The impact of anthropic activities on the primary productivity and carbon sequestered on Mount Ngaoundal in Adamawa-Cameroon

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1 ABSTRACT

This research was conducted to determine the impact of human activities on the primary production of plant species in Mont Ngaoundal. It consisted of using the MARP tools and floristic records sheets of vegetation. Plants parameters and sequestered carbon were assessed using standard equations proposed by several authors. The results indicate that Mount Ngaoundal is influenced among others by zoo-anthropogenic activities such as agriculture (13.94%), pharmacopoeia (12.98%) and ecotourism (11.50%). On a 19.2 ha surface area, the biomass produced by herbaceous species and emerging shoots was 4.780t/ha, and varied from one slope or altitude to another. On the overall, the biomass was the highest in the East (0.093t/ha), at 600m altitude (0.083t/ha), whereas the lowest was encountered in the North (0.036t/ha) and at 200m altitude (0.075t/ha). The most common signs of anthropization in the Mount were trimming of vegetation, burning of trees and cutting of firewood. A total of 4552 plant species were considered as induced by anthropization. The slope with the plant species presenting the highest anthropization indexes were the South (2160 individuals), the East (1009 individuals), while the West slope (516 individuals) was less anthropized. The most vulnerable altitude was that of 200m (1784 individuals: 39.19%), while altitude 600m (1038 individuals: 22.80%) was considered the less anthropized. The total CO2 emitted was 478.035 tC/ha. The stock carbon was the highest in the eastern slope (0.046 tC/ha), compared to the lowest in the northern slope (0.018tC/ha). Moreover, the stock carbon was the highest at 600m altitude (0.044 tC/ha), the lowest at 400m altitude (0.038 tC/ha). It is concluded that for the sustainable management of Mount Ngaoundal, the following proposed strategies to local population are to be applied: circumscription of the sampling area; creation of roads, creation of entrance taxes, and building of rental camps.

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2 INTRODUCTION

In Cameroon, the establishment of mining projects and their exploitation after the discovery of various mines before the independence has always been a subject of speculation. In this case, bauxite and sapphire were discovered in the sub-division of Ngaoundal and estimated to around 200 million tonnes and 1 million tones respectively. The area also possesses other potentials, such as touristic sites and a military training centre. The main economic activities including breeding, agriculture, beekeeping and ecotourism are all practiced at the level of Mount Ngaoundal. All these elements are degradation factors that can reduce the biodiversity of Mount Ngaoundal. The destruction of environment has been reported to lead to the scarcity or the reduced animal and plant species (Swaminathan, 1990). The main needs of populations, the bush fires and drought have caused a marked degradation of this natural environment. This is evidenced by a modification of the floristic composition and structure of the vegetation, a weak natural regeneration of certain plant species, as well as a denudation of soil, as the result of erosion factors (Diatta *et al.*,, 2009). If to meet their basic needs, the local populations exert several pressures on the environment, what will happen to the mining works on Mount Ngaoundal seems to be our concern. Several works have been carried out on the management conservation and development methods within the Guinea savannah Adamawa. These include is the case for the work of (Tchotsoua 1996; 2006), and those of Ntoupka (1998, 1999) on the influence of anthropogenic activities was carried out by in North Cameroon, Achoudong (1996) on the hills of Yaounde, Zapfack (2005) in South Cameroon, Hamawa (2015) in the Sudano-Guinean zone of North Cameroon, Tchobsala (2011) on the peri-urban savannah of Ngaoundere. Despite these researches, no scientific work has yet been conducted on the impact of the natural resources exploitation on the vegetation dynamics of Mount Ngaoundal. Hence, the overall objective of this study was to find out how human activities affect the biodiversity of Mount Ngaoundal, specifically the primary productivity, along with sequestered carbon, in an effort to propose a protection management program of the biodiversity.

3 MATERIAL AND METHODS

3.1 Description of the study area : The study area was located in the Ngaoundal district, Department of Djerem, region of Adamawa, with the GPS coordinates 12°856-13°020 East longitude, and 6°037-7°020 North latitude (Figure 1). It covers a surface area of 4,500 km2, with approximately an estimated population of 70.000 (CDV, 2007). The average annual rainfall is 1.500 mm, while the average temperature is 22°C (Ngaoundere Meteorological Station, 2011). The climate is of Sudano-guinean type comprising two seasons and harbouring a Sudano-guinean vegetation type.

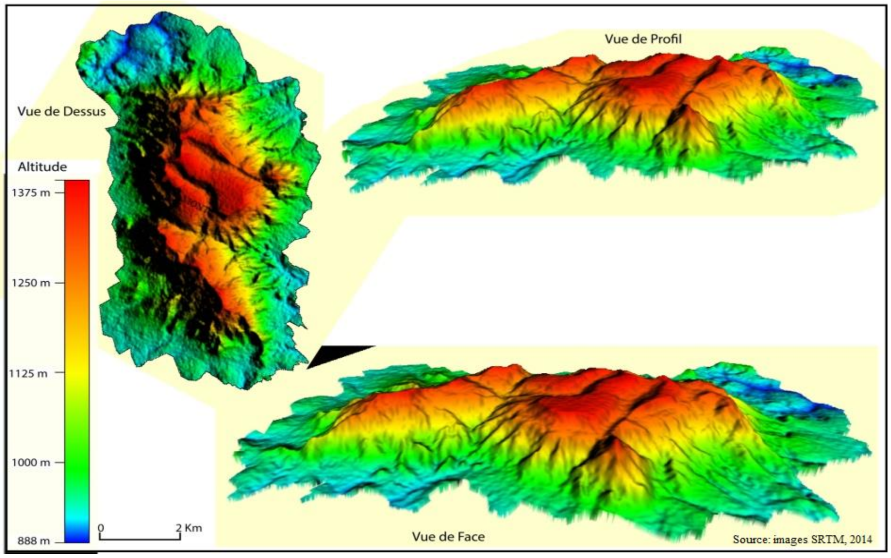

Figure 1. Partial view of Mount Ngaoundal

3.2 Methodology: The methodological approach used in this work was based on prospection and floristic inventories. Villages concerned by the surveys were: Camp Fara, Zimbabwe, Pied du Mont, Tapare, Sansi, Mbalonga, Mandal, Belaka and Cinema. In each village, 30 people were randomly interviewed, using criteria such as gender, ethnic groups and religion. A total of 270 people were interviewed. Herbaceous phytomass and regeneration within each 20m wide x 200m long sub-plot, 4 circles of 1m diameter were established on each side of the plot, while 1 circle in the middle was materialized, using a tape as measurement tool. All measurements were systematically carried out in each of the 20 m x 200 m plot. All the herbaceous plants in each circle were cut low at the ground using a cutlass, piled up, attached and weighed fresh using a Sartorus scale at 0.001 sensitvity. In total, 120 sub-plots (4 slopes x 3 altitudes x 5 sub-plots x 2 replicates) were selected. The fresh mass of all 120 samples was weighed in the field using a portable balance. A sub-sample was taken from each of 120 samples and weighed fresh. All the 120sub-samples were taken back in a container bag to the ENSAI laboratory of the University of Ngaoundere, and oven dried at constant temperature for 48 hours. The sub-samples were then reweighed to determine their dry weight for calculation of their water content as follow:

TE = MF-MS / MS * 100
Where, MF = Fresh Mass, MS = Dry Mass and TE = Water Content (%)
From the water content of sub-samples, the dry mass of the samples was calculated according to the following formula:

MST = 100 * MFT / (100 -TE) expressed in kg, then in t/ha
Where, MST = Total Dry Mass, MFT = Total Fresh Mass.

3.3 Determination of tree Biomasses

3.3.1 Aboveground biomass: The aboveground biomass of trees was assessed in 8 plots of 20m wide x 200m long, each subdivided into 200m altitude steps. The diameter at breast height (1.30 m from the ground) and the height of all trees in these plots were measured respectively using a 5m graduated tape. The biomass was estimated by the indirect method, using a mathematical model that takes into account the diameter at breast height and the height of trees. The Anderson *et al.,* (1937) equation was chosen for this study:

Ba = exp (-3.114 + 0.9719 ln (D2H)) where
Where, Ba = aboveground biomass of the tree, D = diameter at chest height (m) H = height of the tree expressed in (m).

3.3.2 Root biomass: Root biomass was estimated indirectly using the Cairns *et al.,* (1997) equation, which indicates that from aboveground biomass, root biomass (Br) can be obtained by the following equation:

Br (kg) = exp (-1.587 + 0.8836 x ln (Ba))
Where, Br = root phytomass, Ba = aboveground phytomass.

Thus, from the total aboveground biomass of each plant type, root biomass was calculated.

3.3.3 Total phytomass: The total biomass was calculated as the sum of the different biomasses as:

Bt = Ba + Br + B (h + r)
where, Bt = Total biomass; Ba = aerial phytomass, Br = root biomass, B (h + r) = biomass of herbaceous plants and shootings.

3.4 Estimation of carbon stock in the vegetation : The carbon quantities were calculated according to the equation developed by Ibrahima *et al.,* (2002), Saïdou *et al.,* (2012) that considers the value of the vegetation carbon concentration equal to 0.5.

QCv = B x Cv (tC /ha),
Where, QCv = Quantity of vegetation carbon, B = Biomass (t/ha) of each component of the vegetation (aerial and root, herbaceous), Cv = vegetation carbon concentration (0.5), taken when precise values are not available.

The total amount of carbon was calculated by adding the amounts of carbon from all components of the vegetation (above-ground, root, herbaceous and shootings). In other words, it was the sum of aboveground carbon, root carbon, herbaceous and shootings carbon.

Total QC = Aerial QC + Root QC + Herbaceous QC and shootings

3.5 Assessment of the emitted CO_2 in the study area : The amount of carbon dioxide (CO_2) emitted into the atmosphere if trees were inventoried in the sample plots were cut down was calculated by the formula used by Woods Hole Research Centre (2011) in Mali:

CO_2 = QTC * PM CO2/PMC,
Where, QTC is the total amount of carbon in the sampled soil, PM CO_2 is the molecular weight of carbon dioxide (44), PMC is the molecular weight of carbon (12).

3.6 Estimated quantity of CO_2 that will be released by the woody cover of Mount Ngaoundal in 2026 : This is concerned with the projection in the future of the approximate idea on the amount of CO_2 that could be emitted by the woody cover of Mount Ngaoundal by the year 2026, if conditions remain unchanged. To achieve this, the total amount of carbon emitted was first estimated on the entire Mount, in 2000 and 2016. From the obtained two data, the estimation of the amount of CO_2 that could be released in 2026 was deduced. The estimation of the total amount of CO_2 emitted by the entire woody cover of the study area in 2016 was based on data provided from sampling and the calculation of the expansion factor (FE). The expansion factor enables the generalization of the quantity of CO_2 found in the sample plots to the whole of the study area. It was calculated as follows:

FE = Total surface covered by the woody plant/Sampling surface area

The amount of carbon dioxide estimated on the sampled area was multiplied by the expansion factor in order to have an idea of the total amount of CO_2 emitted in the study area. The CO_2 emitted at the scale of the study area (CTS) was calculated as follows:

CTS = F E x CSE
Where, FE = Expansion Factor, CSE = Total CO_2 from the sampled area.

3.6.1 Estimation of the quantity of CO_2 emitted by the woody cover in 2000: Based on previous results, the estimate of the amount of carbon dioxide emitted by woody plants in 2000 was based on the area covered by woodlands during this period, knowing the area covered by trees in 2016, the amount of CO_2 emitted as:

CTS16 = F E * CSE
Where, CTS16 = CO_2 quantity in 2016

3.6.2 Estimation of the quantity of CO_2 emitted by the woody cover in 2026: On the basis of the assumption that the evolution conditions remain the same as in the previous 16 years, in order to be able to make projections over the years, it was necessary to determine the average annual value of CO_2 emissions over the last 16 years. Hence, we subtracted the CO_2 value for the years 2016 and 2000, then divided the result obtained by 16 (corresponding to the 16 years of differences between 2016 and 2000). Knowing the average annual CO_2 emission value, we multiplied it by 10 to get the approximate value of CO_2 emitted over 10 years. Then we summed the obtained value with the total amount of CO_2 for the year 2016, to be projected into 2026.

3.7 Assessment of the protection and conservation method of the vegetation and environment of Mount Ngaoundal: A questionnaire was prepared and administered to 270 people. This questionnaire deals with the co-management measures envisioned by the local population for the protection of the mountain. The questionnaire was supplemented by field observations (rational management of space, fallowing, parking, hut gardens, storage and awareness).

3.8 Data analysis: Socio-economic surveys and floristic surveys were subjected to analysis of variance (ANOVA), carried out to compare within slopes and altitudes each other. Values were compared between means using the Duncan Multiple range test at the indicated level of significance. The Microsoft Excel Office 2010 was used to monitor the data and plot the graphs.

4 RESULTS AND DISCUSSION

4.1 Activities practiced on Mount Ngaoundal : The main activities carried out by the local population on the Mount were agriculture (13.94%), traditional medicine (12.98%), beekeeping (12.71%), harvesting of PFL and NWFP (11.95%), ecotourism (11.50%) and military activity (10.84%), as shown on Table 1. Katakore (2011) has considered these activities to negatively affect woody plants in addition to climatic factors. Hunting (10.49%), animal husbandry (9.81%) and mining (5.51%) were second chosen place activities. All these activities carried out destroy the biodiversity of Mount Ngaoundal, and contribute the reduction or disappearance of certain natural resources. The results of Larwanou (2005) and Katakore (2011) in Niger pointed out that tree cutting, bush fires, agriculture and animal husbandry were activities leading to destruction of vegetation and woody trees, which corroborates with the present results. Agriculture was 100% practiced in villages such as Camp Fara, Tapare, and Belaka.

Table 1: Activities practiced on Mount Ngaoundal by local population (%)

Types of activities	Camp Fara	Zimba bwe	Cinema Mount	Bottom Mount	Tapare	Mbal onga	Sansi	Mandal	Mbel aka	(%)
Agriculture	100	87.5	80	85.71	100	95.83	91.67	85.71	100	13.94
Pharmacopea	100	100	100	100	100	54.17	91.67	28.57	94.74	12.98
Apiculture	100	100	100	100	50	75	100	28.57	100	12.71
PFLet/ PFNL	94.12	100	100	100	100	37.5	58.33	28.57	89.47	11.95
Ecotourism	100	100	100	14.29	100	91.67	50	57.14	68.42	11.50
Militairy	94.12	93.75	100	71.43	50	83.33	16.67	85.71	47.37	10.84
Hunting	100	81.25	100	85.71	100	83.33	0	71.43	0	10.49
Breeding	88.24	93.75	100	100	0	83.33	16,67	57.14	42.11	9.81
Mine	41.18	56.25	60	85.71	50	33.33	0	0	0	5.51
Rites	5.88	6.25	0	0	0	4.17	0	0	0	0.28

4.2 Primary productivity of Mont Ngaoundal: The overall biomass produced by herbaceous plants and shootings on a surface area of 19.2 ha was 4.780 t/ha, thus was higher than the previously obtained by Haiwa *et al.,* (2021) on protected areas in the far north of Cameroon. This biomass varied according to slopes (higher in the East (0.093 t/ha) and lower in the North (0.036 t/ha), and altitudes with higher values (0.083 t/ha) at 600m altitude and lower (0.075 t/ha) at 200m altitude (Figure 2). The dominant herbaceous species were represented by Andropogon spp., Loudetia spp., Hyparrhenia spp., because very few animals were able to graze there.

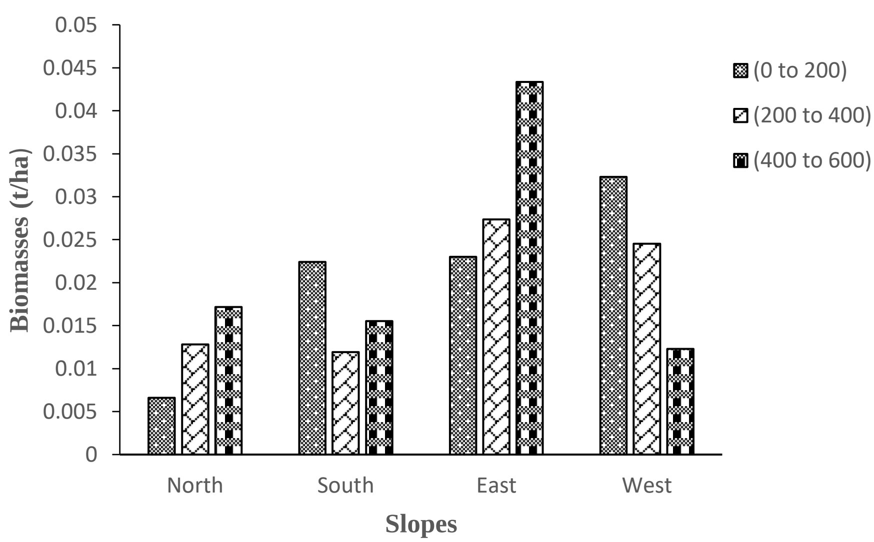

Figure 2. Variation of herbaceous and shootings biomasses with slopes and altitude

4.3 Anthropization indexes of plant species according to slopes: The most common signs of anthropization in the Mount were trimming of vegetation, burning of trees and cutting of woods. The slopes with high anthropization indexes were the South (2160 individuals) and East (1009 individuals), while the North (867 individuals) and West (516 individuals) were less affected by anthropization. Taking into account these dominant indexes, the most affected slopes in order were: the South (739 trimming 508 burns; 398 cuts), followed by the North (188 trimming 246 burns, 282 cuts); East (339 trimming 155 burns, 162 cuts) and finally West (286 trimming 137 burns, 46 cuts). This could be explained by the fact that the southern slope has a waterfall that attracts many visitors for ecotourism, unlike the northern slope, where ecotourism was weakly attracted. The species that were severely damaged were *Daniellia oliveri* (742 individuals), followed by *Piliostigma thonningii* (682 individuals), *Hymenocardia acida* (492 individuals), *Cussonia arborea* (358 individuals) and *Terminalia glaucescens* (350 individuals). The following species were subjected to significant cuts: *Piliostigma thonningii* (79 individuals) followed by *Daniellia oliveri* (62 individuals) and *Hymenocardia acida* (36 individuals). The species that were more skinned were *Terminalia glaucescens* (20 individuals), *Daniellia oliveri* (16 individuals), *Piliostigma thonningii* (13 individuals), and *Pterocarpus lucens* (13 individuals). Pruning was more observed in species such as: *Piliostigma thonningii* (11 individuals), *Terminalia glaucescens* (11 individuals), *Daniellia oliveri* (10 individuals) while for burns, the most threatened species were *Piliostigma thonningii* (101 individuals). As far as trimming is concerned, it is caused either by animals or by humans and the most endangered species were *Daniellia oliveri* (151 individuals), *Hymenocardia acida* (128 individuals), *Piliostigma thonningii* (103 individuals), *Terminalia glaucescens* (69 individuals) and *Cussonia arborea* (61 individuals). Species such as *Piliostigma thonningii* (29 individuals), *Daniellia oliveri* (28 individuals), *Terminalia glaucescens* (26 individuals), *Hymenocardia acida* (22 individuals) were the most attacked by diseases. Those which have undergone other signs of anthropization such as windfall, runoff, erosion were *Daniellia oliveri* (4 individuals) *Ficus sycomorus* (2 individuals), *Annona senegalensis* (2 individuals) and *Terminalia glaucescens* (2 individuals).

4.4 Anthropization indexes of species according to altitudes: The most threatened altitude was that of 200m with 1784 individuals, or 39.19%, while the least man-made altitude was 600m with 1038 individuals, or 22.80%. This could be justified by the fact that at 200m the local population has easy access to the Mount due to weak slopes on one hand, and represent the basal part of the Mount where agriculture is practiced on the other hand. At 600m, access becomes difficult for populations, while plants are less impacted by humans and animals. Trampling (700 individuals) was greater at 200m compared to other altitudes. Cuttings were rather high at 400m (276 individuals), 200m (269 individuals) and 600m (100 individuals). Contrary to our expectations, the lower cuttings at 200m altitude was attributed to excess cut down of trees, due to the accessibility by population compared to 400m altitude. Young shoots were then subjected to trimming if they were not cut. At high like altitude like 600m, the difficult access was the main parameter reducing the cuttings (100 individuals). Species that were very much affected by anthropization indices include *Daniellia oliveri* (673 individuals), *Piliostigma thonningii* (561 individuals), *Hymenocardia acida* (476 individuals), *Terminalia glaucescens* (450 individuals), and *Cussonia arborea* (304 individuals). Cutting was the must exerted on *Piliostigma thonningii* (48 individuals), *Daniellia oliveri* (41 individuals), *Hymenocardia acida* (32 individuals), *Cussonia arborea* (18 individuals), *Terminalia glaucescens* (18 individuals), *Sarcocephalus latifolius* (27 individuals), *Psorospermum senegalensis* (18 individuals). Trimming intensively affected *Hymenocardia acida* (65 individuals), *Piliostigma thonningii* (33 individuals), *Daniellia oliveri* (32 individuals), *Terminalia glaucescens* (9 individuals) and *Steganotaenia araliacea* (8 individuals). Pruning was concerned with *Piliostigma thonningii* (18 individuals), *Hymenocardia acida* (13 individuals), *Daniellia oliveri* (12 individuals), and *Terminalia glaucescens* (10 individuals). Species that have the barks removed were *Hymenocardia acida* (35 individuals), *Terminalia glaucescens* (19 individuals), *Daniellia oliveri* (12 individuals) and *Piliostigma thonningii* (13 individus). Tree species that were burn by fire include *Terminalia glaucescens* (71 individuals), *Cussonia arborea* (65 individuals), *Daniellia oliveri* (54 individuals), *Piliostigma thonningii* (52 individuals), *Hymenocardia acida* (32 individuals), *Psorospermum senegalensis* (27 individuals) and *Pterocarpus lucens* (26 individuals). Other species were affected by pasture and include *Daniellia oliveri* (170 individuals), *Hymenocardia acida* (94 individuals), *Piliostigma thonningii* (61 individuals), *Terminalia glaucescens* (93 individus) and *Cussonia arborea* (56 individus). Tree species presenting disease symptoms were *Piliostigma thonningii* (19 individuals), *Daniellia oliveri* (19 individuals), *Hymenocardia acida* (19 individuals) and *Terminalia glaucescens* (13 individuals). Species damaged by other factors were *Hymenocardia acida* (15 individuals), *Piliostigma thonningii* (15 individuals) and *Daniellia oliveri* (4 individuals).

4.5 Effect of slopes and altitudes on the phytomass of species: A total of 62 plant species contributed to the primary production of Mount Ngaoundal. The total biomass of the woody species of Mount Ngaoundal was 261.86t/ha, with 198.07 t/ha accounting for the total aboveground phytomass, while 64.02 t/ha was for root phytomass. Depending on the slopes, the above ground biomass was estimated to 198.07 t/ha, comprising 63.61 t/ha for the East, 50.17 t/ha for the West, 28.65 t/ha for the North and 55.64 t/ha for the South slopes of the Mount, the greatest accounting for the East slope. This result is similar to that of Grouzis (1991), who indicated that degraded zones can only produce very little phytomasse. Plant species that produced the most aboveground biomass were identified as *Combretum molle* (8.71 t/ ha), *Daniellia oliveri* (6.72 t/ha), and *Piliostigma thonningii* (4.08 t/ha). The root biomass was evaluated to 64.15 t/ha, with 19.89 t/ha, 15.25 t/ha, 9.88 t/ha, and 19.13 t/ha, respectively for the East, West, North and South slopes. Daniellia oliveri (1.87 t/ha), *Piliostigma thonningii* (1.20 t/ha), Pterocarpus lucens (1.20 t/ha), *Terminalia glaucescens* (1.14 t/ha), were in this order the tree species that provided the most root biomasses. This result is in line with that of Ibrahima *et al.,* (2002) in the tropical humid forest of South-Cameroon where phytoomass was important in less affected zones. On the overall, the Eastern slope provided the highest biomass (83.49 t/ha), followed by the South (74.42 t/ha), the West (65.42 t/ha), whereas the North slope produced only 38.53 t/ha. This could be attributed to the heavy exposition of tree species of this slope to the sunshine. At the level of each slope, the aboveground phytomass was greater than the root biomass. As the result of anthropization, the decrease in phytomasses production was more pronounced for species such as *Erythrina sigmoidea*, *Ficus abutifolia*, *Elaeis guineense* and *Bridelia scleroneura*, that could only release respectively 0.11 t/ha, 0.13 t/ha, 0.63 t/ha and 0.84 t/ha of phytomasses. Considering the altitude, the entire aboveground biomass produced was 199.81 t/ha dispatched into 53.87 t/ha for 200m altitude, 91.20 t/ha for 400m altitude, and 54.74 t/ha for 600m altitude. The greatest aboveground biomass found at 400m altitude, could be related to the important density of plants at this level. Plant species found to produce the best aboveground biomasses were recognized as *Pterocarpus lucens* (4.06 t/ha), and Piliostigma thonningii (4.08 t/ha). As for root biomass, a total of 62.06 t/ha was produced with 25.39 t/ha, 20.15 t/ha, and 16.52 t/ha accounting for 400m, 600m and 200m altitudes respectively. Root biomass was the highest at 400m altitude. The species producing the most important belowground biomasses were *Piliostigma thonningii* (1.20 t/ha), and *Terminalia glaucescens* (1.58 t/ha).

4.6 Carbon stock: The quantity of carbon produced by the herbaceous plants in the Mount was 0.124 tC/ha (Figure 3). The carbon stock was the highest on the East slope (0.046 tC/ha) and the lowest for the northern slope (0.018 tC/ha). Similarly, the carbon stock was the highest at 600m altitude (0.044 tC/ha) and lowest at 400m altitude (0.038 tC/ha). This difference could be explained by the fact that in the North, the exploitation of rocks involves trimming of herbaceous plants, while agricultural practice requires the cuttings and ploughing. In the south, the presence of the waterfall and the drinking troughs causes numerous trimming of the herbaceous plants and of the shootings. To the east, the presence of military activity (firing range) prevents access to neighbouring populations and promotes the development of herbaceous plants. This result is in agreement with that of Ntoupka (1999) obtained in the sudano sahelian zone of Cameroon. As for the western slope, it was the strongest slopes, which did not allow the populations to climb easily and stress the vegetation. The 600m altitude provides the most carbon (0.044 t/ha) from herbaceous plants and shootings, while the 400m (0.036 tC/ha) and 200m (0.037 tC/ha) altitudes provide the least carbon, in line with previous results by Ibrahima *et al.,* (2008) within the woody and arbustives Sudano-guinea savannah of Ngaoundere. This result could be justified by the fact that the density of herbaceous species was not important. At 400m altitude, woody species with high density impede the development of herbaceous, resulting in the declined carbon stock (0.38 tC/ha) at this altitude.

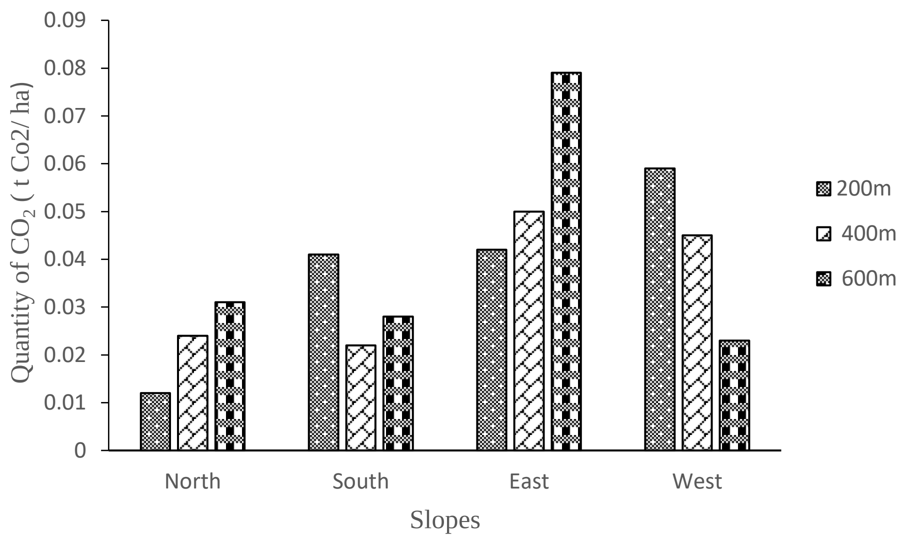

Figure 3. Sequestered carbon in herbaceous and shootings phytomasses as affected by slopes and altitudes

4.7 Sequestered carbon by ligneous species as affected by slopes and altitudes : The 62 tree species identified sequestered 130.92 tC/ha, indicating that Mount Ngaoundal is little anthropized and that pollution is not high. The greatest carbon stock per hectare was produced on the eastern slope (41.74 tC/ha), while the northern slope provided only 19.09 tC/ha. The Eastern slope with 41.74 tC/ha sequesters more carbon. This could be due to the fact that, although this slope was anthropized, it benefited from sunlight, unlike the other slopes. Regeneration being important, favoured the permanent sequestration of carbon despite the cutting and burning of trees. The total soil carbon stock is 98.84 tC/ha. It is greater than the amount of total hypogenous carbon (32.08 tC/ha). For each slope, the aboveground carbon stock is greater than the belowground carbon. The species sequestering the most carbon were *Daniellia oliveri* (10.22 tC/ha), *Terminalia glaucescens* (8.04 tC/ha) and *Piliostigma thonningii* (7.13 tC/ha). Those accumulating little carbon were Gardenia aqualla (0.03 tC/ha), Flacourtia indica (0.04 tC/ha, Ficus abutifolia (0.06 tC/ha). Depending on the altitude, the sequestered carbon is 130.25 tC/ha. The sequestered carbon stock was greater at 400m with 58.29 tC/ha, followed by 600m (37.43 tC/ha) and 200m (35.20 tC/ha). The 400m altitude sequestered the highest carbon (58.29 tC/ha), the 200m altitude provided little carbon (35.2 tC/ha). This could be attributed to the high density of species at altitude of 400m. This finding is closed to the observations of Abib (2005) who showed that the quantity of carbon was more important in some humid savannah of ngaoundere that were not degraded. The aboveground carbon was 99.91 tC/ha, whereas the belowground carbon was 31.01 tC/ha. The species sequestering the most carbon were *Daniellia oliveri* (10.22 tC/ha), *Terminalia glaucescens* (8.04 tC/ha), *Piliostigma thonningii* (7.13 tC/ha), similar to consistent carbon quantity revealed in California la forest (Gonzalez *et al.,*, 2010).

4.8 Quantified CO_2 emitted: The CO_2 emitted was 478.035 t/ha from herbaceous plants and shootings on the one hand and woody plants on the other. Figure 4 indicates that the herbaceous plants and the shootings provide 0.457 tCO_2/ha. The Eastern produced the most CO_2 (0.171 tCO_2/ha), followed by the West, which provided 0.126 tCO_2/ha. The Southern (0.091 tCO2/ha) and Northern (0.067 tCO_2/ha) produced little CO2. Depending on the altitude 600m provided 0.161 tCO_2/ha, followed by 200m which produced 0.154 tCO_2/ha and finally 400m which yielded 0.140 tCO_2/ha.

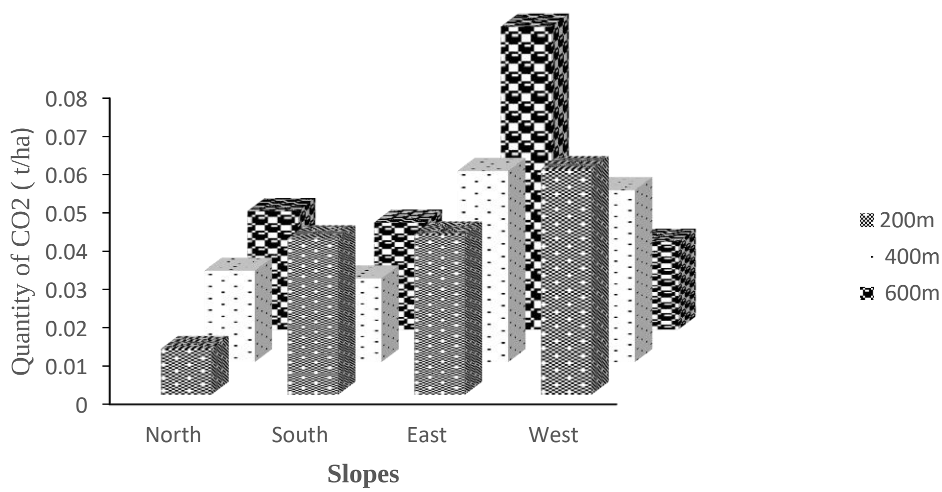

Figure 4. CO_2 emitted by herbaceous and shootings

The woody plants of the study area (19.2 ha) provided 477.578 t/ha of carbon dioxide. The eastern slope produced 151.31 t/ha, the southern (135.69 t/ha), the western provided 119.93 t/ha of CO_2 and the northern 70.62 t/ ha of CO_2. This could be explained by the fact that the eastern and the southern had a high density compared to the northern. This result is the same as that of Massaoudou *et al.,* (2015) who showed that as one leaves the South for the north of Niger, plant population decreases. The species that provided most CO_2 were *Daniellia oliveri* (37.462 t/ha), *Terminalia glaucescens* (29.482 t/ha), *Piliostigma thonningii* (26.142 t/ha), *Combretum mollis* (25.351 t/ha), *Pterocarpus lucens* (22.246 t/ha), *Vitellaria paradoxa* (19.908 t/ha), *Terminalia laxiflora* (19.083 t/ha).

4.9 Simulation of CO_2 emitted by Mount Ngaoundal in 10 years time : Human are heterotroph, therefore, needs oxygen for his breathing. Oxygen is supplied to plants through photosynthesis, which takes place through the absorption of the CO_2. During this same phenomenon, plants purify the air. Evaluating therefore the amount of CO_2 emitted in 10 years would enable the protection of species that produce more, so that the mountain continually serves as an oxygen reservoir without which life is not possible. Figure 5 shows that the amount of CO_2 emitted increases over the years, due to cuttings of wood. The lower quantity of CO_2 emitted by plants of the Mount Ngaoundal justifies the fact that the Mount is little anthropized.

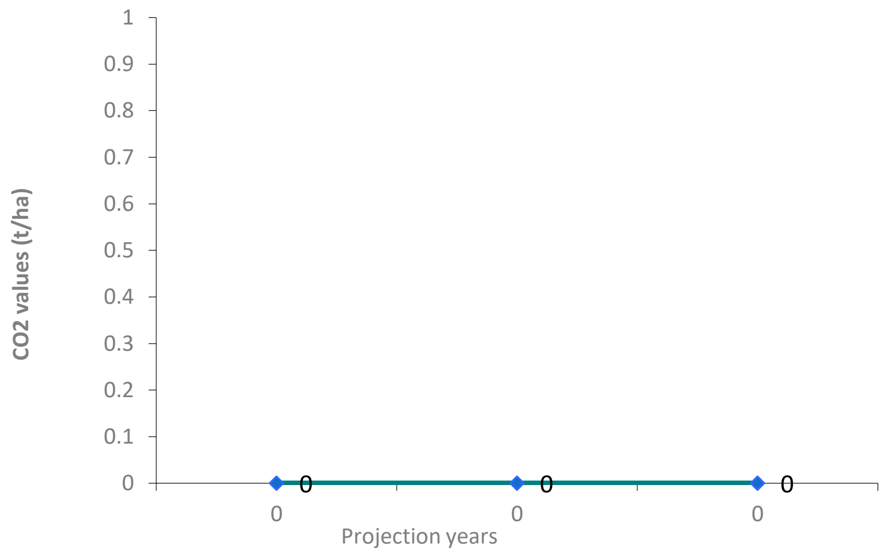

Figure 5. CO_2 emitted by Mount Ngaoundal in 10 years projection

4.10 Strategies measures to protect Mount Ngaoundal: The measures proposed in table 2 take into account the problems encountered, their causes and the resulting consequences, and the solutions envisoned for a sustainable management of the Mount Ngaoundal.

Table 2. Proposed measures to sustain Mount Ngaoundal

Causes	Effects	Consequences	Solutions
Rock samplings	Erosion	destruction of soil and vegetation	Selection of sampling zones
Visits (water falls)	Ecotourism	Financial income	Construction of roads, creation of entrance taxes construction of logging camps
ploughing	Production of CO2	Emission of greenhouse gases (pollution)	Avoid pollution activities (wastes, effluents) Teach people the importance of vegetation

5 CONCLUSION

The outcome of this research is that six (6) activities carried out by the local population on the Mount are agriculture (13.94%), traditional medicine (12.98%), beekeeping (12.71%), harvesting of PFL and NWFP (11.95%), ecotourism (11.50%) and military activity (10.84%). Poaching and/or hunting (10.49%), animal husbandry (9.81%) and mining (5.51%) come second. All these activities carried out on the Mount destroy the biodiversity of this ecosystem. The most common signs of anthropization in the Mount were trimming of vegetation, burning of trees and cutting of wood. The slopes with high anthropization indexes were the South with 2160 individuals, the East with 1009 individuals, the North has 867 anthropogenic individuals and the West with 516 individuals. The most affected altitude was that of the 200m with 1784 individuals, or 39.19%, the 400m with 1731 individuals come second (38.02%). The least anthropized altitude was 600m with 1038 individuals, or 22.80%. The total amount of biomass produced by the Mont is 4,896,192 tones. Depending on the slopes, the eastern slope which produces the most important biomass (41.74 tC/ha) compared to the other slopes which provide little while, depending on the altitude, it was the altitude 400m that produces the more biomass (58.29 t/ha) compared to other altitudes which produce little. The largest carbon stock per hectare was produced on the eastern slope (41.74 tC/ha), compared to the northern slope with only 19.09 tC/ha. The East with 41.74 tC/ha sequestered more carbon. Depending on the altitude, the carbon sequestered was 130.25 tC/ha. The sequestered carbon stock was greater at 400m altitude with 58.29 tC/ha, then 600m (37.43 tC/ha) and only 35.20 tC/ha at 200m altitudes. The 400m altitude sequestered more carbon (58.29 tC/ha), than the 200m altitude (35.2 tC/ha). In order to protect the mountain, the local population has become aware of the consequences of the exploitation of the mountain and has formulated proposals for the safeguard of the mountain. These include circumscription the sampling area, creation of roads, and creation of an entry tax, building of rental camps, prohibition of polluting activities (throwing out of non-degradable garbage, throwing products that could destroy the microflora and microfauna of the soil, and educating all users of the importance of vegetation.

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