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RESEARCH ARTICLE

IMPACT OF MOUNT NGAOUNDAL EXPLOITATION ON VEGETATION EVOLUTION: IMPLICATION ON SUSTAINABLE MANAGEMENT

***Haoua Madeleine, Ibrahima Adamou and Tchobsala**

University of Ngaoundere, Faculty of Sciences, Department of Biological Sciences, Laboratory of Biodiversity and Sustainable Development, Cameroon P.O BOX 454

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ABSTRACT

A study was carried out on the impact of exploitation of mount Ngaoundal vegetation evolution. Anthropic activities expose mount Ngaoundal to damage and heavy deforestation. The main activities in practice on the mountain include agriculture (91.82%), pharmacopeia (85.46%), ecotourisim (75.72%), military activity (71, 38%). Hunting (69. 08%), rearing (64.58%) and activities practiced by miners (36.27%) constitute secondary activities. The local population picks enough products from mount Ngaoundal. Firewoods (92.42%), followed by barks (52.80%) and leaves (36.67%) are mainly picked from mount Ngaoundal. The populations get foodstuffs mainly from the mountain. Some people treat themselves specifically from local plants. Products less represented include arabic gum (1.44%), seeds (4.62%), and flowers (7.53%). Products such as honey (21.04%), mushrooms (33.06%), roots (33.90%) and fruits are intermediates. All these activities have impacts on the vegetation evolution. Analyses of satellite images on the mountain evolution showed that mount Ngaoundal vegetation is heavily fragmented since 1985. The grassy savanna has cut down dramatically and given room to vegetable formations such as thin or gallery forests. Those forest surfaces have increased on the detriment of grassy and ligneous savannas with 152.84ha and 430.67ha in 1985 to 505.79ha and 657.97ha in 2016 respectively. In order to preserve anthropic activities, revering populations have put in place protective measures such as village eco-keepers (31.40%), vigilante committees (21.12%) and intensification of sensitization of revering populations on the importance of mount Ngaoundal (11.52%).

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INTRODUCTION

In Central Africa, demographic explosion that has been observed these last decades has negative consequences on environment because management of available natural resources is not sustainable (Palmberg-Lerch, 1997). Increasing needs of population, wildfires, erosion and anthropic action have provoked serious deterioration of ecosystems. These damages constitute today threats to biodiversity since they lead to inevitable, rare or disappearance of species (Swaminathan, 1990). Facing the seriousness of the environment damage, many countries met in 1992 in Rio de Janeiro for the 1st summit on earth. These countries established a convention on the biological biodiversity, with the objective of protecting biodiversity worldwide. The convention marked the international awareness on environment.

****Corresponding author: Haoua Madeleine***
University of Ngaoundere, Faculty of Sciences, Department of Biological Sciences, Laboratory of Biodiversity and Sustainable Development, Cameroon P.O Box 454

Cameroon on its side marked its support to the convention by promulgating the law 94/01 of January 20th/94 on forest, wildlife and fishery policy by emphasizing on integration of innovative strategies on natural resources. To this, the law 96/12 of August 12th 1996 on management of environment was added. These two laws focus on strategic and political framework which objective is to promote sustainable management of Cameroon forest by encouraging the participation of all users to the process of decentralization of forest utilization and management. Adamawa region in Cameroon, situated between the northern desert region and the south tick forest belongs to a sudano-guinean phytogeographic zone that is subjected to natural and anthropic pressures. Satellite images on lands occupation showed that Ngaoundere town surface changed from 120ha in 1991 to 1256ha in 2001(Tchotsoua, 2006). Savanna surfaces were reduced to 10.8% in 2001 compare to 1951. Priority factors on vegetation damages include fire clearing agriculture (Zafact, 2005), combined effects of firewood's cutting and wildfires on pastures (Ntoupka,1994;1998), activities practiced by miners

and hydroelectricity, demographic growth (Tchosoua, 2006) urbanization and human activities (Mapongmetsem *et al*., 1997) wildfires and erosion. A man becomes a parasite in his environment and this changes the running of ecology, leading to the disappearance of many species (Wanders, 2000). The discovery of ores on mount Ngaoundal in the Ngaoundal subdivision before the independence of Cameroon, has created a project now almost at the level of its finalization. The Ngaoundal subdivision has other potentialities among which touristic sites, a military training centre etc... Other economic activities based on livestock rearing, agriculture, beekeeping and ecotourism are practiced on the mount Ngaoundal. All these factors have contributed to the deterioration of mount Ngaoundal and to the bad sustainable management of environment. The aim of this work was to study the impact of anthropic activities on the state of evolution of mount Ngaoundal for a devised together management of the mountain. Specifically it is: i) to determine the causes and consequences of anthropic activities practiced on the mount Ngaoundal; ii) to show the impact of exploitation on vegetation; iii) to study the vegetation evolution and iv) to propose protective and conservationist methods on mount Ngaoundal vegetation.

MATERIALS AND METHODS

Study area

Ngaoundal is one of the subdivisions under the Djerem division. It is situated between the 12°856 and 13°020 longitude East, 6°037 and7°020 latitude North (Figure 1). The population is about 7000 inhabitants. Annual mean precipitation is 1500mm (Meterology Centre of Ngaoundere). The climate is sudano-guinean type. The mean temperature is 22°C (Haoua, M 2007), with a landmass of 4500km (CDV, 2007). Mount Ngaoundal is a chain of young mountains with the highest altitude of 1393km named from the Mbum language "Ngaoundaye" that means "mountain of cattle". It is from this that originated the town of "Ngaoundal" in the French language. The Mbum, Dii, Mbgaya are the indigenous. Other ethnic groups like the Bororo, Fulani, Bassa, Massa, Toupouri, Bamileké and Anglophone are also present.

Study design and sampling techniques

A field trip with guides on mount Ngaoundal was made to prospect the study area. Surveys were carried out in nine (9) villages because of their proximity around the mountain.

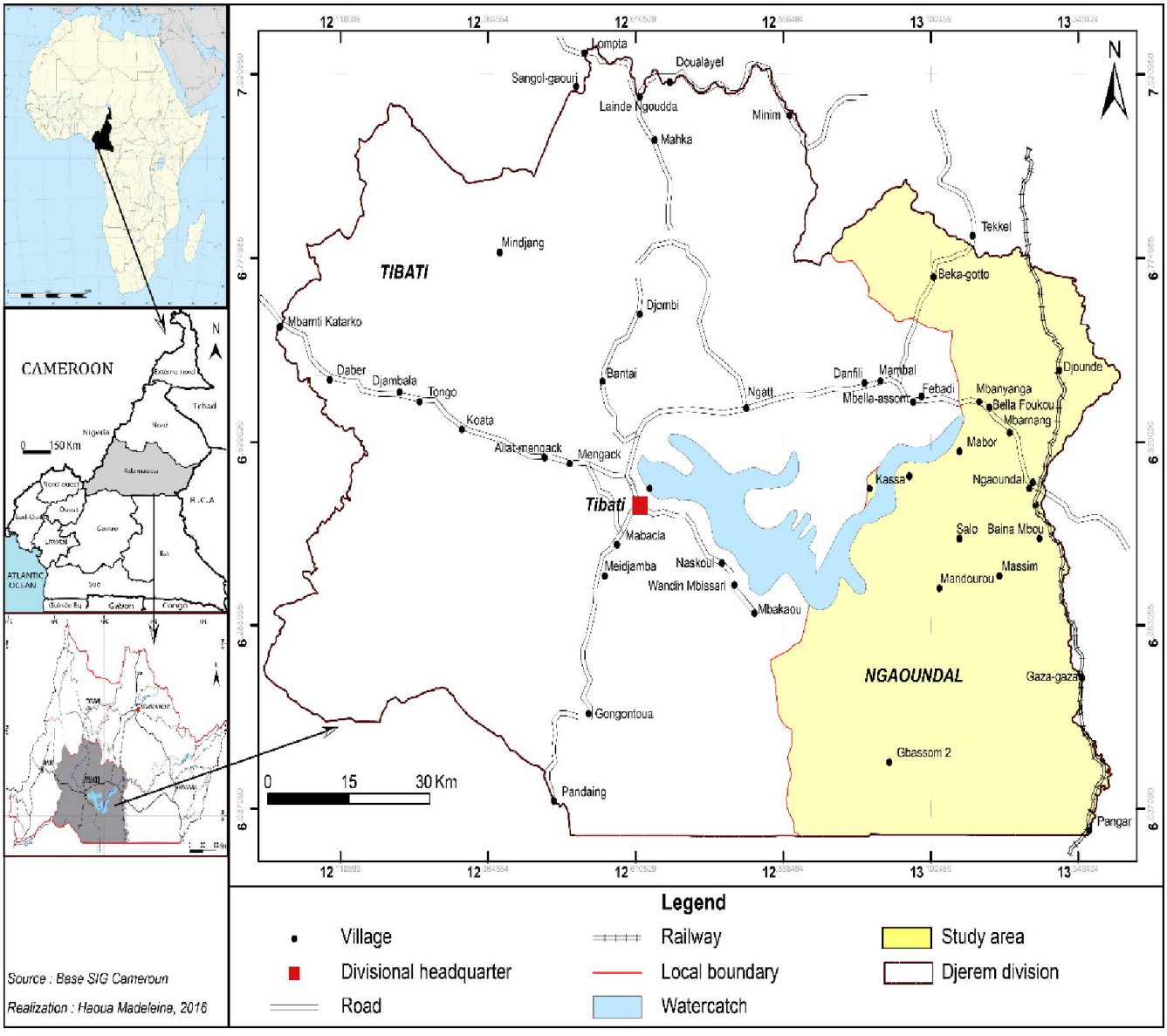


Figure 1. Map of localization of the study area (Mount Ngaoundal)

In each village, 30 people were randomly interviewed, this without age, sex, ethnic group and religion differences. Questions were asked to people above 15 years old so as to maximize reliable answers. Two hundred and seventy (270) persons in total were interviewed. The map of vegetation evolution was drawn from satellite images. The images were downloaded freely from the Earth Explorer site. These images were downloaded while avoiding those covered by clouds. These were Landsat's images with a definition of 30m at the "tif" format. For the 2016 image, we used the Landsat 8 OLI (Operational Land Imager), the Landsat's 7 ETM+(Enhanced Thematic Mapper plus) for the 2000 imagery and the Landsat 5 for the 1985 image.

Steps in the acquisition of satellite images

Definition of classes

The process in the mapping was followed using the elaboration of predefined classes of land occupations that helped in the definition of legend. The thematic definition of classes was made after many field trips. Seven (07) classes were defined and these included: gallery forests, thin forests, ligneous savanna, bushy savanna, grassy savanna, shadow, built or bare soil.

Treatments of images

Treatments of images helped to show the state of land occupation in the study area. These were made on the Landsat images with the help of the visual-interpretation of colored compositions.

Preliminary operations

These include all operations from the assemblage of bands at the creation of colored compositions through the extraction of the study area.

Assemblage of bands and stages

The first step of our work was the gathering of 09 bands of 11 that constitute the landsat image. This was done through the use of the spectral /layerstack command of the Erdas Imagine Software. This operation helped to get a stage covering the study area.

Extraction of the study area

The extraction was made from the sphapetile of the area in our possession. The command that was used was the Subset and chip/Create subset image.

Creation of colored compositions

It is an operation consisting in the combination of data from three bands by their automatic visualization in the three primary colors namely the RGB (Red, Green, Blue). Its objective was to visualize properly the types of land occupation.

Creation of areas of drive

A parcel land of drive also called "area of interest" is a pixel or a group of pixels chosen for the representation of a class.

Creation of the spectral signatures file

Each object at the surface of soil receives pencil of rays from sun. From its nature and characteristics, it can remit or reabsorb the received radiation. This giving out or reflectance of the object depends on the length of waves and this helps for its identification on the satellite images (Abena, 2011). Once the file is created, it is registered for use in the course of classification. Figure 3 shows the spectral signature file created from the ERDASIMAGINE software.

Class #	Signature Name	Color	Red	Green	Blue	Value	Order
1	Grassy savanna		0.000	1.000	0.000	1	1
2	Bushy savanna		0.498	1.000	0.000	2	2
3	Wooden savanna		1.000	0.753	0.796	3	3
4	Shadow		1.000	1.000	1.000	4	4
5	Gallery forest		0.000	0.392	0.000	5	5
6	Thin forest		0.498	1.000	0.000	6	6
7	Bare land / build land		1.000	0.000	0.000	7	7

Figure 2. Example of files of spectral signatures

Operations of classifications

A classification is a process of sorting out and gathering of pixels of an image that helps to pass from satellite images to soil occupation maps. The aim of classification is to map a representation more accurately from spectral values of pixels constituting the source of image and some, according to a define nomenclature previously established (Aoudou, 2010). There are two types of classification: the first is the directed and supervised classification and the second is the unsupervised that takes place independently from the user. Within the scope of our work, we used a directed classification. The principle of a directed classification is to supply to the software samples of pixels (AOI) representing the referenced region of known nature of drive sites (classes).

Choice of the method of classification

We opted for the method of classification named "maximum de vraissemblance" or "maximum of likelihood in English", for its popular use in teledetection (Kouedjou, 2015). This method is based on probabilistic methods. It consists in calculating the probability of a pixel to belong to a class rather than another. At the end of this operation, each image pixel is linked to one of the classes of land occupation previously listed (Aoudou op. cit. Kouedjou op. cit).

Creation of the geodatabase, import of shapefiles and calculation of thematic classes surfaces.

After the supervised classification, a geodatabase is created with Arc MAP10. Then rasters files ensuing from the classification are converted in shapefile and integrated in the geodatabase with the module Arc catalog of the software. In each associated table attributed, one attribut "Area" is added and will contain the surface of each polygon.

Evaluation of classification

This evaluation is through spectral signatures of the objects. It can be done either trough the matrix confusion or through the calculation of the kappa index.

Kappa index

It is an index mostly used in teledetection and helps to estimate the classification precision. It measures precision and expresses the proportional reduction of the acquired error from a classification, compared to an error obtained from a classification completely by coincidence (Anonymous, 2013; Anaba, 2010). From Anonymous (2013), this is the formula:

$$K = \frac{N*xii - \sum_{i=1}^{r}(Xi*Xii)}{N^2 - \sum_{i=1}^{r}(Xi*Xii)}$$

r is the number of lines of confusion matrix
xii is the number of observations in the line i and the row i
$Xi\ et\ Xii$ are marginal totals of the line i and row i
N is the total number of observations.

Validation of results from the classification through the Kappa index

The Kappa index (K) is used to validate and estimate the classification precision. The mean value of the Kappa index obtained within the frame work of 03 classifications is higher than 93%. According to Pontius (2000) cited by Anaba (opcit), in a study of land occupation, if the evaluated Kappa index in operations of classifications is between 50 and 75 %, the adopted classification could be valid. Whereas when it is above 75 % like in our case, the classification is very good.

Method used for the protection and preservation of vegetation and the environment in mount Ngaoundal

An index card of questionnaires was prepared and administered to 270 people. Questions concerned measures of co- management to be considered by the local population for the protection of the mountain. Questionnaires were completed after visual observations in the field (concerted management of space, fallow, parking, house gardens, stocking, sensitization).

Statistics

Double data entry and validation were performed in Excell version 2013, and statistical analyses were done with XLSTAT version 2007. Both descriptive (mean, standard deviation) and bivarate analyses were performed controlling time for point**.** The distribution parameters were displayed graphically using Microsoft Excel software. All p values ≤ 0.05 were considered significant.

RESULTS

Activities in practice by the local population and their impact on mount Ngaoundal

Table 1 presents the main activities practiced on mount Ngaoundal. Agriculture (91. 82%), ethnomedicine (85.46%), beekeeping (83.73%), PFL and PFNL, harvesting of PFL and PFNL (78.76%) ecotourism (75.72%), and military activity (71.73%) are the main activities practiced. Howe ever, poaching and/or hunting (69. 08%), breeding (64.58%) and mining (36.27%) are not the least activities practiced. Camp Fara, Tapare and Belaka villages are 100% agriculture inclined because these are the Bgaya and Mbum villages and have mostly agriculture as vocation. Even though the Bgaya are excellent in hunting, they use agriculture for their foodstuffs.

Photo 1 a. A mining not closed

Photo 1 b. Animals grazing around mining wells not closed

The 2nd main activity practiced by the population is the ethnomedicine (85.45%) because the mountain possesses a vast floristic diversity that offers to them the first medical care they are in need of.

Table 1. Activities in practice on mount Ngoundal according to the local population (%)

Activities	Camp fara	Zimbabwe	Cinema le mont	Pied du mont	Tapare	Mbah longa	Sansi	Mandal	Mbelaka	Mean±SD
Agriculture	100	87,5	80	85,71	100	95,83	91,67	85,71	100	91,82±7,49[a]
Pharmacopeia	100	100	100	100	100	54,17	91,67	28,57	94,74	85,46±25,97[b]
Beekeping	100	100	100	100	50	75	100	28,57	100	83,73±25,48[bc]
PFL eand/or PFNL	94,12	100	100	100	100	37,5	58,33	28,57	89,47	78,67±29,14[cd]
Eco tourism	100	100	100	14,29	100	91,67	50	57,14	68,42	75,72±29,14[de]
Military activity	94,12	93,75	100	71,43	50	83,33	16,67	85,71	47,37	71,38±27,86[def]
Poaching and/or hunting	100	81,25	100	85,71	100	83,33	0	71,43	0	69,08±40,38[ef]
Rearing	88,24	93,75	100	100	0	83,33	16,67	57,14	42,11	64,58±37,57[g]
Mining	41,18	56,25	60	85,71	50	33,33	0	0	0	36,27±30,77[h]
Rituals	5,88	6,25	0	0	0	4,17	0	0	0	1,81±2,77[i]
Maen±SD	68,63±32,33[ab]	68,23±29,82[ab]	70±32,38[a]	61,9±36,76[c]	54,17±41,16[d]	53,47±30,44[d]	35,42±41,09[f]	36,9±31,9[f]	45,18±42,54[e]	54,88±27,2[d]

Values assigned and characters are not significantly different at 0.05 level.

Table 2. Vegetation evolution from 1985 to 2016

	1985	%	2000	%	2016	%	Synthesis 15 years (1985-2000)	Synthesis 31years (1985-2016)
	surface/ (ha)		surface/ (ha		surface/ (ha		surface/ (ha	
Grassy savanna	1332.45	16.3	1001.04	12.7	810,31	9.93	-331.41	-522.14
Bushy savanna	3275.13	40.4	5010.49	61.0	3634,98	44.5	1735.36	359.85
ligneous savanna	2842.58	34.4	1120.61	13.3	2395,69	29.6	-1721.97	-446.89
Shadow	30.2	0.37	38.16	0.47	32,76	0.40	7,96	2.56
Gallery forest	430.67	5.28	607.05	7.44	657,97	8.06	176.38	227.3
Thin forest	152.82	1.87	275.155	3.37	505,79	6.20	122.335	352.97
Bare land/built land	96.17	1.18	108.36	1,33	122.625	1.50	12.19	26.455
Total	8160.02		8160.85		8160.125			

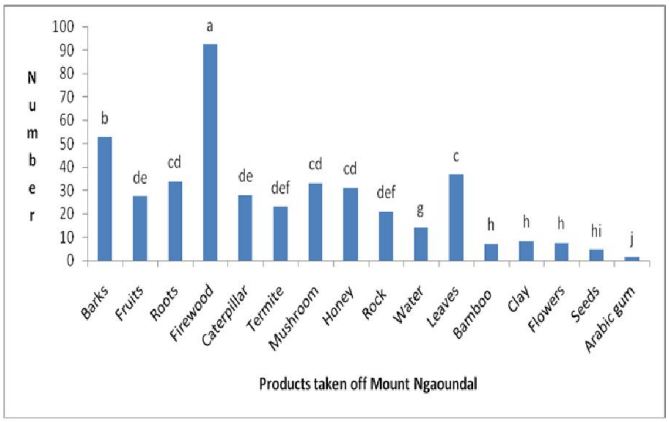
Table 3. Measures of co- management taken for the protection and preservation of Mount Ngaoundal

Measure of co-management	Camp Fara	Zim babwe	Cinema le mont	Pied du mont	Tapare	Mbah longa	Sansi	Mandal	Mbe laka	mean
Exploitation with portion	64,7	18,8	0	0	0	4,17	0	0	0	9,74
Profitable and sustainable planning.	76,5	56,3	12,5	40	25	20,8	0	28,6	15,8	30,6
Sensitization	70,6	12,5	6,25	0	0	4,17	8,33	0	0	11,3
Reforestation	70,6	75	12,5	20	25	12,5	8,33	0	5,26	25,5
Ecoguard	70,6	43,8	12,5	20	0	25	16,7	42,9	47,4	31
Vigilante committee	23,5	6,25	12,5	80	0	16,7	0	14,3	36,8	21,1
Reduction of anthropication	41,2	25	0	0	0	4,17	0	0	0	7,82
Preservation of species	29,4	56,3	25	20	0	0	0	0	0	14,5
Definition of areas putting of defend	88,2	31,3	0	20	0	12,5	16,7	0	5,26	19,3
House gardens	0	37,5	18,8	0	0	25	33,3	42,9	52,6	23,3
Granary	0	18,8	6,25	20	0	8,33	16,7	28,6	52,6	16,8
Orchard	17,7	12,5	37,5	20	175	20,8	8,33	114	0	45,1
Réduction of pollution	0	25	0	0	0	0	8,33	0	0	3,7

Indigenous and foreigners go there and harvest the first parts (bark, leave, root, seed) of species (*Bridelia scleroneura, Piliostigma thonningii, Uapaca togoensis* etc.) that are components of treatments in some diseases such as malaria, gastrointestinal worms, wounds, and sexual transmittable diseases etc; some for their magical spiritual properties. It is the case of the association of four (4) species (*Piliostigma thonningii, Ficus vogelii, Cussonia arborea* and *Maytenus senegalensis*) used as charms. In contrary, mining (36.27%) that has not really started is not intense. Field observations have helped to identify some mine wells closed or opened. These wells are dangers for animals and people (photo1.a and 1.b). No sign posting is available and moreover, no effort is made to close wells. All those activities practiced on the mountain have harmful consequences on the biodiversity of this ecosystem and lead to the reduction or disappearance of some resources. For this, people say wild animals have disappeared from the mountain because of hunting and the constant presence of people. These people destroy their ecological niche that is favorable for their reproduction and provoke movement of animals to other places less favorable therefore exposing them to many threats.

Taking-off a quota of products from mount Ngaoundal and their impact on environment

Figure 3 shows that the local population is taking - off a quota of many products from mount Ngaoundal. Firewoods mainly are taken-off from mount Ngaoundal (Mean percentage, 92. 42%), followed by barks (52. 80%), leaves (36.67%). In his majority the population gets food resources from mount Ngaoundal. Some people treat themselves with local plants. Products less represented include arabic gum (1, 44%), seeds (4. 62%), flowers (7.53%). The rest of products such as honey (31.04%), mushrooms (33. 06%) and roots (33. 90%) are intermediate products. All these products are consummate locally and or exported to other towns and neighboring countries. Exploitation of products from mount Ngaoundal has a negative effect on environment and evolution of vegetation.



Values assigned and characters are not significantly different at 0.05 level.

Figure 3. Products taken-off from mount Ngaoundal

Evolution of vegetation from 1985 to 2016

Figure 4 shows that the vegetation in 1985(Figure 4 a) was homogenous (color) on mount Ngaoundal; 15 years later that is in 2000 (Figure 4 b), there was a fragmentation of this vegetable unity in many marks. Colors increase, the height of marks decrease because of the rupture of continuity; increase of isolation of those marks is visible on the maps. This result shows that the phenomenon of fragmentation of areas touches most of regions and its importance has increased because of the development of human activities. It has been recognized as a major ecological risk. In 2016 (Figure 4 c), it is noticed that the coloration reappears and the fragmentation does not develop.

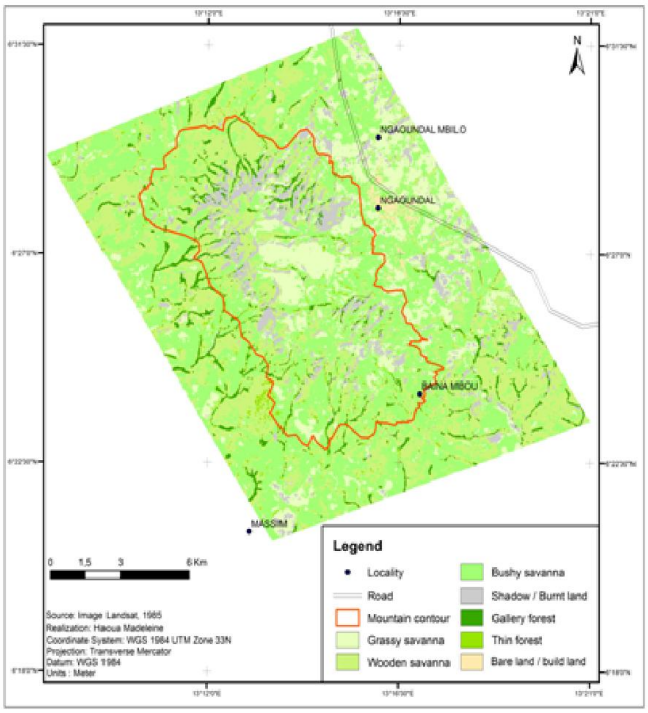


Fig. 4 (a). Land occupation in 1985

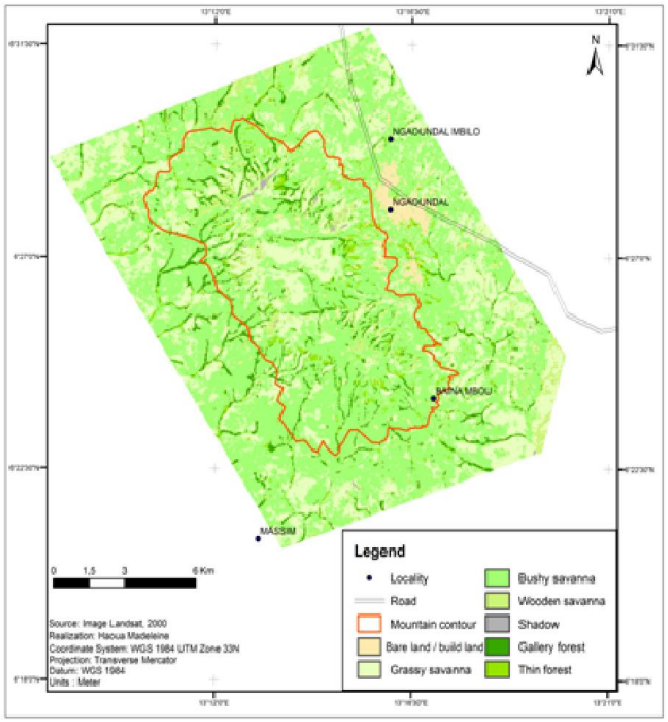


Fig. 4 (b). Land occupation in 2000

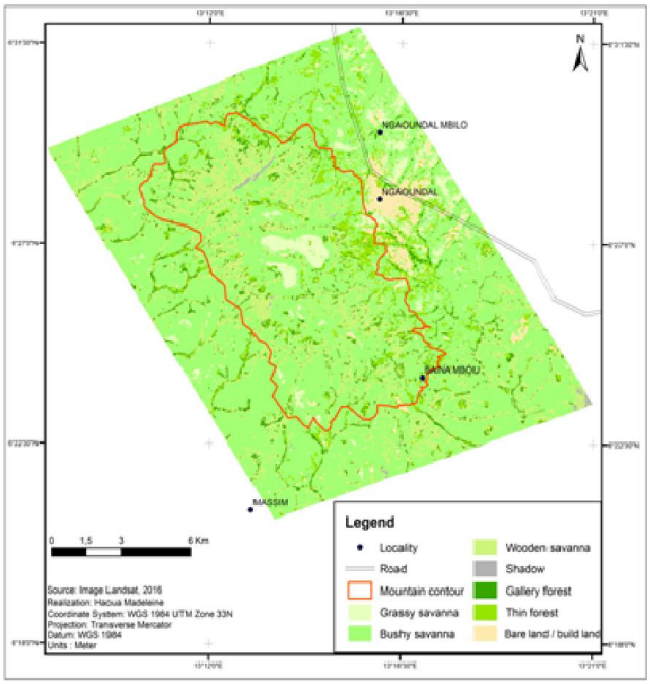


Fig. 4 (c). Land occupation in 2016

Figure 4. Evolution of vegetation on mount Ngaoundal from 1985 to 2016

For a total surface of the mountain estimated to be 8120. 02 ha, different vegetable formations occupy this surface (Table 2). The evolution of deforestation does not affect all the vegetable covers, because there is a progress of other types of vegetable formations at the detriment of others. From 1985 to 2016, it was noticed that the surface of the grassy savanna has reduced considerable from 13332.45 ha in 1985 to 810.31 ha in 2016 (Table 2). Gallery and thin forests increased considerable from a surface of 430, 67 ha in 1985 to 657.97 ha in 2016 for the gallery forest and 152.24 ha in 1985 to 505.79 ha in 2016 for the thin forest. In contrary, the woody savanna had in 2000 a surface reduction of more than half before picking up again (Table, 2). This could be explained by the observed heavy reduction of rains in the northern Cameroon in 1970 en 1979 and again in 1981 and 2011 (Figure 5).

To these effects, it could be added human activities in the mountain. The combination of activities and low rains may have caused the progressive fragmentation of this ecosystem. Observations from satellites have shown the regression of the surface occupied by vegetables at this particular period, thus showing the impact of activities on the vegetation. Concerning the bushy savanna, the latter surface increased in 2000 (5015.49 ha) at the detriment of grassy savannas. During the same year, the bushy savanna was increasing, while the ligneous and grassy savannas had allowed the establishment of thin and gallery forests and a great regeneration of the site as observed with the regaining of coloration. About the area built land, the table shows a gradual occupation (96.17 ha in 1985 to 122.625ha in 2016) of the land due to the increase of the land by population. Figure 5 shows evolution of rainfall from 1968 to 2014 in Adamawa region. It could be concluded from this figure that during the years from 1985 to 2016 corresponding to the period of satellite images, there was an increase in the quantity of rain that favored a positive evolution of mount Ngaoundal vegetation towards forests.

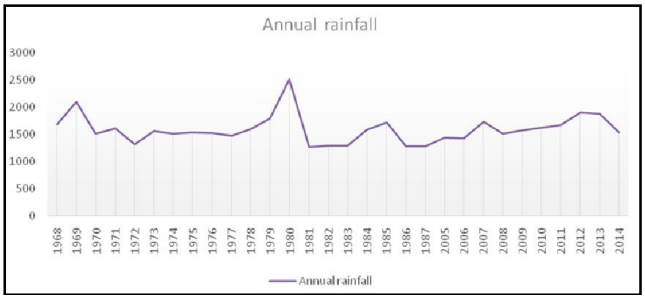


Figure 5. Annual precipitation from 1968 to 2014 in Adamaoua region

The amount of rains and the hydrographic system of the area may have played a key note on the vegetation evolution.

Orohydrography of mount Ngaoundal

As satellite images were not able to capture the presence of rivers on the mountain during snappings, it was then necessary to establish an orohydrograhic map of the mountain so as to confirm the direct observations of the land. Figure 6 shows that the mountain is supplied by many rivers of levels 1 and 2.

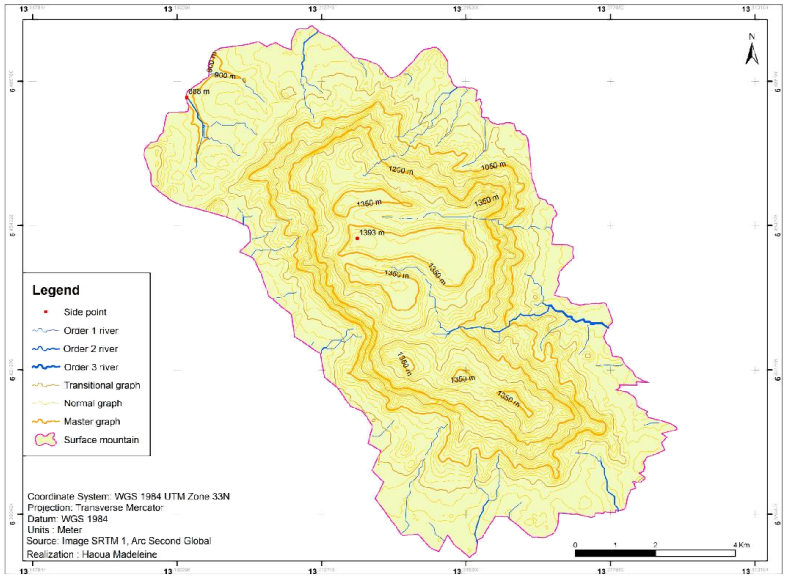


Figure 6. Hydrographic net work of mount Ngaoundal

The order 3 river which is the most important in terms of volume of water is at the origin of the water fall on the mountain. Rivers and the water fall are strewn with forests (thin and gallery) along their beds. This could explain the decline of other vegetable formations for the benefit of thin and gallery forests. The latter's for their shadow marking cover river beds, thus not allowing to see the presence of water on the vegetation map. The main collector is situated in the South-East of the mountain and corresponds to the mount Ngaoundal water fall. This collector has a winding laying out with the No-SE direction of flow. Although the region is abundantly watered, it is characterized by a hydrographic network less dense with 56454.07 m of the total length of all the rivers. This hydrographic network is composed of a main river and dependent affluents. The study of the relief shows relatively important altitudes (above 1300 m) whereas depressions are at 880 m.

On the entire map, there is a less tabular imposing form with an irregular surface. It is a mountain, and is1393 m at its highest point. This mountain, North-south looking is in fact a part of Adamawa plateau. On this mountain, important valleys in form of U and V could be seen. The slopes are in most of cases asymmetrical. This hydrographic network, always present in all seasons does not dry but its output decreases during the dry season, feeds the mountain the whole year and has many gallery and thin forests that strew it. Mount Ngaoundal has predominant strong slopes in the South, East and West. These slopes do not allow its easy access. The North is mainly with weak and average slopes. It is the reason why the population accesses to the mountain through that side. This easy access through that side has an impact on the vegetation. These insurmountable slopes help the mountain to possess many species of forests that develop whereas it is in an area of Savanna. That is why it is important to simulate the evolution of the vegetation for ten (10) years for its protection.

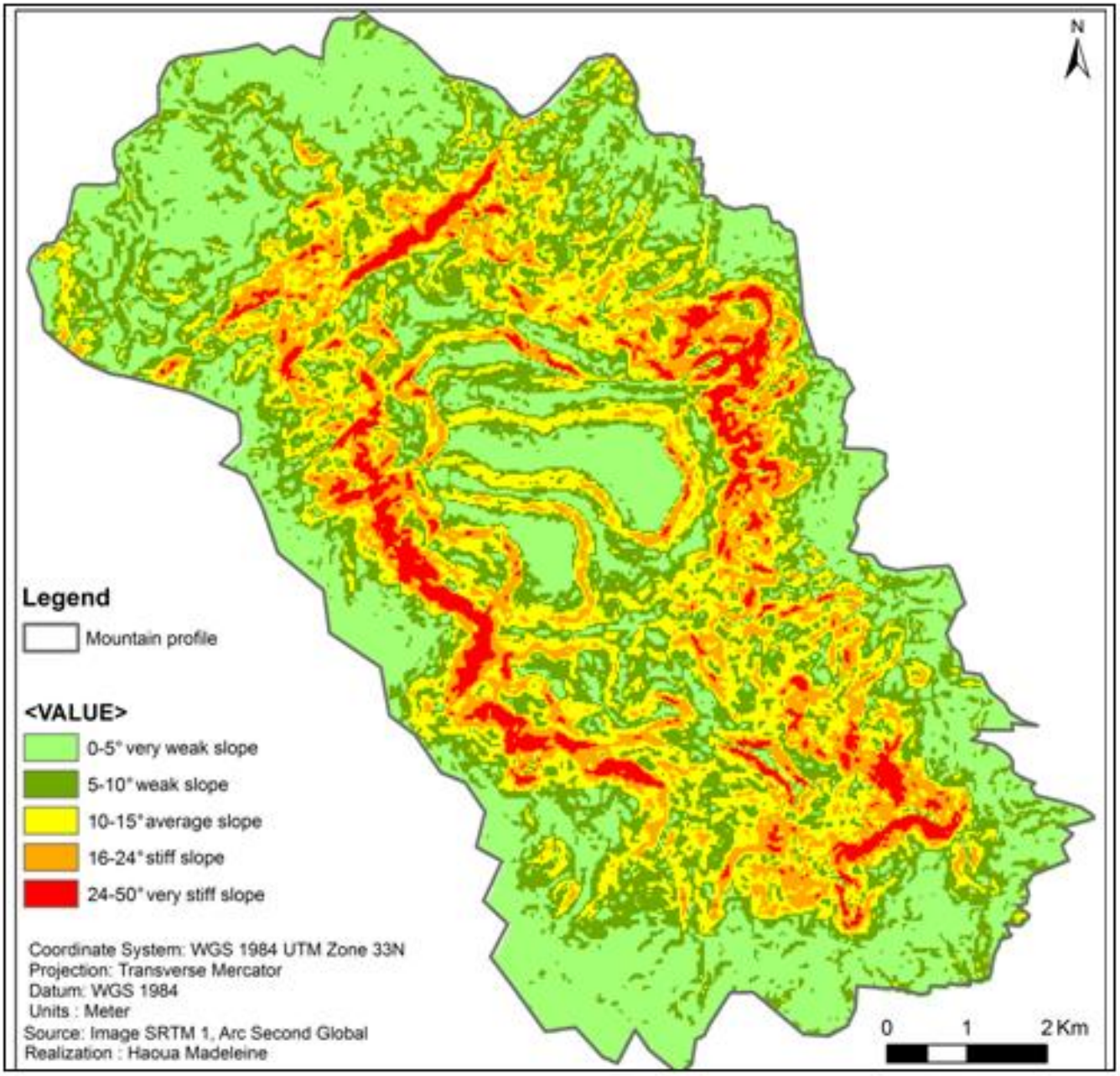


Figure 7. Map of the maoutain slope

Simulation of the vegetation evolution on mount Ngaoundal for 10 years

A statistical simulation was done on the vegetation evolution on Mount Ngaoundal by taking into account the percentage of evolution per year. Note should be taken that the value of percentage of evolution per year is the mean percentage of evolution of types of land occupation for a period of 31 years. Considering that, passed and present factors (rainfall, temperature, wind etc) of the dynamic of the land occupation evolve identically. Figure 8 shows that the grassy savanna will decrease to -16.73 ha, but also the woody savanna to -42.33 ha. During the same time, surfaces of bushy savannas (51.70 ha), gallery forests (5.92 ha), thin forests (7.06 ha) and built lands (0.13 ha) will increase dramatically. It has been observed that if nothing is done, with time, savannas (grassy, bushy or woody) will give room to forests (thin and gallery). One would then find an ecosystem not different to that of forests. That is why it would be better and urgent to propose the co-management of this mountain in order to preserve it.

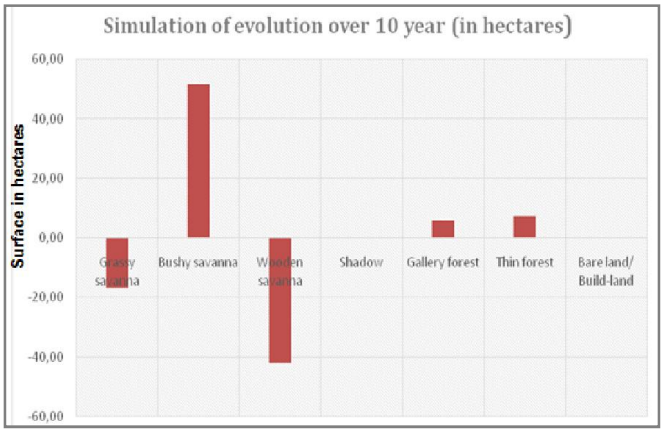


Figure 8. Simulation of mount Ngaoundal evolution in over 10 years

Measures taken by the government and population for the co-management, protection and preservation of mount Ngaoundal

To safeguard and protect mount Ngaoundal from anthropic threats, measures of co- management were envisaged by the revering population (table 3). In total, twelve (12) measures of protection and safeguarding of Mount Ngaoundal were envisaged by the revering population and government. Among these measures are the training of ecoguards (37.87 %) and the vigilante committees (24.62%) to supervise the mountain; sensitization (21.77%) on dangers of exploitation with anarchy of mount Ngaoundal; creation of orchards (47.67%); and rational exploitation of soils (37.57%); sustainable and profitable adjustment (30.93%), reforestation of surfaces that were deforested (28.29%); for the protection of the mountain and the construction of modern granaries (49.67%); the creation of house gardens and orchards for the reforestation of their environment. The installation by the council of the club of friends of nature from the government secondary school of Ngaoundal, plaques on educational messages on environment "Nature is our friend let us protect it"; "let us respect environment"; "do not throw your refuse".

Techniques for preservation of natural resources on mount Ngaoundal

The Bororos living on the mountain do develop techniques for preservation well adapted to natural resources. They do construct stage houses with renewable materials (wood, bamboo, creeper) that help for kitchen. The down part is for kitchen and storage of firewood against rains during the rainy season and the upper part is a granary for storage of corn and or for other foodstuffs during hardship (Photo 2). This granary allows them to preserve harvestings from house gardens with fire bellow for cooking that allows smoke and heat to protect harvestings at the same time against humidity and weevils.

Photo 2. Kitchen in a Bororo camp in mount Ngaoundal

Preservation of firewood

The Bororos do pile firewood's for drying and storage during the dry season. This piling of wood equally helps for drying of food, for their preservation and for hard periods. Woods are kept on stones to stop them from being attacked by termites, so as to facilitate circulation of air and rain water.

Photo 3. Model for presentation of firewood in a Bororo camp on Mount Ngaoundal

DISCUSSION

Activities practiced on mount Ngaoundal by the local population of Ngaoundal are mainly agriculture, traditional pharmacopeia, beekeeping, harvesting of PFL and PFNT. This result is similar to that of Leaky (1996) and Ruiz *et al.* (2004) who have shown the importance of non ligneous forest products in Burkina Faso houses. In addition many products are taken-off, among which firewoods followed by barks (52.80%) and leaves (36. 67%). This result is similar to that of Landy (2000), who showed that plants are very used as firewood in sahelian zones and west Africa. This result is also similar to that of MINFOF (2014) who observed that Ngaoundere (90.6%), Garoua (83.4%) and Maroua (95.4%) towns use enough wood for energy in households despite the will of public powers to cut down sensibly the use of wood for energy by promoting domestic gaz. The populations in majority get their food and health items from mount Ngaoundal. This result corroborates that of Sarfaras *et al.*(2011) who proved that the use of medicinal plants is increasing in developing counties.

It is also the case of Motlhanka and Makhabu (2010) and Saoting *et al*.(2010) who showed that many plant species used in the traditional pharmacopeia will disappear in the long run and some are not more found. Products less represented include Arabic gums with a mean of 1.44%, seeds (17.62%) and flowers (7.53%). The rest of products like honey (31.04%), mushrooms (33.06%), roots (33. 90%) and fruits are transitional. Despite the practiced activities on the mountain, vegetation follows its evolution in link with some factors such as rain, temperature, winds, etc. From 1985 to 2016, it was observed that the grassy savanna is decreasing dramatically from 13332.45 ha in 1985 to 810.31 ha in 2016. Gallery and thin forests on their own parts are increasing considerable in surface from 430.67 ha in 1985 to 657.97 ha in 2016 and 152.24 ha in 1985 to 505.79 ha in 2016 respectively. This result is similar to that of Yanda (2007) who observed that gallery surfaces increase at the detriment of the grassy savanna in the East of Cameroon. In contrary, the bushy savanna or the ligneous savanna have in 2000 reduced in surface to more than half before regaining ground in 2016.

This increase of the bushy savanna and the decrease of the ligneous savanna have helped the establishment of thin and gallery forests. This has as a consequence the regeneration of the observed site by the regaining of coloration. This result is similar to that of Wilcox and Murhy (1985).The reduction of grass species surface with time, show a logical trend for the installation of vegetable in an ecosystem with grass species such as *Aframamun latifolia, Hyparrhenia* spp., *Andropogon gayanus, Pennisetum pedicelatum* as pioneer species. This result strongly agrees with that of Yanda (2007) in the East of Cameroon. From this work, it could be said that years 1985 to 2016 that correspond to the period of capturing of satellite images show an increase in rain levels that favor a positive evolution of vegetation of mount Ngaoundal towards forests. This result resembles that of Dwyer *et al.* (1998) and Kalda (2015) who showed that a savanna protected from wildfires could move about a forest. All these push for the simulation of the mountain vegetation for 10 years in order to understand what it would look like. It emerges from this work that grassy savanna will decrease to -16.73 ha, the same with the bushy savanna to -42.33 ha, while the ligneous savanna (51.70 ha), gallery forests (5.92 ha), thin forests (7.06 ha) and built land (0.13 ha) will increase considerably. If nothing is done or nothing changes with time, savannas (grassy, bushy or ligneous) will give place to forests (thins and galleries). One would then find an ecosystem of a savanna with an aspect of a forest. That will then be a positive consequence. This result is in agreement with the work by Dwey *et al.*(1998) and Yanda (2007) who showed that savannas may move about forests if protected against deforestations.

Descents may play an important role in the preservation of the biodiversity in the sense that they allow the development of plants without undergoing any anthropic activity. Therefore, South and East faces don't have many species because of their vigorous descents that make them inaccessible. That is why it would be wise and urgent to propose measures of co-managements of the mountain to preserve it. In total twelve (12) measures of protection and safeguard of mount Ngaoundal were envisaged by the revering population. Among these measures, training of ecoguards (37.87%) and the vigilante committee (24.62%) for watching of the mountain, sensitization (21.77%) about the dangers of anarchistic exploitation of mount Ngaoundal; orchards (47.67%), exploitation by portion (37.57%), sustainable and profitable resource management (30.93%), reforestation (28.9%) for the protection of the mountain and granaries, preservation of species (19.39%) for preservation. Some people do create house gardens and orchards to reforest their environment. Along the passage, the ascension of the mountain, the council, the club of friends of nature of Ngaoundal Secondary Grammar School have put signboards with educational messages on environment.

The Bororos who live on the mountain have well appropriate preservative techniques of natural resources. They are constructing stage houses with firewood. The down part is kept for kitchen and storage of corn and all other foodstuffs for hard periods. This granary allows them to preserve harvestings from their house gardens and the fire set down for kitchen allows smoke and heat that protect harvestings against weevils and humidity. This result strongly agrees with that of Haoua (2003) in the Faro et Deo. The Bororos pile pieces of wood on top of others for drying and storage during dry season. This piling of wood equally allows drying of foodstuffs for their preservation for hard periods. Woods are deposited on stones to protect them from any attack from termites, and also to facilitate air circulation and rain water.

Conclusion

The mountain is a reservoir for carbon, a genetic bank, a factory that provides to revering populations everything that they are in need of (firewood, wood for art, source of medicament etc.). The major activities practiced on the mountain include agriculture (91.82%), pharmacopeia (85.46%), ecotourism (75.72%) and military activity (71.38%). Secondary activities include hunting (69.08%), rearing (64.58%) and mining (36.27%). For products taken-off from it,

firewood (92.42%), barks (52.80%), leaves (36.67%) are the most requested. These activities practiced on the mountain impact on the dynamism and evolution of mount Ngaoundal vegetation. From 1985 to 2016, the grassy savanna has decreased dramatically in its surface (from 13332.45 ha in 1985 to 810.31 ha in 2016) and has given place to gallery and thin forests. The latter's increased their surface from 430.67 ha in 1985 to 657.97 ha in 2016; and from 152.84 ha in 1985 to 505.79 ha in 2016 respectively. This help to envisage a savanna with a face of a thick forest if conditions (precipitation, temperature, wind etc) in which they were put in place remain the same. Simulation over 30 years reveals that this mountain shows that there is a permanent threat if the government and population are not conscious of the sustainable management of environment, whereas, efforts were made by the local population and government to safeguard mount Ngaoundal. The efforts include training of ecoguards (37.87%) and vigilante committee (24.62%) for watching the mountain, sensitization (21.77%) on the dangers of anarchistic exploitation of mount Ngaoundal. Orchards (47.67%), exploitations of portions (37.57%); sustainable and profitable harnessing (30.93%), reforestation (28.90%) of the mountain, protection and granaries (49.67%) for the preservation. It would be advantageous to continue with studies on the gain of exploitation of won mineral of the mountain and what the mountain can offer as years are going to revering populations. To carry out a study of the impact of exploitation of mineral on public health; to sensitize, to educate revering populations on the way in which to take non-ligneous and ligneous forest products and at last to evaluate the carbon credit of the mountain so as to encourage population to protect it.

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