IMPACTS OF THE EXPLOITATION OF ROCK MODELS ON PHYTODIVERSITY IN THE AGBELOUVE TOWNSHIP AND ITS SURROUNDINGS

ABSTRACT

The exploitation of rocky outcrops is increasing and leading to the loss of biodiversity in the canton of Agbélouvé and its surroundings. This study aims to assess the impact of the exploitation of these rocks on the flora and vegetation, in order to contribute to the sustainable management of plant resources. It is based on floristic inventories of the exploitation sites and off-site. The collected data was processed by the Excel 2016 spreadsheet, and software XLSTAT 2008. The results of this research show that this activity is at the origin of the destruction of the vegetation cover and the modification of the topographic landscape. 234 species were recorded in 96 surveys, including 95 species belonging to 41 families on the exploitation sites, compared to 139 species belonging to 51 families off-site. The Shannon diversity indexes are 1.86 and 2 respectively on and off sites. Pielou's equitability index is 0.94 on the exploitation sites and 0.93 off-site. The analysis of the biological spectrum shows the predominance of phanerophytes (60.76%) off sites against (37%) therophytes on the exploitation sites. The analysis of the phytogeographical spectrum indicates the predominance of Afro-tropical species on the two sites explored. Faced with the negative impacts of the exploitation of the rock formations on the vegetation, it is necessary to take measures for the restoration of the exploitation sites.

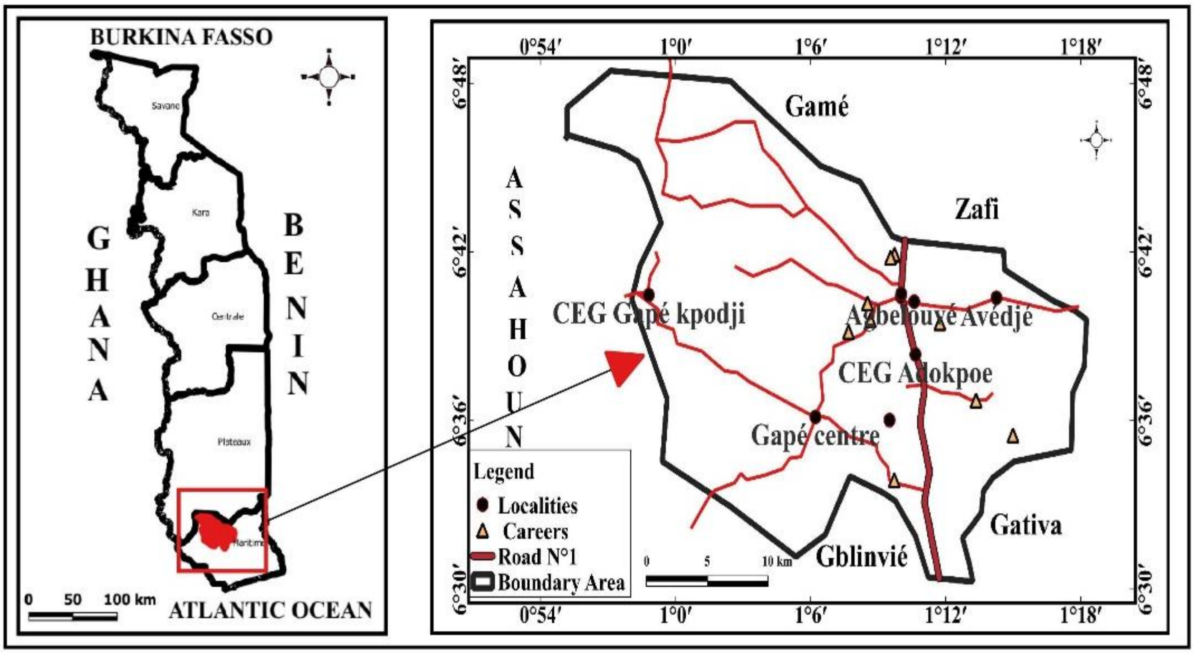
***Key word:** Rocks, exploitation, impacts, Agbelouvé, South Togo.*

1- INTRODUCTION

Under the influence of attractive national mining policies on the one hand and of strong investment from the foreign private sector on the other hand, there has been significant development of the mining sector in West Africa for several decades. This desired and international supervised development has allowed the opening of a large number of mining and oil exploitations and is reflected in a significant weight in GDP and export earnings (IUCN, 2011). Togo is a country whose economy is essentially based on the primary sector. The share of the added value of extractive industries in the gross domestic product (GDP) is 2.7%, including 2% for phosphates, which constitute the main mining production in Togo (with a contribution to growth of 0.6%) and 0.7% for other extractive activities in nominal terms) (INSEED, 2015). Togo has moved towards a mining diversification policy in order to increase its financial revenue. This commitment is reflected in the various reform policies whose objective is to make the extractive industry an instrument of development and the fight against poverty. To achieve this objective, the strategy adopted is to make private investment the driving force of development of the mining sector while improving the investment-friendly environment and the basic geological infrastructures (https://sustainabledevelopment.un.org/content/documents /dsd/dsd_aofw_ni/ni_pdfs/NationalReports/togo/mining.pdf.). In this regard, the industrial exploitation of granito-gneissic rocks, which was once less well known, has grown to the point where private companies are settling with large machines in the field to blast and dismantle the rock. Indeed, gravel like sand, and especially crushed rocks, are increasingly in demand these days for various uses: road construction, modern housing, exploitation for commercial purposes and so on. As a result, quarries are opening up here and there across the country. In the prefecture of Zio, Agbélouvé and its surroundings is the area where companies intensively exploit the granito-gneissic models with high-performance mechanical means allowing them to extract a large quantity of blocks in a short time. Despite the socio-economic importance of this natural resource, its exploitation leads to the destruction of vegetation. However, the absence of quantified data on the impact of the exploitation of these rock formations on phytodiversity in Togo contrasts with the abundance of references available on other tropical regions, particularly in Africa.This study aims at assessing the impact of the exploitation of these rocks on the flora and vegetation, in order to contribute to the sustainable management of plant resources.The hypothesis predicts that the natural vegetation of Agbelouvé and its surroundings has lost its floristic and phytogeographic specificities. The presentation of the study environment, materials and methods, results and discussion constitute the main sections of this research.

2- Background to the study area

Agbélouvé and its surroundings cover 760 km² and is located between latitude 6°18' North and 7°23' North and between longitude 0°52' East and 1°39' East. It is limited to the northeast by Gamé, to the south by Gblinvié and Gativa, to the northwest by Assahoun and to the southwest by Kévé.



Source: From OSM vectors (OpenstreetMap) and GPS points
Fig. 1. Location map of the study area

The study area falls entirely within the vast Benino-Togolese peneplain. It is affected by the Precambrian granito gneissic basement located in the northern part of the Togolese coastal sedimentary basin of late-Tertiary age. It is a polyconvex model which rises regularly from the coastal sedimentary basin to the Mounts Togo with varying altitudes between 100 and 400 m from the South towards the North and North-West with modest altitudes clearly less than 200 m (Y.T. Gnongbo, 1996). It is a flattening surface made up of wide ridges of roughly flat and lowered interfluves which alternate with shallow valleys with flat bottoms combining long convexo-concave slopes with low slopes, rarely greater than 3%. They often dominate the watercourses that limit from 20 m to 25 m (D.A.B Ayivi et al, 2016). Agbelouvé is characterized by non-indurated ferralitic soils and tropical ferruginous soils. The study area has a Guinean climatic regime that is characterized by two rainy seasons (the long rainy season from the end of March or April to June and the short rainy season from mid-September to the end of October) and two dry seasons (the long dry season from December to March and the short dry season in July and August). The average temperature is generally high. It is 28°C. Precipitation varies between 1000 and 1200 mm/year. It is watered by the Zio River (to the west) and Lili stream (to the east). The plant formations are much degraded. It is a vegetation of wooded savannahs and shrubs characterized by species such as *Anogeissus leiocarpus, Ceiba pentandra, Sterculia setigera, Khaya senegalensis* (F. Folega, 2018). With an average population of 26,314 inhabitants km^2 including 12,641 men and 13,671 women (DGSCN, 2010), Agbelouvé and its surroundings is characterized by the indigenous population made up of Ewe and Adja speakers alongwith Losso, Kabyè, Moba, Fulfilde speakers who make up the non-native population. These different socio-cultural groups carry out various economic activities. Agriculture, livestock, trade and crafts are the economic activities that take place at Agbelouvé and its surroundings. Agriculture is the most popular economic activity because of the fertility of the soil. It is more practiced by Kabyè, Losso, Kotokoli and Fulfilde migrants. They grow corn, yams, rice, cowpeas, raise sheep, pigs, poultry, beef, etc. Artisanal activities such as agro-food processing (gari, palm kernel oil, sodabi, local soap, etc.) are produced by the majority of the indigenous populations. Other activities such as pottery, carpentry, hairdressing, sewing, embroidery, weaving, masonry, vehicle mechanics, welding, and shoemaking are also done in the area. All these activities

allow the population to meet their daily needs. The methodology of data collection involved investigation, documentary and laboratory data. The collected data was processed and analyzed in order to achieve the objective of this study.

3- MATERIALS AND METHODS

3- 1 Materials.

For the purpose of this study, the following field equipment is used: Camera – digital cameras for taking photos. GPS (Geographic Positioning System) for orientation and taking geographic coordinates within each station. Pruning shears and bags for cutting specimens intended for the herbarium. A 10 meter tape was used in the delimitation of the survey surface and the distance between the different sampling stations. Floristic inventory sheets were used to name species. For this study, the Excel spreadsheet and XELSTAT 2008, and QGIS3.6 software are used for the processing and analysis of the collected data.

3- 2 Methods

3-2-1 Collection of floristic data

The floristic inventory is carried out on the operating sites and off-site. It was done at the beginning of the small rainy season during which the plant species are in bloom. It enabled a well distinction of species in the field. The collection of this data was carried out as follows: the geolocation of the operating sites through the geographical coordinates by the GPS mobaye topographer. This method is relevant for the choice of field investigation and sampling sites. A total of four sites are chosen on the basis of the accessibility of the rock modeling sites and the representativeness of the vegetation cover. They are Lilikopé and Kpéyi operated by (Togo carrière company and FAO); Agbelouvé and Adidokpo operated by (Togomatériaux, Granutogo, CECO, Togorail, Chinese company, Lacitow and SGC companies). The transect number in each site and that of plots per transect vary according to the floristic and topographic homogeneity on the sites. In total, 96 floristic inventory readings are carried out, i.e. 48 readings on the operating sites and 48 off-site. A plot surface varies according to the types of vegetation on the exploitation sites and off sites. This plot area is defined with reference to West African phytosociology work (K. Adjossou and K. Kouami 2009; K. Adjonou, 2016). Thus in the savannahs as in the fallow land, plots of $100m^2$ (10m x 10m) are made. Each plant formation is identified according to the Yangambi classification. All the species are identified and listed on floristic inventory sheets that were assigned an abundance-dominance coefficient according to the method of Braun-Blanquet (1932). In each of the surveys, the vascular flora (trees, shrubs, lianas, grasses) was exhaustively listed. The recognition of species in the field is based on experience, knowledge of the botanical traits of the species by a specialist in botany from University of Lomé. Unidentified species are collected and kept in a herbarium for their identification in the botany laboratory at the University of Lomé. The correction of scientific names has been made according to the classification of APGIII (2009).

3- 2- 2 Processing of floristic inventory data

The data processing of the floristic inventory was carried out using different applications. The double-entry table "record x species" is drawn up on the basis of the abundant presence of species. There were species in rows and statements in columns. The corresponding biological form and phytogeographical affinity (F. White 1979, 1986) cited by (K. Adjossou, 2009) are carried out on the basis of each statement, species, family. This developed double-entry table is subjected to multivariate analysis techniques which aim at highlighting the main groupings of the vegetation cover. The absolute (Fa) and relative (Fr) frequencies of species were calculated. The specific richness, rank-frequency curve and dendrogram were carried out. This processing was encoded by using the spreadsheet Excel 2010, XLSTAT 2008. Thus, a comparative analysis of the floristic characteristics of the exploitation sites and off-site is made in order to highlight the impacts of the exploitation of rock models in the area of Agbelouvé and its surroundings.

Specific diversity:

Specific diversity is defined by the specific richness and the diversity index. Species richness represents the total number of species in a given phytocenosis. R = N0 (N0 is the total number of species)

Diversity indices are frequently used in ecology because they constitute stand characterization parameters (F. Ramade, 1994), quoted by (N. Sayah, 2018). Moreover, these indices provide a lot of information, particularly on the quality and functionality of the stands. Among the commonly used indices are the Shannon-Weaver index and the Pielou (E) evenness index. According to N. Sayah, (2018), the Shannon-Weaver diversity index measures the average amount of information given by the indication of the species of an individual in the collection. This average is calculated from the proportions of species that have been identified. It is obtained from the following formula.

$$pi = \frac{n}{N} \text{ whers ni ranges from 0 and N}, pi \text{ ranges from 0 to 1}$$

N: total number, ni: number of species i in the sample S: total number of species in the sample. The high Shannon-Weaver index values reflect the good environmental conditions for the installation of species, while the low values show that the conditions are not favorable for the installation of species. This index varies both according to the number of species and

$$H' = -\sum pi \ Log_{(2)} \ pi$$

ve portion of the collection of different species. It can vary between 1 surveys. According to N. Sayah, (2018), this index can be maximum (H max) by considering values between 8 and 9 for samples including in particular 100 and 200 species or maximum when all the individuals are equally distributed on all species. However, it is minimal if all the individuals in the stand belong to the same species. It enables the evaluation of the Pielou evenness index.

The Pielou evenness index (E) is the ratio between the calculated diversity H' and the maximum diversity H' and which is represented by the (log) of the specific richness (S). It is a measure of the degree of achieved diversity by the stand. Its value varies from 0 and 1. When the value E is close of 0, the distribution between individuals of the species is irregular. On the other hand, when the values of E are close to 1, it shows a regularity of distribution

$$E = H'/ H' \ max.$$

between the individuals of the species. It has the formula:

H': Shannon's index and H'max is log(s) is the theoretical value of the maximum diversity that can be reached in each group; it is the equal distribution of all the individuals among all the species of the group.

Relative frequency:

$$Fr = ni \times 100/N$$

where Fr: relative frequency, ni: number of readings in which species i is present and N: total number of readings.

Absolute frequency:

$$Fa : ni/N$$

where Fa: absolute frequency, ni: number of readings in which is species i and N: total number of readings.

Biological types:

For all the species in the group, the biological spectrum consists in the establishment of the percentage of species that belong to each of the biological types existing in the floristic list of the study area. The biological types used in phytosociologies are those defined by C. Raunnkaier (1934), quoted in K. Adjossou (2009). They are:

Phanerophytes (Ph): plants whose shoots or persistent buds are located on aerial axes more than 40 cm from the ground. They are divided into:

Megaphanerophytes (MP): trees >30 m tall;

Mesophanerophytes (mP): 10 to 30 m trees;

Microphanerophytes (mp): 2 to 10 m trees;

Nanophanerophytes (np): 0.4 to 2 m trees;

Chamephytes (Ch): plants whose buds or ends of persistent shoots are located near the ground, on creeping or upright branches;

Geophytes (ge): plants whose persistent shoots or buds are sheltered in the ground during the bad season;

Hemicryptophytes (he): plants whose replacement shoots or buds are located at ground level;

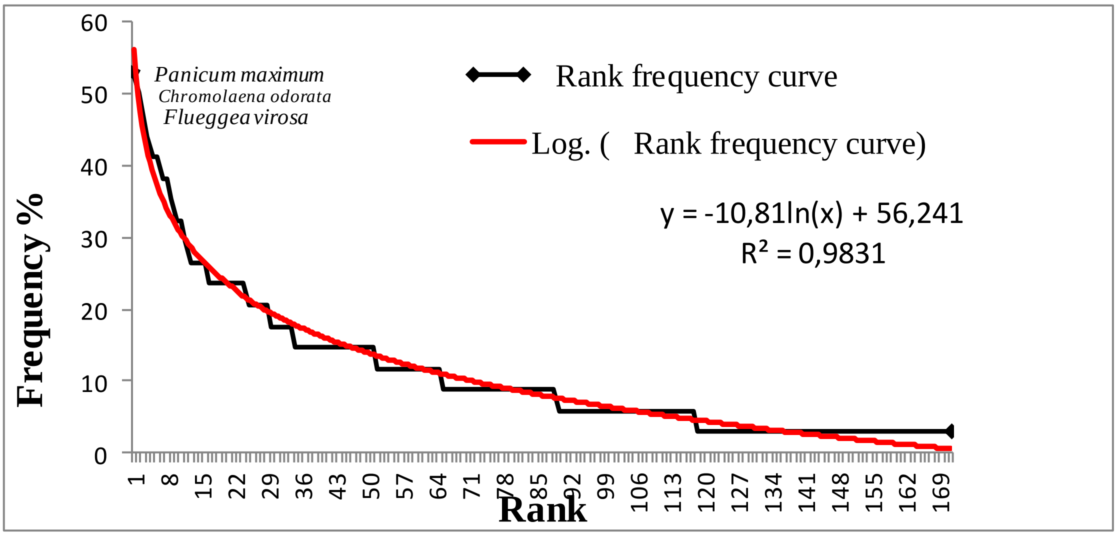
Therophytes (th): annual plants, without persistent vegetative organ and which propagate from year to year by means of seeds;
Hydrophytes (hy): aquatic plants, whose persistent buds are located at the bottom of the water and whose life cycle takes place entirely in the water.
Phytogeographical types:
The phytogeographical types chosen in this study were adopted in accordance with the chorological subdivisions generally accepted for Africa (F. White 1979, 1986, quoted by K. Adjossou, 2009). They are grouped into:
Species with a wide geographical distribution:
Cosmopolitan (Cosm): species distributed in both tropical and temperate regions
Pantropical (Pan): species distributed in all tropical regions: Africa, America and Asia
Paleotropical (Pal): species in tropical Africa, Asia, Madagascar and Australia
Afro-American (AA): species distributed in Africa and in tropical America;
Introduced (I) : introduced species ;
Multi-regional African species:
Pluriregional African (PRA): species whose area of distribution extends to several floral regions of endemism;
Afrotropical (AT): species distributed in tropical Africa;
Sudano-Zambezian (SZ) species: species distributed in both Sudanian and Zambezian regional centers of endemism;
Guinean-Congolian species (GC): species widely distributed in the Guinean and Congolian region;
Sudanian (S): species widely distributed in the Sudanian regional center of endemism;
Sudano-Guinean basic element (SG): species distribution

4- RESULTATS

The results are obtained from various analyzes of the collected data. They are the results of the floristic data. The floristic inventory carried out in the zone of Agbelouvé and its surroundings enabled the identification of 96 species and 41 families on the mining sites; 139 species and 51 families off-site. This floristic diversity is indeed unevenly distributed in the study area.

4- 1 Specific diversity of species on operating sites and off sites

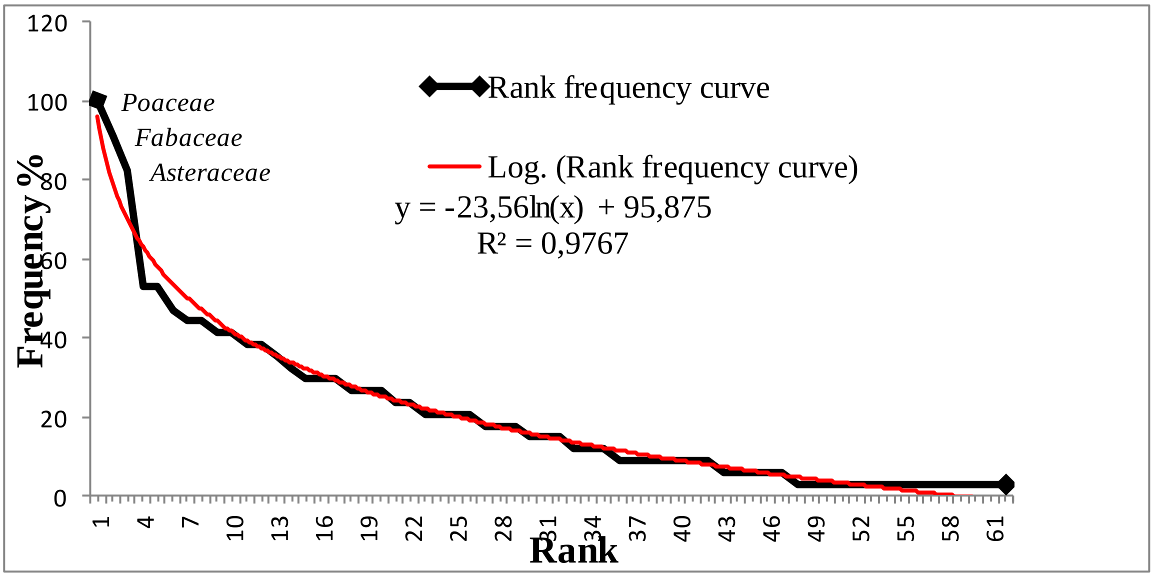
The rank-frequency diagram of the species (Fig. 2) indicates a logarithmic pattern. This pattern reveals the predominance of some of the most frequent species, followed by a number of medium frequency species and rare species. The dominant species are Panicum maximum (52.94%), Chromolaena odorata (50%), Flueggea virosa (47.06%). These species will then be discriminated and individualized using multivariate analyses.



Source: Statistical processing of floristic inventory data 2020
Fig. 2. Distribution species frequencies

4- 2 Specific diversity of families on mining sites and off-sites

The rank-frequency diagram of the families presents a logarithmic shape. This pattern indicates the predominance of a few families. Indeed, only Poaceae (100%), Fabaceae (91.18%), Asteraceae (82.25%) have higher relative frequencies. These families will then be discriminated and individualized using multivariate analyses.



Source: Statistical processing of floristic inventory data 2020
Fig.3. Distribution des fréquences des familles

4- 3 Hierarchical Ascendant Classification (HAC) on coordinates

The Hierarchical Ascendant Classification (HAC) (Fig. 4) on the coordinates of the surveys enabled the partitions into 6 plant groups. For the dendrogram cut, the choice of the P1hierarchical levels was not only based on the analysis of the heights of groupings, but also on the reality of the ground namely in relation to the forest types and the communities of plants at the threshold of 70%. These plant groups from the study area are described as follows: **G1:** group of shrubby savannas, type of widespread vegetation characterized by the existence of very open shrubs, often thorny. They surmount a discontinuous herbaceous cover based on annual grasses. The characteristic species are *Anogeissus leiocarpus, Combretum glutinosum, Sterculia setigera, Khaya senegalensis, Ceiba pentandra*; **G2**: group of grassy savannas, savannah composed solely of annual and perennial graminoids, sometimes within shrubby savannahs. The dominant species belong to the Poaceae family. It includes varieties such as Heteropogon contortus, Andropogon gayanus. **G3**: Fallow, constitute the cropping areas left fallow for their regeneration. They are mainly composed of annual and perennial graminoids. **G4**: group of surveys of flooding grassy savannahs set up by the abandonment of the old exploited quarries. The characteristic species of these savannahs are *typha australis, polygonum senegalinzé, ludwicha vicarins*. **G5**: group of readings of wooded savannas, formations resulting from the degradation of open forests. They are very often maintained by bush fires. They are by far the most frequent plant formations in the entire area of 'study. Characteristic species are *Afzelia africana of Pterocarpus erinaceus, Parkia biglobosa*, etc. and they measure between 18 to 20 meters. **G6**: Wooded Savannah survey group, plant formation set up for economic purposes. The characteristic species are the Tectona grandis of the Laminaceae family.

Source: Statistical processing of floristic inventory data, 2020
Fig.4. HCA Dendrogram of the coordinates of the readings

4- 4 Impacts of the exploitation of rock formations on floristic diversity

Table (1) illustrates the floristic diversity of the operating sites and off-sites in the study area. This table infers that operating sites contain lower species richness (96 species) than off-sites (139 species). Except quarries, the Shannon index is 1.86 bits on the operating sites and 2 bits show that there is a variability of species in the study area. The Pielou evenness indices of the two sites show that the individuals are moderately distributed.

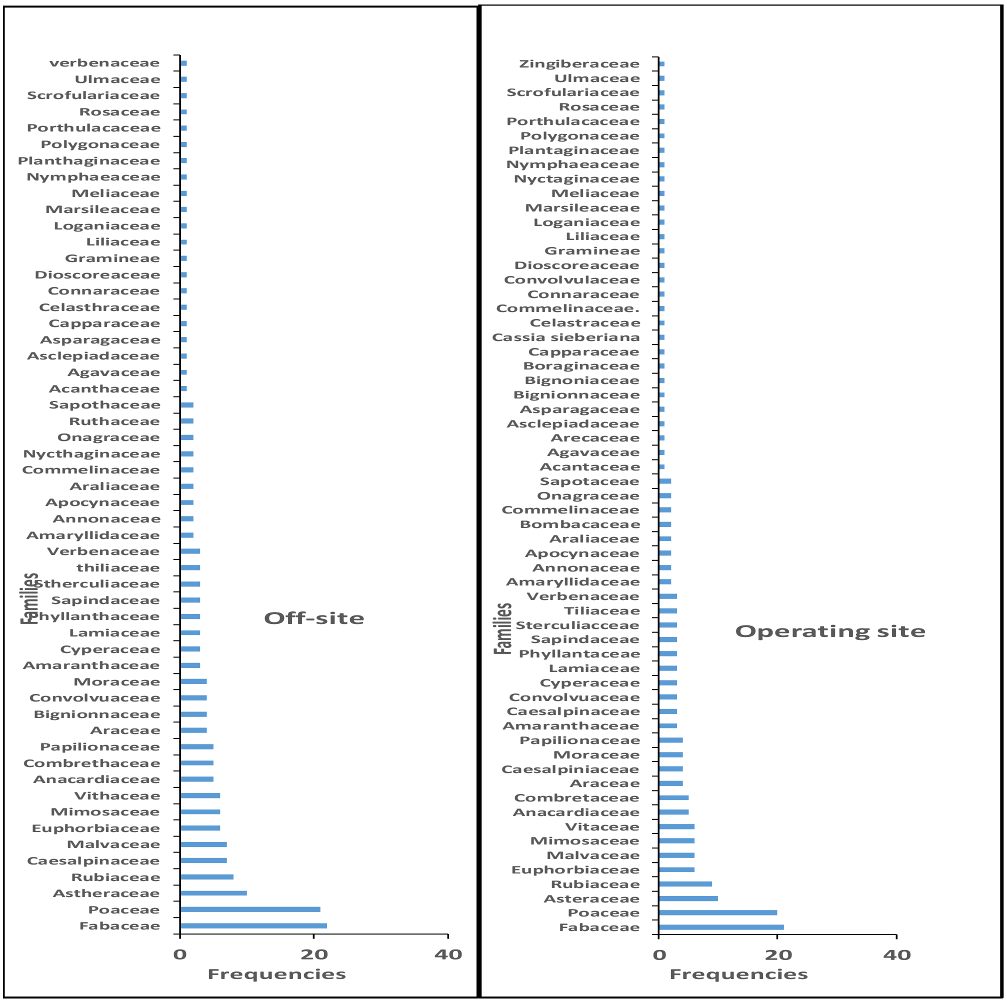
Table 1. Floristic diversity of operating sites and off-site

Type of Site	Operating sites	Off-sites
Species richness	96	139
Number of families	41	51
Shannon Index (H)	1.86bits	2 bits
Pielou evenness indices	0.94bits	0.93bits

Source: Statistical processing of floristic inventory data, 2020

4- 5 Impacts of the exploitation of rock formations on the families of flora species

Fig (5) shows the difference between the proportion of families on mining sites and off-sites. The most dominant families on the mining sites are the Poaceae (6.67%), Fabaceae (13.73%), Asteraceae (6.86%). The less represented families are the Zingiberaceae, Ulmaceae, Rosaceae each having 0.98%. Off-sites have the same families, but with different percentages: Poaceae (31.32%), Fabaceae (29.17%), Asteraceae (17.67%). The less represented families are the Verbenaceae, Ulmaceae, Tiliaceae (2.08% each). The frequency of the first three (03) families of mining sites show that the exploitation of rocky landforms is a major factor in the regression of woody plants. It illustrates a predominance of herbaceous plants on the mining sites.

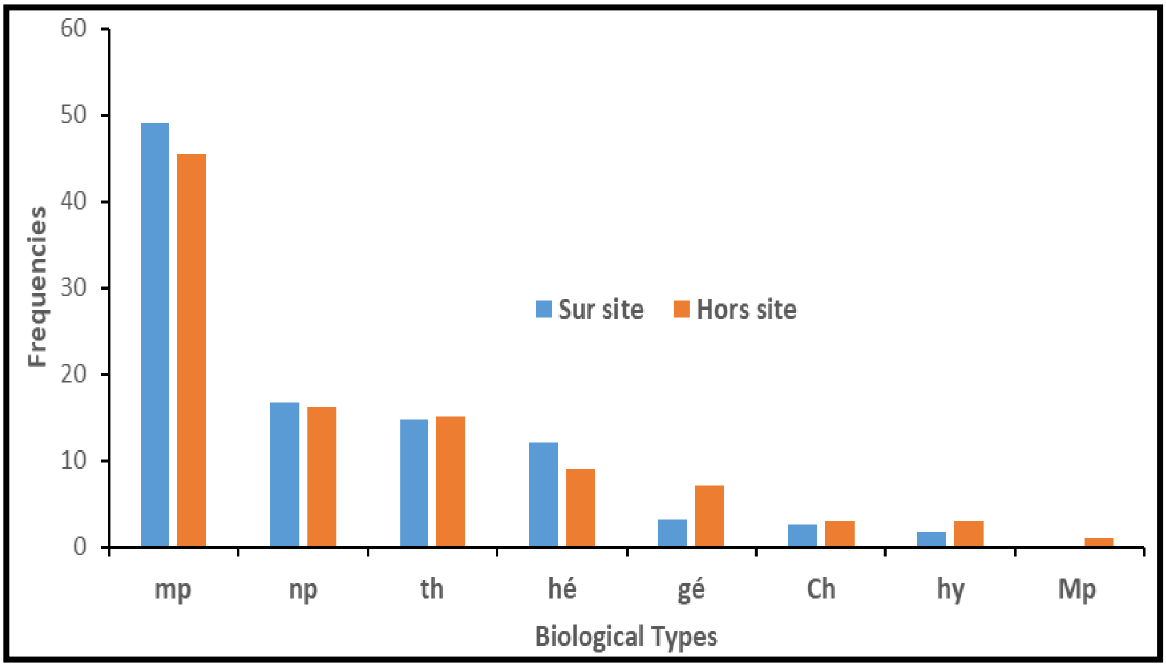


Source: Statistical processing of floristic inventory data, 2020

Fig. 5. Difference between the proportions of families on mining sites and off sites

4- 6 Impacts of the exploitation of rock models on the variation of biological spectra

Fig (6) shows that the dominant biological types from the exploitation sites are phanerophytes (40%) with microphanerophytes (17%), nanophanerophytes (8%), mesophanerophytes (8%) and Megaphanerophytes (7%). They are followed by therophytes (37%), hemicriptophytes (10%), chamephytes (5%), hydrophytes (5%) and geophytes (3%). On the other hand, off-site exploitation presents a predominance of higher phanerophytes (60.4%) from which there were microphanerophytes (28.86%), nanophanerophytes (14.09%), mesophanerophytes (11.41%) and Megaphanerophytes (6.04 %). They were followed by therophytes (22.82%), geophytes (7.38%), hemicriptophytes (6.71%) and Chaméphytes (2.68%). There is thus a predominance of herbaceous plants on the exploitation sites (60%) and a predominance of phanerophytes (60.4%) off the sites. The result shows that the exploitation of rock formations has had a negative impact on the flora, especially on the woody species in the study area.

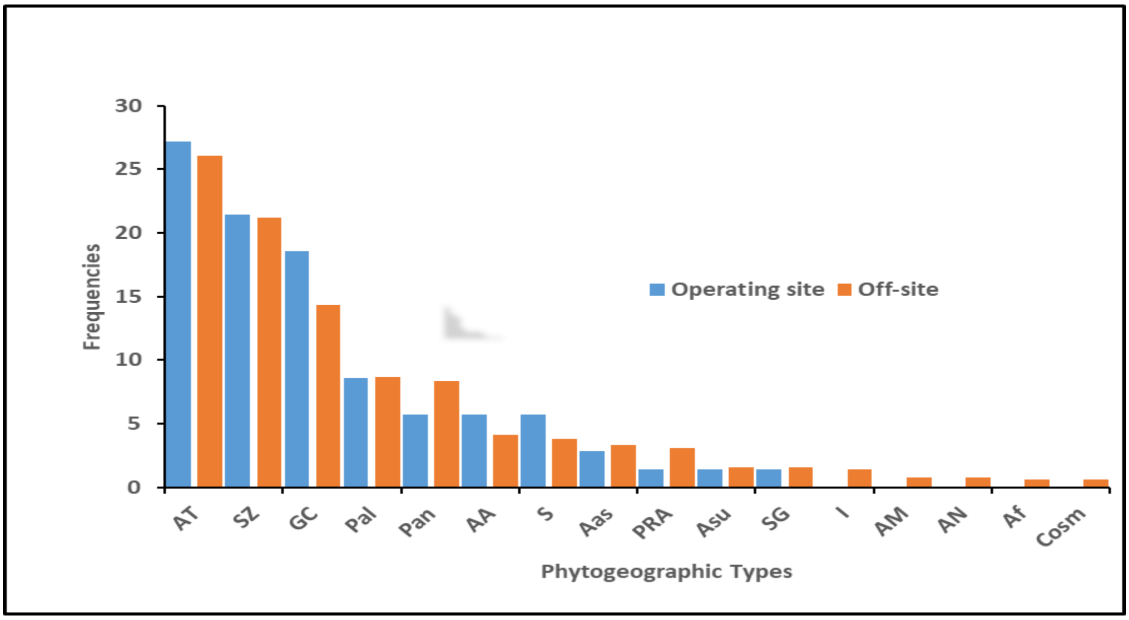


Source : Fieldwork, 2020

Fig. 6. Variation of the biological types of mining sites and off-site

4-7 Impacts of the exploitation of rock models on the variation of the phytogeographical spectrum

Fig (7) shows the different phytogeographical spectra of the exploitation sites and off-site. The analysis of this figure reveals that Afro-tropical species (35.58%) are the most abundant on the exploitation sites. They are followed by Sudano-Zambezian (15.38%) and Guinean-Congolese (11.54%) species. The same abundances of phytogeographical types characterize the off-sites, but in more or less significant proportions: Afro-tropical species (35.03%), Sudano-Zambézian (20.38%) and Guineo-Congolese (11.48%) %) species.



Source : Fieldwork, 2020

Fig. 7. Variation of phytogeographical types of exploitation sites and off-site

5- DISCUSSIONS

The assessment of specific diversity remains an indispensable tool in the implementation of biodiversity conservation and ecosystem management strategies (Lisingo *et al*, 2015). Indeed, in tropical rainforests, the richness and specific diversity are almost always high but vary in space. Several studies have been conducted at the local scale to assess the richness and floristic composition of forests in the Guinean zone. It should be noted, however, that in this study, the assessment of the impacts of the exploitation of rocky outcrops is carried out at the local scale in the Guinean zone where savannahs predominate. The assessment of phytodiversity in Agbelouvé Township and its surroundings is based on the floristic inventory. This method is used to identify the different species on and off the logging sites. The floristic characteristics of the inventoried species are compared in relation to the abundance and absence on the two different sites. The present study shows that off sites have higher species richness (139 species) than the operating sites (95 species). These results indicate that the exploitation sites are more disturbed by quarrying. Thus, the most represented families on the exploitation sites are Poaceae (16.67%), Fabaceae (13.73%), Asteraceae (6.86%). The work of ISSAH et al, (2018), carried out in limestone quarries in southeast Togo also present similar results. They obtained 114 species outside the quarry sites and 98 species on the quarry sites. The similarity of these results is explained by the fact that the study sectors are located in the same ecological zone V (Five) and moreover in the Guinean zone benefiting almost the same floristic diversity. As for the work of KHATER (2004) on the quarries of exploitation in Lebanon, present a small nuance at the level of families. The most predominant are Asteraceae (14.8%) followed by Fabaceae (11.8%). This difference would come from the climatic and edaphic conditions of the studied sites. The biological types are a classification proposed in 1904 by the Danish botanist Christen Raunkiær in order to organize all the plants according to the positioning of the organs of survival and thus of their growth meristems during the unfavorable period. However, through the analysis of field work, the study area presents a diversity of biological types not only in off-site but also on site. Indeed, the most dominant biological types in the study area are phanerophytes, therophytes and hemicriptophytes. Therophytes are predominant on the exploitation sites. On the other hand, off-site, phanerophytes predominate. This explains why the exploitation of rocks has progressively more effects on phanerophytes (size greater than 30m) especially at exploitation sites. These results corroborate with those of KHATER (2004) in Lebanon which have on the whole of the quarries therophytes (43%) and Chaméphytes (31%). Thus, Afro-tropical species (35.58%), Sudano-Zambézian species (15.38%) and Guinean-Congolese species (11.54%) are the most represented phytogeographic types in the study area.

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