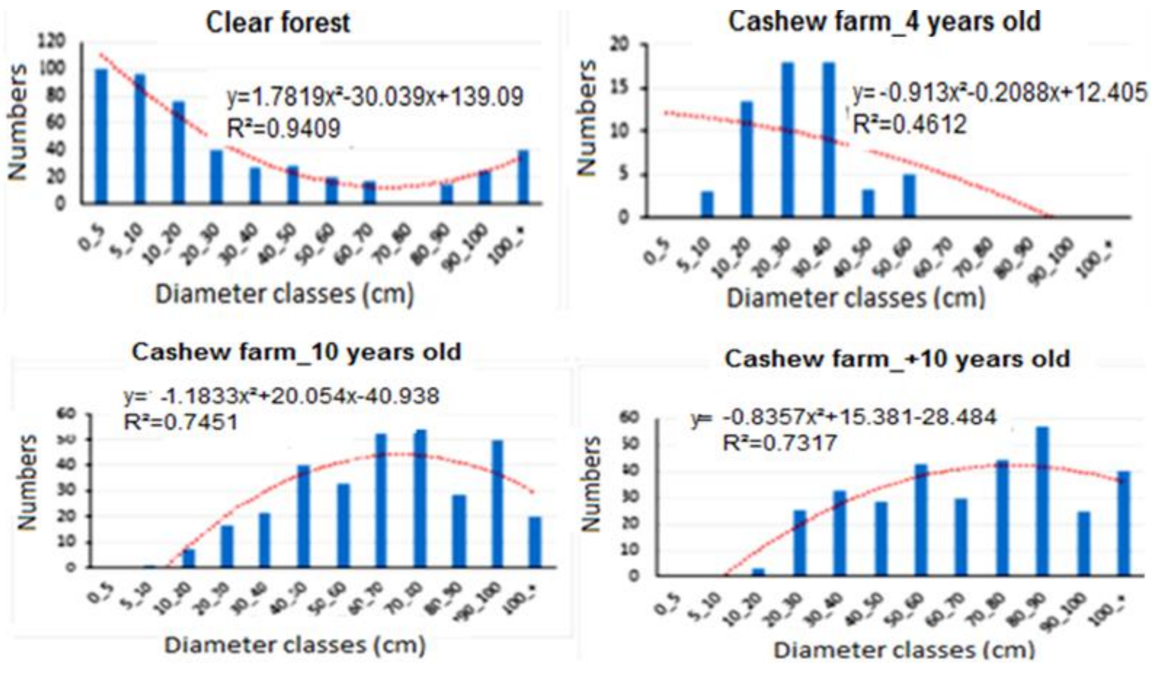

Fig. 2. Distribution of woody individuals by diameter class.

The distribution of individuals in the different biotopes according to the height of the bole is shown in figure 3. This distribution is presented in 3 types:

The histograms of stem distribution by height class show a variety of shapes. These shapes can be grouped into 3 types:

Type 1: Decreasing distribution in inverted "J" shape, in clear forests. This pattern indicates that individuals in low height classes are better represented than tall individuals.

Type 2: Bell-shaped distribution in cashew farms 4 years and older with a better representation of intermediate height classes compared to extreme classes. This distribution is characteristic of monospecific stands with mainly young individuals.

Type 3: "J"-shaped distribution in cashew farms 10 years and older with a better representation of high height classes. This distribution is characteristic of monospecific stands with mainly mature individuals.

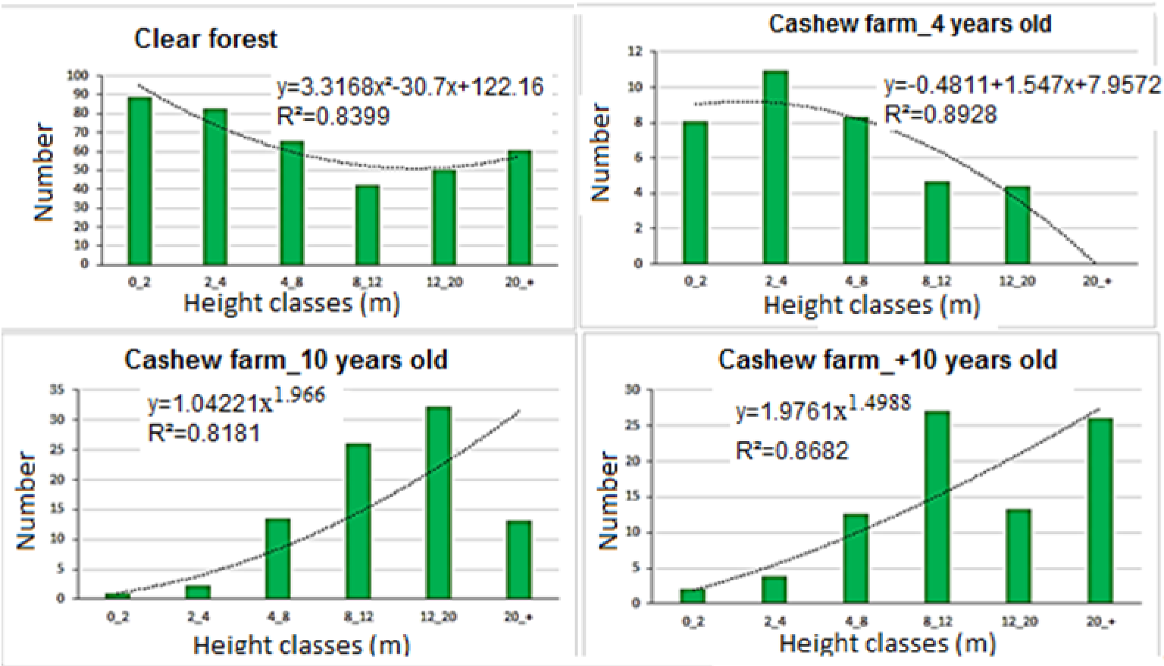

Fig. 3. Distribution of woody individuals by height class.

Table I. Average values of the parameters in the different biotopes.

Biotopes	Basal area (m^2 /ha)	Total Biomass (t/ha)	Carbon Stock (t/ha)
Clear Forest	19.36 ± 14.76^b	355.71 ± 502.51^b	177.86 ± 251.28^b
Cashew farm_4 years old	3.50 ± 1.7^a	17.32 ± 11.36^a	8.66 ± 5.68^a
Cashew farm_10 years old	13.82 ± 4.67^{ab}	132.61 ± 63.79^{ab}	66.3 ± 31.89^{ab}
Cashew farm_+10 years old	16.02 ± 7.31^b	386.64 ± 359.06^b	193.32 ± 179.53^b
Statistiques du test	χ^2=13.31 : *P-value<0.004*	χ^2=13.74 ; *P-value <0.003*	χ^2=13.74; *P-value <0.003*

The mean values assigned the same letter are not significantly different at the 5 p.c level.

The clear forest records the highest value of the basal areas. This value is 19.36 ± 14.76 m^2 / ha (Table I). While the lowest value is found in the 4 years old cashew farm with a value of 3.5 ± 1.7 m^2/ ha. The Kruskal-

Wallis test indicates that the differences observed between these mean values are significant (χ^2 = 13.31; *P-value* <0.004).

3.2. *Biomass and Carbon Stock*

Regarding the total biomass, cashew trees planting more than 10 years old records the highest value of the total biomass (Table I). This value is 386.64 ± 359.55 t / ha. While the lowest value is found in the 4 years old farm with a value of 17.32 ± 11.36 t / ha. The Kruskal-Wallis test indicates that the differences observed between these mean values are significant (χ^2 = 13.74; *P-value* <0.003). Regarding the rate of sequestered carbon, a farm older than 10 years records the highest value. This value is 193.32 ± 179.53 t / ha (Table I). While the lowest value is found in the 4-year-old farm with a value of 8.66 ± 5678 t / ha. The Kruskal-Wallis test indicates that the differences observed between these mean values are significant (χ^2 = 13, 740; $P < 0.003$). The evolutionary curve of the carbon stock tells us that cashew trees during their evolution sequester carbon until they are more than 10 years old or their sequestration rate increases and exceeds that of the clear forest (Figure 4). It should therefore be remembered that cashew trees over 10 years old have succeeded in recovering the rate of carbon lost when cutting the clear forest.

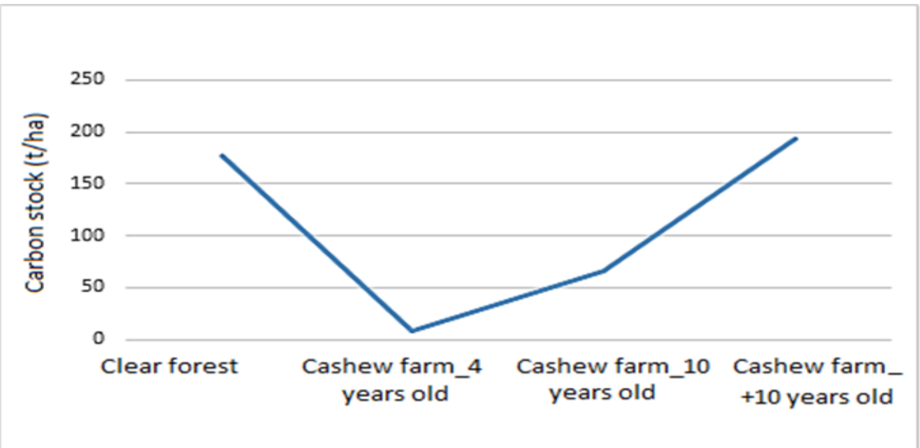

Fig. 4. Evolution of the carbon stock in the different biotopes.

IV. Discussion

The physiognomy and structure of plant formations result from a confluence of environmental factors (soil, climate, topography, etc.) which determine their distribution in the ecological zones of the world. This is how the savanna zone in the north of the Cote d'Ivoire has different types of vegetation.

On the structural level, the results of the study showed that clear forests have an exponentially decreasing distribution. This distribution is typical of forests of multiple ages [9]. In this type of forest, the histograms show the abundance of regenerating individuals (woody remnants) and individuals that have acquired regeneration (young individuals). This high proportion of woody recruits and young individuals is proof of the stability of a forest whatever its surface area [14]). In clear forests, the histograms give a structure of demographic in inverted "J" shape. This reflects both low disturbance of forest biotopes and significant regeneration of species that creates a high concentration of individuals in small diameter classes [19]). These results are similar to those of [3] in the classified forest of Wari-Maro in central Benin. Similarly, in cashew farms of different ages, young or small-diameter individuals are in the majority. This means that cashew seeds germinate easily in this area.

Moreover, in plantations, the different histograms confirm that the growth and development of species is regularly interrupted by farmers during maintenance operations [14]. Indeed, in mature plantations, cashew trees are in the phase of full production. Farmers' strategy is therefore to eliminate all species that could compete with cashew trees. These are mainly regeneration species and large trees from which they do not benefit and which could harbour cashew tree predators.

The basal area of the clear forest is greater than each of the cashew farms of various ages. The basal area of the open forest is 19.35 m^2/ha, which is larger than each cashew tree of various ages. This difference is explained by the fact that the density is higher in the open forest, resulting in an increase in basal area. In contrast, the basal areas in forests and farms older than 10 years are statistically equal. This would show that after 10 years cashew farms tend to turn into forests. The present research revealed that the total biomass and carbon stock in *A. occidentale* farms varies with age. Indeed, in the Ferme du Haut-Bandama, the older cashew farms have a higher biomass and stored more carbon. In the Ferme du Haut-Bandama and on the same type of soil (ferralitic), the biomass and carbon stock evolve from the highest to the lowest age. According to [16], the larger the tree grows, the more carbon it sequesters. Older farms have more biomass and stored more carbon than younger farms. Moreover, the biomass and carbon stock of farms older than 10 years are statistically equal to those of the open forest. This implies that after 10 years, the carbon released into the atmosphere after destruction of the clear forest for cashew nut cultivation can be recovered.

In all farms except 4 years, the carbon stock is higher than that estimated by [7], which is 31 tC/ha for the dry tropics, and that obtained [12] in a cocoa-based agroforestry system, which is 42 tC/ha. The total carbon stock obtained in *A.occidentale* farms varies between 8.66 ± 5.68 and 193.32 ± 179.53. According to [2], the carbon storage capacity of an agroforestry system varies between 12 and 228 tC/ha with an average value of 95 tC/ha. The values obtained in this research are within this range, except for 4 years farms.

V. Conclusion

The cashew tree was introduced in Cote d'Ivoire in 1968, particularly in the northern regions to combat deforestation and soil degradation. However, it was not until the 1990s that its cultivation became popular among farmers because of its economic profitability.

The present study aimed to determine the role of cashew tree plantations (of various ages) in mitigating the effects of climate change through the capture of atmospheric carbon in northern Côte d'Ivoire, more precisely in Napie.

The analysis of structural parameters revealed that plantations of more than 10 years old have a structure and biomass close to that of open forests. The cashew cultivation carried out has a pronounced effect on population structure, biomass and carbon stock in the first years of plantation. Cultivation over several years leads to a decrease in atmospheric carbon. The study demonstrated that cashew plantations, in addition to being a cash crop, can play an important role in climate change mitigation. The study also provides evidence that plantations of perennial crops need to be considered in the REDD+ process as part of the global effort to address climate variability and change.

Agriculture combines to climate change is causing severe degradation of ecosystems. In order to be able to guide the conservation of plant formations, it is therefore necessary to have a whole series of information on the current state of biodiversity. Many parameters such as, biomass, carbon stock and structural parameters were calculated to present the results.

REFERENCES

[1] Adjakpa B.J., Yedomonhan H., Ahoton L.E., Weesie P.D.M. & Akpo E.L., 2013. Structure et diversite floristique des ilots de forets riveraines communautaires de la vallee de So du Benin (Floristic structure and diversity of community riparian forest islands in the So valley of Benin). *Journal of Applied Biosciences*, 65: 4902 – 4911.

[2] Albrecht A, Kandji ST. 2003. Carbon sequestration in tropical agroforestry systems. *Agriculture, Ecosystems and Environment*, **99**: 15-27. DOI : http://dx.doi.org/10.1016/S0167-8809(03)00138-5.

[3] Assogbadjo AE, Glele Kakai RL, Sinsin B, Dieter P. 2009. Structure of *Anogeissus leiocarpa* Guill., Perr. natural stands in relation to anthropogenic pressure within Wari-Maro forest reserve in Benin. *African Journal of Ecology*, **48**(3): 644–653. DOI: 10.1111/j.1365-2028.2009.01160.x.

[4] Bhagwat S.A., Willis K.J., Birks J.H.B., Whittaker R.J., 2008. Agroforestry: a refuge for tropical biodiversity? *Trends in Ecology and Evo[4[lution*, 23: 261pp.

[5] Brown S., 1997. Estimating biomass and biomass changes of tropical forest: A primer.FAO Forestry Paper 134, Rome, Italy.

[6] FIRCA, 2018. La Filière du Progrès magazine d'information du fonds interprofessionnel pour la recherche et le conseil agricoles. Note d'information n°2, septembre.

[7] IPCC, 2003. Good Practice Guidance for Land Use, Land-use Change and Forestry (LULUCF). Institute for Global Environmental Strategies, Hayama, Japan.

[8] IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Published by the Institute for Global Environmental Strategies (IGES), Hayama, Japan.

[9] Morrison I.K., Foster N.W., Hazlett P.W., 1993. Carbon reserves, carbon cycling, and harvest effects in three mature forest types in Canada. *NZ Journal Forestry Science* 23(3):403–412.

[10] Murthy, I.K., M. Gupta, S. Tomar, M. Munsi, R.T.G.T. Hegde, N.H. Ravindranath, 2013: Carbon Sequestration Potential of Agroforestry Systems in India. *Earth Science and Climate Change* 4: 131. *http://dx.doi.org/10.4172/2157-7617.1000131*.

[11] Ouattara D., Vroh B.T.A., Kpangui K.B. & N'Guessan K.E., 2013.- Diversite vegetale et valeur pour la conservation de la reserve botanique d'Agbaou en creation (Plant diversity and value for the conservation of the Agbaou botanical reserve in creation), Centre-ouest, Cote d'Ivoire. *Journal of Animal & Plant Sciences*, 20 (1) : 3034 - 3047.

[12] Palm CA, Woomer PL, Alegre J, Arevalo L, Castilla C, Cordeiro DG, Feigl B, Hairiah K, Kotto-Same J, Mendes A, Moukam A, Murdiyarso D, Njomgang R, Parton WJ, Ricse A, Rodrigues V, Sitompul, SM, Van Noordwijk M. 2000. Carbon séquestration and trace gas emissions in slash-and-burn and alternative landuses in, the humid tropics. Final Report, Alternatives to Slash and Burn (ABS). Climate Change Working Group, Phase II. ICRAF, Nairobi, Kenya. 29 p.

[13] Pascal C, Peter S. 2015. Climat: 30 questions pour comprendre la Conférence de Paris, Éditions Les Petits Matins (30 questions to understand the Paris Conference, Editions Les Petits Matins). 200 p.

[14] Reyes G., Brown S., Chapman J., et Lug A., 1992.Wood densities of tropical tree species. Rapport technique general, Nouvelle Orleans, Louisiane USDA Forest service, 15p.

[15] Rondeux J. 1993. La mesure des arbres et des peuplements forestiers : *Les presses agronomiques* de Gembloux, Belgique, (Measuring trees and forest stands: Les presses agronomique de Gembloux, Belgium) 521 p.

[16] Thompson J. R., Nowak D. J., Crane D. E. & Hunkins J. A., 2004: <<Lowa, U S, Communities benefit from a tree-planning program/ characteristics of recenty planted tree>> *Journal of arboretum*, vol. 30. 9 p.

[18] Tsayem D. M., 2002. Caracterisation et suivi de la deforestation en milieu tropical par teledetection : application aux defrichements agricoles en Guyane française et au Brésil. These de doctorat, universite d'Orléans, France (Characterization and monitoring of deforestation in tropical environments by remote sensing: application to agricultural clearing in French Guiana and Brazil. Doctoral thesis, University of Orleans, France).

[19] Wala, K., Sinsin, B., Guelly, K.A., Kokou, K. & Akpagan, A.K. (2005). Typologie et structure des parcs agroforestiers dans la préfecture de Doufelegou (Typology and structure of agroforestry parks in the prefecture of Doufelegou) (Togo). *Secheresse (Drought)*, 16 : 209-216.

AUTHOR'S PROFILE

First Author
Dr. Koffi kouadio Arsene Dieudonne, Originally from the Ivory Coast, he was born on September 30, 1980. Assistant Professor at the Felix Houphouet-Boigny University of Abidjan, UFR Biosciences, Department of Botany. He specializes in forestry and biodiversity conservation. He has conducted research on the conservation of ancient cultivated areas and climate change. email id: arsenekoffi@yahoo.com

Second Author
Dr. Silue Pagadjovongo Adama, Ivorian, he is an assistant at the Univesity of Peleforo Gon Coulibaly of Korhogo, at the UFR Biosciences, Department of Biological Sciences. He specializes in forestry and silviculture. He carried out research on the dynamics of land occupation in the North of Cote d'Ivoire. email id: pagadsilue@gmail.com

Third Author
Dr. Kouassi Konan Edouard, Ivorian. Professor of tropical botany at the Félix Houphouet-Boigny University in Abidjan. He specializes in Forestry. He drove research on environmental impact studies in tropical areas.
email id: kouasedward@yahoo.fr

Fourth Author
Coulibaly Naminata Tioporo, Ivorian. She is a botany master's student at the Félix Houphouët-Boigny University in Abidjan. He specializes in agrobiodiversity. She carried out research on the reconstitution of cashew plantations in the north of Cote d'Ivoire. email id: naminatacoulibaly4@gmail.com

Fifth Author
Koutouan-Kontchoi Milene Nadege, Ivorian. She is a researcher in botany and climate change at the West African Science Service Center on Climate Change and Adapted Land Use / African Center of Excellence on Climate Change, Biodiversity and Sustainable Agriculture (WASCAL / CEA-CCBAB). She specializes in Biodiversity and Climate Change. email id: milydege@yahoo.fr.