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Carbon storage of anthropoid's vegetation on the Ngaoundere escarpment (Adamawa, Cameroon).

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Abstract

A study carry out on carbon storage of anthropoid's vegetation on the Ngaoundere escarpment on four vegetal types (fallow, farms, shrub savanna and woody savanna) with the aim of fighting against climate change. Dendrometric data to determine phytomass and carbon storage were carried out on plot of 20m x 50m. Data analysis with the aid of soft ware programs like excel, Stat graphics plus S.O and XLSTAT showed the most anthropoid vegetation (fallow and farms) present a low production of phytomass and carbon storage as compared to natural vegetation (shrub and woody savannas). Carbon credit is proportional to the quantity of carbon storage in the different vegetation formations to alleviate the effect of human activities of the vegetation of the escarped the subvention of the local population through carbon should be encouraged.

Keywords

Escarpments Phytomass; Carbon storage; Ngaoundere; Adamawa; Cameroon.

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Introduction

The degradation of ecosystems today constitutes a threat to biodiversity, for the destruction of natural environment inevitably leads to scarcity, or even the disappearance of species (Swaminathan, 1990; Tchobsala and Mbolo M., 2013). Africa is highs affected by the disappearances of forest (4 million hectares each year). The convention on biological diversity shows that in 2000, 54000 vegetal species and 5200 animal species were threatened by extinction, and principally due to the human action (SCBD, 2000). The reduction of the number woody plants is manifested by a modification of floristic composition, vegetation structure and a low natural regeneration of certain species land use in Ngaoundere shows that the surface area of savanna reduced by 10.8% in 2001 compared to 1951 (Tchotsoua, 2006) . The main causes of this vegetation regeneration are slash and burn shifting cultivation (Zapfack, 2005), the combined effects of tree felling, bush fire and over grazing (Ntoupka, 1994; 1998), urbanization of Ngaoundere town and uncontrolled human activities (Mapongmetsem et al. 1997). Meanwhile, forests by their leys of role constitute solutions as carbon sink and reservoir that can contribute significantly to the increasing in carbon thus permitting the reduction of Greenhouse gases.

The durable solutions for three protection and conservation of our forest resides on the application of REDD mechanism (reduces the emission of greenhouse gases cause by deforestation and degradation of vegetation) is one of main topic on international debate. REDD mechanism has an aim to compensate individuals communities, projects and countries who reduces the emission of greenhouse gases link to forest. REDD programmer can reduce in less time and at low cost the emission of CO_2 at the same time contributing to poverty reduction and sustainable development (Angelsen 2009; S. K. Entenmann et al. 2013).

According to the Bali Plan of Action, REDD+ is the reduction of emission resulting from deforestation and the degradation of forest, including the means of conservation, sustainable management of forest and the degradation of the forest and the increase of forestry carbon storage. Perceived as a means of attracting financial credits REDD+ is a mechanism for the conservation of tropical forest rich in biodiversity and to generate new flux of revenue in these regions for poor population living in rural milieu. Carbon credit based on carbon market offers the potential to play an important role in the world's rapport of fighting against climate change within the framework of convention within the frame united nation fight against climate change. The application of carbon credit is little known in our Cameroonian forest band particularly in the subject to anthropogenic presumes like the intensification of agriculture, over grazing, road construction, camp and installation of immigrants. All there threats have contributed to considerable reduction of the forest surface area and carbon storage in this zone. Ether more, few works have been carried out on the impact of forest exploitation on the African carbon storage apart from those Ibrahima et al. (2002) on the population of phytomass and nutrient cycle in the

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dense and humid tropical forest of south Cameroon, of Abid (2005) on the quantification of carbon in some human savanna of Ngaoundere, of Tchobsala et al. (2014) on the impact of wood logging on the phytomass and carbon sequestration in the guinea savanna of Ngaoundéré, Adamaoua Region, Cameroon. The quantifications of phytomass and carbon sequestered permit the local population and government to know the load and the state of vegetation.

The exploitation of vegetal resources of the Ngaoundere escarpment has an impact on the production of biomass and the storage of carbon. It’s become major problem for its conservation and sustainable management of this vegetation. This study is aimed at showing the impact of the exploitation of vegetal resources on the production of biomass epigeic and hypogeic on the different vegetation types of the escarpments, estimate the carbon storage and to evaluate the carbon credit of this vegetation and finally to study the correlations between the production of biomass, the storage of carbon and carbon credit for the rehabilitation of this degraded vegetation.

Presentation of the study site:

The study was carried out on the Ngaoundere escarpment, Adamawa region, Cameroon. This region covers a surface area of 63700km characterized by an escarpment which crosses from East and West and separated the North and South of the country (Minister of Sports, 2010). This forested highland our study zone is situated in the wack village 50km from Ngaoundere (Fig 1). Study site is located between latitude 07°40’05.3’ and 07°40’484’ N and longitude 013°32’474’ and 13°33’13.1’’ E. it is situated on an altitude of 697 to 884 m.

The climate is the sudano-guinean type characterized by the two seasons: a rainy season and a dry season (Yonkeu, 1993). The annually rainfall is 1479mm with a variation coefficient of 9,8%. The minimum temperature range varies between 5 to 7° C and between 30 and 35°C for a maximum temperature (Mope, 1997). The mean annual temperature varies between 22,08°C and 22,93°C, average humidity ranges from 64,1C to 67,6°C, mean rainfall varies from 1227,9mm to 1675,8mm (Tchuengeum, 2005).

In Ngaoundere we have mainly, the Dourou or Dii, Mboum and Gbaya, but also the Massa, Kotoko, Mousgoum, Toupouri, Peul and Moundang from Extreme North of Cameroon, the Bantu (Beti and Fang Beti) who arrived during migratory period of the 11th century and finally the Bamileke and Bamunus market gardeners who arrived during the 19th century have unfiltered all the South East of Adamawa (MINEF, 1994).

The exploitation of natural resources is done principally through agriculture, cattle nearing, apiculture and fishering (MINEF, 1994). Agriculture is also market by an important practice of market gardening with the production by *Manihot esculenta, Hibiscus esculentus*, *Hibiscus sabdarifa, Arachis hypogea*, *Ipomea batatas*, *Solanum tuberosum*, *Lactuca sativa*, *Daucus carota* (Mapongmetsem, 2005).

The cultivation of yanking the North and the cassava to the South contributes to the survival of the population made up of the Dourou or Dir in the North high to the fool of the escarpment, the Mboum in the centre and East, the Baya, Tikar and Nyen-Nyen to the South West.

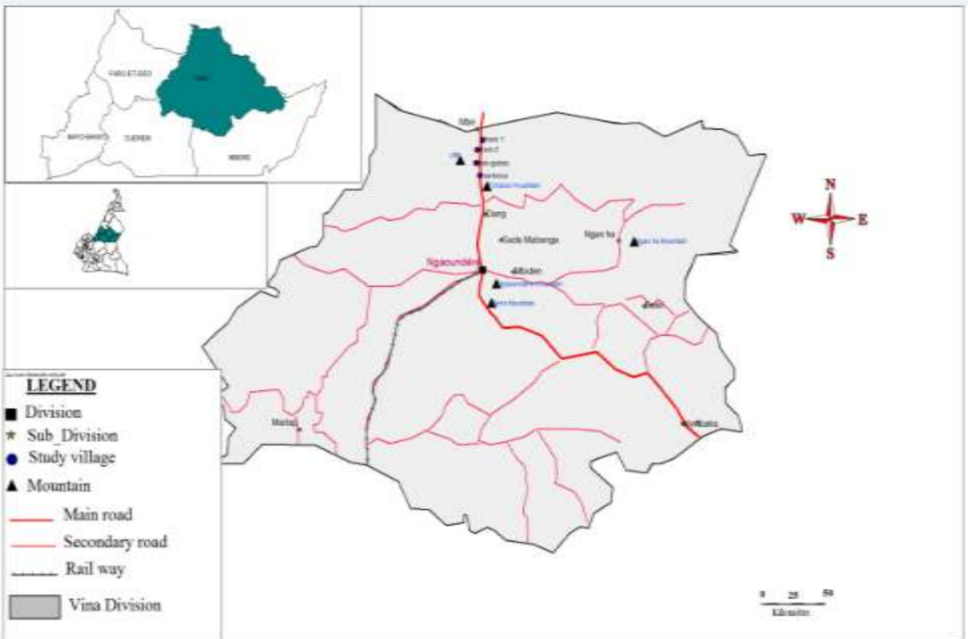


Figure 1: localization of study zone

Experimental dispositions and recording of dendrometric parameters of the study site:

The noting sown of vegetation was carried out on 24 sites from the external toward the center of the escarpment on four different vegetation types (fallow of less than 5 years, farms, shrubs savanna, and woody savanna) on a prepared dates recording from. Six retrained transects from North to East directions were realized each 300m on though area of 20m x 500m. The experimental disposition is a random complete block with four vegetation types (M1 = less than 5 years, M2 = farms, M3 = shrubs savanna and M4 = woody savanna), six transects (S1, S2, S3, S4, S5, S6) and four “repetitions” (R1, R2, R3 and R4) (Table 1). All these “ligneous” species were systematically identified by their scientific or vernacular names with the aid of Arbonnier flour (2000) and the village guides. The unidentified species were harvested and put in herbarium for identification at the Wakwa or at the national herbarium in Yaoundé. The height of the tree were measured or estimated with the aid of a graduated bamboo stem. The diameter at breast height (DBH) in m and the height (H) of the trees in m were carried out following the four cardinal points (North, South, East—West) with aid of a decameter. The geographic coordinates of smalls squares of floristic inventory” were registered with the aid of a GPS.

Table 1: Experimental dispositions

R=sampled; S=transect, M=vegetation types, 1,2,3 and 4 represents respectively fallow of less than 5 years, farms, shrubs savanna and woody savanna.

	S1	S2	S3	S4	S5	S6
R1	M1	M1	M2	M2	M4	M4
R2	M1	M1	M3	M3	M3	M4
R3	M1	M2	M2	M3	M3	M4
R4	M1	M2	M2	M3	M4	M4

Estimates of aerial biomass:

Aerial biomass is obtained by determining the biomass of the tree. The biomass of trees were indirectly estimated on the same plots by using allometric model taking into consideration the parameters of the tree such as DBH and the height. Among the equation used to estimated the biomass, that

The biomass of the big trees (size upper to 2 m) was estimated indirectly on the same plots of land by using an allometric model taking into account the

parameters of the tree such as the DHP and the height. The equation of Anderson and Ingram (1993) used by Tchobsala et al. (2014) was used to estimate the biomass because it was developed in the climatic conditions where the annual average rainfall varied between 1500 and 4000 mm thereby including that of Adamaoua which is between1200-2000 mm, and the determination coefficient between the biomass of trees and their two parameters (DBH) and height (R^2 = 0,987).The equation is as follows: B (kg) = exp.(3.114+0.9719 Ln (D^2H)), where B is the biomass of trees in kg, D the diameter DHP and H the height of the tree.

Estimate of underground Biomass:

The biomass of the rooting system was estimated with the aid of relation developed by Cains et al. (1997). Br=exp (-1,0587 + 0,8836 Xln (Ba), where Br= root biomass, ln=Napery logarithm and Ba=aerial biomass.

Estimates of the total biomass:

To determine the final values of the biomass, the aerial biomass wad added to the biomass of the roots under the ground surface (BT=Ba + Br) where BT=total biomass, Br=root biomass and Ba=aerial biomass (FAO, 1997).

Estimates of the carbon storage and carbon credit:

The evaluation of carbon storage is obtained by the measure of the calculated biomass. The stock of carbon in the total biomass was evaluated using the equation by Ibrahima and Habib (2008) and Tchobsala et al. (2014) CE=BxFC where CE=carbon stored in the total biomass (tc/ha), B=biomass (t C/ha) and FC carbon fraction (C %) FC=50%.

For the evaluation of carbon credit, the method proposed by saidou et al. (2012) and Tchobsala et al. (2014) were adopted. According to these methods carbon credit is obtained by multiply the stock of carbon by 95 dollars.

Statistical Analysis to the date:

The matrix elaborated was subjected to multivariate technics of analysis with the aim of portraying the dispersion of species and also the main vegetation types. The analysis of variance with the aid of software programmed likes XLSTAT and STAT GRAPHICS plus 5.0 was used to verify the difference between treatments at the level of numbers and the surface. In the presence of the analysis of significant variance, the comparisons of averages were carried out with the aid of Fisher test. On the other hand the difference in the composition of the milieu (vegetation types) was tested by the analysis of multi varied variance. Parameters such as height, density, land's surface and diameter, phytomass, the stock and carbon credit were the main components of analysis (ACP), analyze factorial of correspondence (AFC) and Hierarchies' ascendant classification (CAH).

Results:

Phytomass production by woody plant of the different vegetation types:

The production of phytomass and the different Vegetation types are presented in table 2. Woody savanna (121.62 t/ha), presenting the highest quantity of phytomass in relation to shrub savanna (112.18t/ha), fallow (49.60t/ha), farms (43.74t/ha). These results at linked to density, DBH and the height of trees, this is why the woody savanna presents a phytomass per hectare superior to that of shrub savanna follow and farms. The conversion of forest space of the escarpment into farmlands through the felling down of trees has led to a drastic drop of phytomass. The statistical test indicates the existence of a great difference between the amount values of biomass and different vegetation types.

Table 2: Phytomass produce by woody plant of the different vegetation types

Different Vegetation types	Aerial biomass	Root biomass	Total biomass
Fallow	32,43±0,98[a]	17,17±0,83[a]	49,60±0,97[a]
Farms	28,58±1,04[b]	15,16±0,66[b]	43,74±0,92[b]
shrub savanna	80,6±2,76[c]	31,58±3,07[c]	112,18±2,33[c]
woody savanna	90,01±2,86[d]	31,61±3,89[d]	121,62±2,85[d]

Notes: Data affected with same letter explain that there is no significant difference between them ($p < 0, 05$).

Carbon storage in the different vegetation of the escarpment:

The table 3 presents the cost of carbon sequestrated in the different vegetation types. The stock of carbon is proportionate to the quantity of the biomass produced. In effect the most important stock of carbon per hectare are located on the woody savanna with a stock of 60.81 tc/ha (table 2), farms (21.87 tc/ha) have the lowest amount lower than the one sequestrated by follow (24.87tc/ha). The shrub savanna (56.09tc/ha) and woody sequestrates, none carbon than those permutated constantly by man. After the felling and burning of trees for farm land carbon is more or less liberated into the atmosphere it will be progressively sequestrated with the reconstruction of the vegetation in the fallow. The analysis of variance confirms this variability with the existence of the great difference between the different vegetation types ($0.000 < 0.001$).

Table 3: Sequestration of carbon in the different vegetation types of the escarpment

Different vegetation types	Epigeic Carbon	Hypogeic carbon	Total carbon
Fallow	16,22±0,56[a]	8,58±0,43[a]	24,8±0,48[a]
Farms	14,25±0,35[b]	7,62±0,74[b]	21,87±0,46[b]
shrub savanna	40,89±1,09[c]	15,2±1,31[c]	56,09±1,16[c]
woody savanna	45,03±1,22[d]	15,78±1,87[d]	60,81±1,42[d]

Notes: Data affected with same letter explain that there is no significant difference between them.

Application of REDD+ for the conservation and protection of the vegetation in escarpment of Ngaoundere:

From this figure 2, it can be observed the carbon credit is proportionate to the quantity of carbon sequestrated. The highest of carbon credit is registered in the woody savanna (5776. 96 dollars). This high amount of credit in this vegetation type is due to the presence of huge trees that sequestrate much more carbon. The carbon credit of shrub savanna (5328. 35 dollars) is more than that of fallow (2356.19 dollars) and farms (2077.49 dollars) because shrub savanna is less subjected to human actions than fallow of less than 5 years and the farms. On the other hand the variance analysis reveals the existence of a highly significant difference between the four vegetation types (0.000 < 0.001). In effect for a better conservation and management of the vegetation of Ngaoundere escarpment the population must apply the REDD+ mechanism which is based on the carbon market. The forbidding or limitation of cash crop cultivation that reduces carbon credit in this escarpment will lead to the sustainable management of these natural resources.

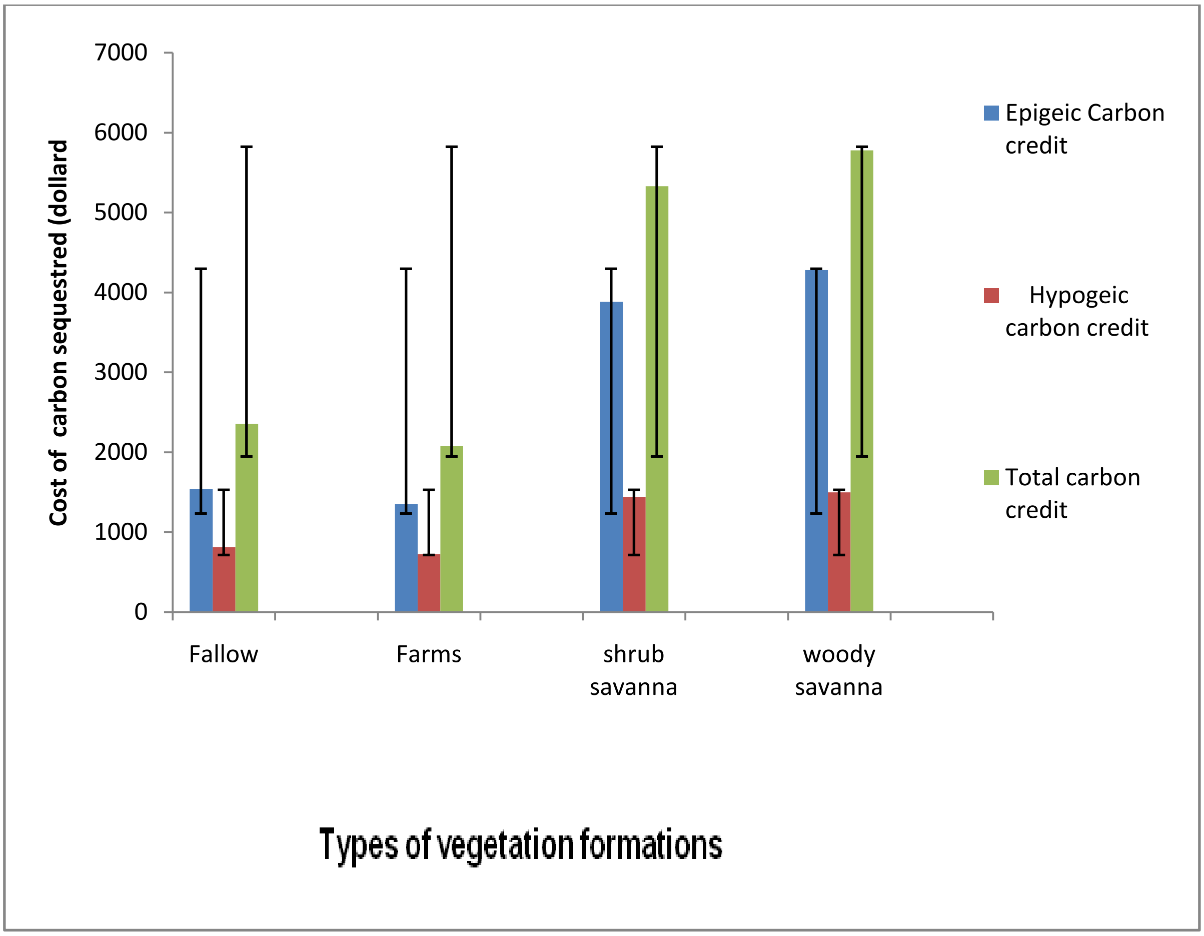


Figure 2: Cost of carbon sequestered (dollard)

Correlation between phytomass, carbon storage and carbon credit in the different vegetation types.

The Analysis of Principal Components (ACP) between the production of phytomass, the stock and carbon credit shows that there exist a positive and perfect correlation (R=1; P=0.05) between phytomass of fallows (B1) of less than 5 years and the stock (CI) and carbon credit (CCI) in fallows it is the same for the phytomass of farms (B2) and stock (C2) and carbon credit (CCI) of farms (Table 3). In a general manner, phytomass, the stocks, and carbon credit in a vegetation type are positively correlated. On the contrary there is a weak correlation between these three parameters when the environments are different for example the correlation between the phytomass of fallow (BI) and shrub savanna (B3) (R=0,230; P=0, 05) is very low.

The "Analysis factorials of correspondence" (AFC) of phytomass, of stock and carbon credit in the different vegetation types present a 77.40 % correlation according to the F1 and F2 axis shared (distributed) in 42.44% for X- axis (F1) and 34.96% according to the Y- axis (F2). According to the axial symmetry, the species are grouped in three lines forming clouds. These clouds signify a strong correlation between the phytomass, the stock and carbon credit. On the other in function of colons, species are isolated showing a week correlation between phytomass, the stock and the carbon credit (figure 3)

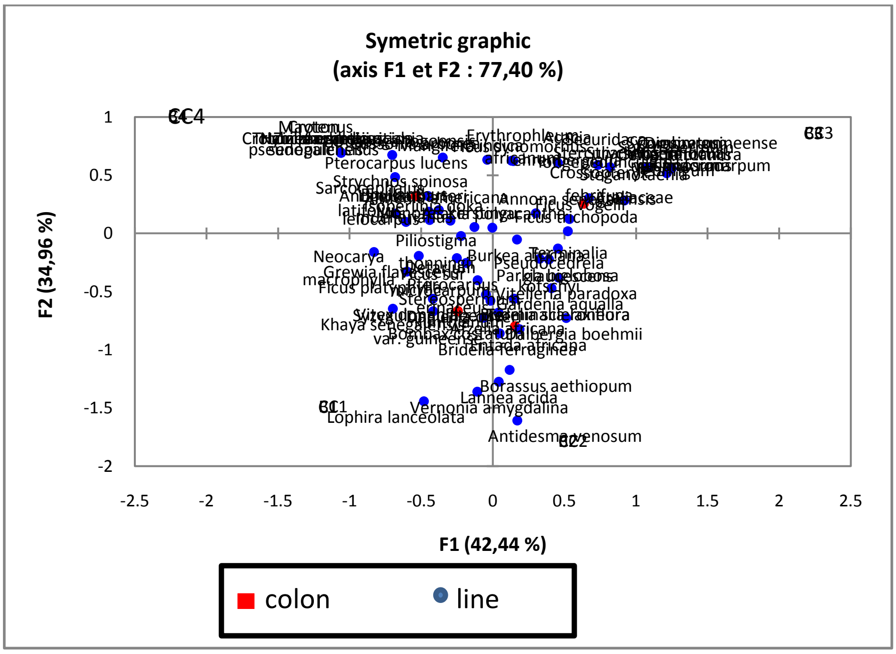
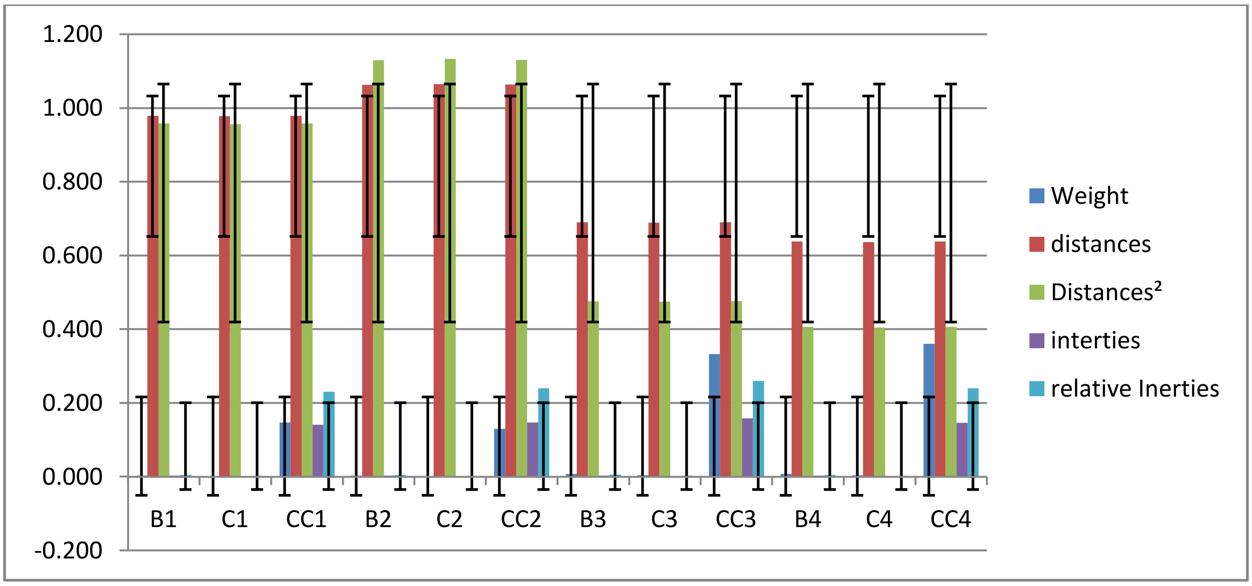


Figure 3: Correlation between phytomass, stock and carbon credit in the different vegetation types.

Weight, distances and interties between phytomass, stock and carbon credit in the different vegetation types

The Correspondences of Factorial Analysis (CFA) between the production of phytomass, storage and carbon credit shows that in colon, the most important relative weight is confined at the level of carbon credit in the shrub savanna (CC3; 0332). The quadratic distances at the origin are classified in this order; the farms>fallows> shrub savanna > woody savanna, for phytomass, the stock and carbon credit. This classification follows the degree of “anthropisation” of the vegetation of Ngaoundere escarpment. The mine of the vegetation in “anthropostised”, the mine it is degraded and consequently the distance between phytomass, the stock and carbon credit is higher. A significant difference does not exist between the relative inertias of carbon credits in the four vegetation types (figure 4).

Figure 4: Weight, distances, inertias between phytomass, storage and carbon credit in the different vegetation types.



Notes: B1: fallow phytomass, C1: fallow stock of carbon, CC1: carbon credit in the fallow, B2: farm phytomass, C2: stock of carbon of farms, CC2: carbon credit of farms, B3: phytomass of shrub savanna, C3: stock of carbon of shrub savanna, CC3: carbon stock of shrub savanna, B4: phytomass of wood savanna, C4: carbon stock of wood savanna, CC4: carbon credit of wood savanna.

Ascendant hierarchies' analysis of species in function of the phytomass, stock and carbon credit in the different vegetation types.

Ascendant hierarchies analysis (AHC) shows that the species are regrouped in three class indicated in the dendrogramme (figure 5)

Class1 comprises 41 species (*Acacia ehrenbergiana, Acacia polyacantha, Anogeissus leiocarpus, Bombax costatum, Bridelia ferruginea, Bridelia scleroneura, Cussonia arborea, Croton pseudopulchellus, Croton zambesicus, Daniellia oliveri, Entada africana, Erythrophleum, africanum Ficus platyphylla, Ficus synomorhus, Ficus sur Grewia flavescens Hymenocardia, acida Isoberlinia doka, Khaya senegalensis, Lannea acida, Lannea barteri, Lophira lanceolata, Mangifera indica, Maytenus senegalensis, Monotes kerstingu, Neocarya macrophylla, Nauclea gilletii, Ouapaga togoensis, Phyllanthus muellerianus, Piliostigma thonningii, Pterocarpus erinaceus, Pterocarpus lucens, Sarcocephalus latifolius, Stereospermum kunthianum, Strychnos spinosa, Syzyguim guineense* var. *guineense, Terminalia laxiflora, Trichilia emetica, Vernonia amygdalina, Ximenia americana, Ziziphus mauritiania).*

Class 2 presents 20 species (*Acacia tortilis, Annona senegalensis, Burkea africana, Ceiba pentandra, Combretum glutinosum, Crossopteryx febrifuga, Diospyros mespiliformis, Ficus trichopoda, Ficus vogelii, Gardenia aqualla, Securidaca longepedunculata, Parkia biglobosa, Pseudocedrela kotschyi, Sporospermum febrifigum, Steganotaenia araliacea, Sterculia setigera, Strychnos innocua, Syzyguim guineense* var. *macrocarpum, Terminalia glaucescens, Vitelleria paradoxa).*

Class 3 presents 6 species (*Afzelia africana, Antidesma venosum, Borassus aethiopum, Dalbergia boehmii, Detarium microcarpum* et *Vitex donania*)

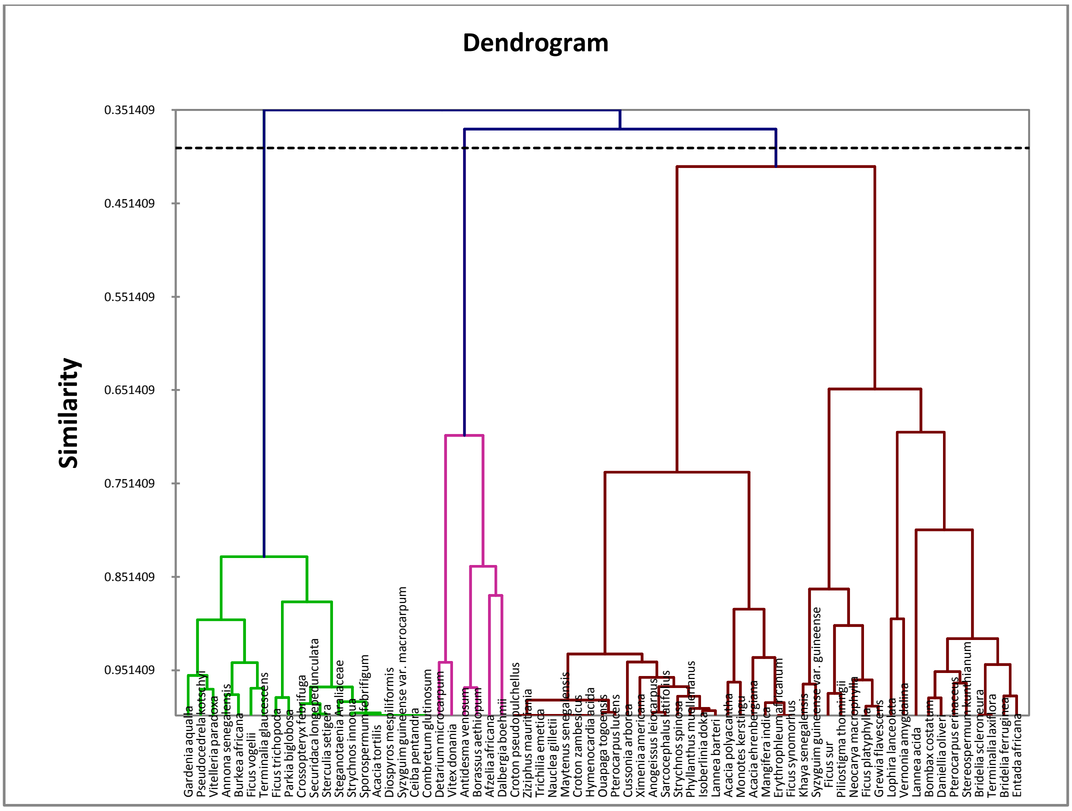


Figure 5: Dendogram of the phytomass, stock and carbon credit in the different vegetation types

Discussion

Human activities are the principal actor in the reduction of vegetation biomass (Oumarou SB, 2000). The deforestation of the escarpment by uncontrolled agricultural activities wood felling for heating and the service, the practice of bush fire, and overgrazing are factors of the degradation of the vegetation. These anthropoid activities lead to the reduction of the vegetal phytomass of the Ngaoundere escarpment. This production of the phytomass is low in the farms and fallow of less than 5years and higher in the word savanna. These results corroborates to those obtained in the peri-urban savanna of Ngaoundere by Tchobsala (2011) that shows that the wood savanna (169.91 t/ha) produces more phytomass and consequently sequestrate much mine carbon compared to shrub savanna (49.18 t/ha) and cleared plots (36.53 t/ha). Similar results were obtained in the woody savanna by Lamotte et al. (1983) who noted 150 t/ha of phytomass in the humid woody savanna of the tropics and to those of Ibrahima and Habib (2008) in the Adamawa who discovered 145.12 t/ha. Woody savannas are most often protected by the service of forest and ranches. The sequestration of carbon is hacked to the production of phytomass of the vegetation types in the Ngaoundere escarpment. This capacity of carbon sequestration at the level of savanna is 500Tgc, with 200 to 300 Tgc in the soil representing 10 to 20% of soil carbon of terrestrial ecosystems (Houghton, Anekson 1991). The production of carbon in the Ngaoundere escarpment is similar to the result of GIEC (2007) on the sequestration of carbon in longer forest ecosystems in France who found out that fairies sequestrates less carbon than fallow and natural vegetation.

Honan et al. (1998) demonstrated that dry savanna of Niger contains a total of 0.25 to 1.5 t/ha of carbon. These values are inferior to those of Ibrahima and Habib (2008) who showed that the shrub and woody savanna stock respectively 81.46 tc/ha and 118.36tc/ha. This difference is situated at the level of the sites (shrub and woody sources) she low production of carbon sequestrated in the farms shows that the intensive practice of tree felling on the vegetation greatly reduces the production of carbon (1,91tc /ha/gr. Kotto-Same et al. (1997) show that the conversion of biomes into pasture and farming liberates 15 to 20% of atmospheric carbon that is 44 to 66 tc/ha. Slash and burn shifting cultivation with a rate 2400 to 4200 Tgc/gr liberated in the atmosphere is also one of the main sources of carbon and also deforestation. This flux represents 43 % of total phytomass burnt (Hall and Scurlack, 1991). The practice of forest exploitation leads to the liberation of more than 0.33 Gt/c in the atmosphere (Kotto-Same et al 1997).

As confirmed by Kotto-Same et al. (1997) organic carbon contained in the soil is the most stable component during the change of land use. As such it is indispensable for us to better protect the components of the “aerial” pact without neglilating those of the rooting part in order to gather great stock of carbon in our savanna and realize a great profit in the carbon market.

When the vegetation is cut and burnt for agricultural purposes, the carbon that was sequestrated in this vegetation is liberated and affects climate change. Carbon credit is directly linked to the stock of carbon in the vegetation. The REDD+ mechanism that is a method based on carbon credit to encourage the population to protect, conserve, sustainable manage the ecosystems and vigorously follow up. If the neighboring population of Wack are conscious of the danger the vegetation of Ngaoundere escarpment and if they apply carbon credits which is a virtual market in which carbon credits is bought and sold and they can gain double; first the protection of their forest and secondly financial gains that the Cameroon government will give them in exchange for safeguarding the vegetation. Concretely the entities which limit its emission or sequestrate carbon obtain credit while the entity which reduces its emissions can buy carbon credits to compensate it. The compensation of emission of carbon is a mechanic permits the compensation of emissions non evitable by paying another entity to sequestrate GES (GIEC, 2002).

Conclusion and perspectives

The vegetation of the Ngaoundere escarpment is highly degraded by the implication and installation of autochthones and allochthones population in the search of substantial resources to satisfy their needs. These population exploits the vegetation of the escarpment for agriculture, forest, herb… product, traditional pharmacopeia, services etc. The conversion of forest space of this escarpment to farmlands through the phenomenon of tree felling beach to a drastic reduction of phytomass of the vegetation, consequently the stock of carbon of the vegetation. The sensibilisation of the population on the carbon market and the certification of the escarpment mountain forest will be a better approach to the biodiversity that threatened by extinction the putting in place of the REDD + system in the Ngaoundere region will be a long term (durable) solution for the protection and sustainable management of the natural ecosystem and the reduction of the poverty of the population through the carbon market.

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