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RESEARCH ARTICLE

Impacts of the iron ore extraction on the flora of the localities of Bangolo and Logoualé west of Côte d'ivoire

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Abstract

This work concerns the identification and assessment of the negative impacts of iron ore extraction on flora communities of Bangolo and Logoualé in western Côte d'Ivoire. It includes the analysis of potential bio-eco-climatic imbalances depending of the exploitation of iron ore on the flora of the operating area. Based on floristic inventories, the main objective was to characterize the impacts associated with the mining of iron ore on the flora of targeted communities. The results show that the flora of the study is rich approximately 441 species of which 36 are with particular status. This flora is fairly diversified and its characteristics make it possible to predict the risks of imbalances biological which can occur with short, average and long run in this locality. The flora knows a gradual degradation of the south north of perimeter of exploitation. Many impacts whose reduction of the diversity of the exploited arborescent ligneous, fragmentation of the forests and the rarefaction of the lianas were identified in this locality. The linked activities with the project were potential sources of negative impacts on the flora they contributed to destroy to a significant degree.

Introduction

The natural resources available on planet, are born, evolve and become exhausted over the years. Several factors and phenomena are often quoted as being the leading causes of the exhaustion of these resources. Among these factors, itinerant agriculture appears in pole position. Face these problems, integrated and durable agriculture is the principal solution recommended to prevent any form of ecological imbalance. STINNER and HOUSE (1990) have defines agriculture integrated and durable as being that based on methods preserving the environment and the soil. In addition, DORAN (2002) has defines this agriculture, as being an agriculture which serves the man by preserving the environment. Over the years, the populations, especially those of the countries in the process of development know a demography increasing. In many African countries, in particular in Côte d'Ivoire, the problematic of growth of the population and availability of the natural resources is deeply posed.

Also, the land pressure is felt it in a gradual way. The problem of land rural moreover frequent, sometimes, source of fatal conflicts, is one of the immediate causes of the land pressure. The reduction of the forest ecosystems and exhaustion of resources natural are caused inter alia by the fast urbanization of rural environments, increasing demography, the anarchistic exploitation of the known as resources, etc. In such a context, the survival of the bordering populations of these degraded environments requires the identification and the application of measures of durable management of spaces and the natural resources. Nowadays, these measurements are recommended more and more, to prevent possible bio-éco-climatic imbalances. One of these measurements after any source activity of disturbance of the ecosystems is the study of environmental impact (EIE). The impact study of the exploitation of the iron ores on the flora of the localities of BANGOLO and LOGOUALE is a capital phase of identification and

evaluation of the impacts of the iron ore extraction on 7 mountains of these localities. This, in order to search corrective measures and/or of attenuation.Material and methods.

1- Materials and methods

The perimeter of exploitation, belongs to the Guinean field. One meets there the wet sempervirente forest, the semi-décidue wet dense forest, of the marshy forests, the raphiales, etc These forests at one time luxuriant, is seriously started and gives way today to vast pieces of cultures of revenues comprising the Cacao-tree (Theobroma cocoa), the Coffee-tree (Coffea will caenophora), the Hevea (Hevea brasiliensis), of many pieces of food crops (rain rice, corn, yam) and of the secondary formations. This perimeter covers approximately 800 km ² surface (Fig.1).

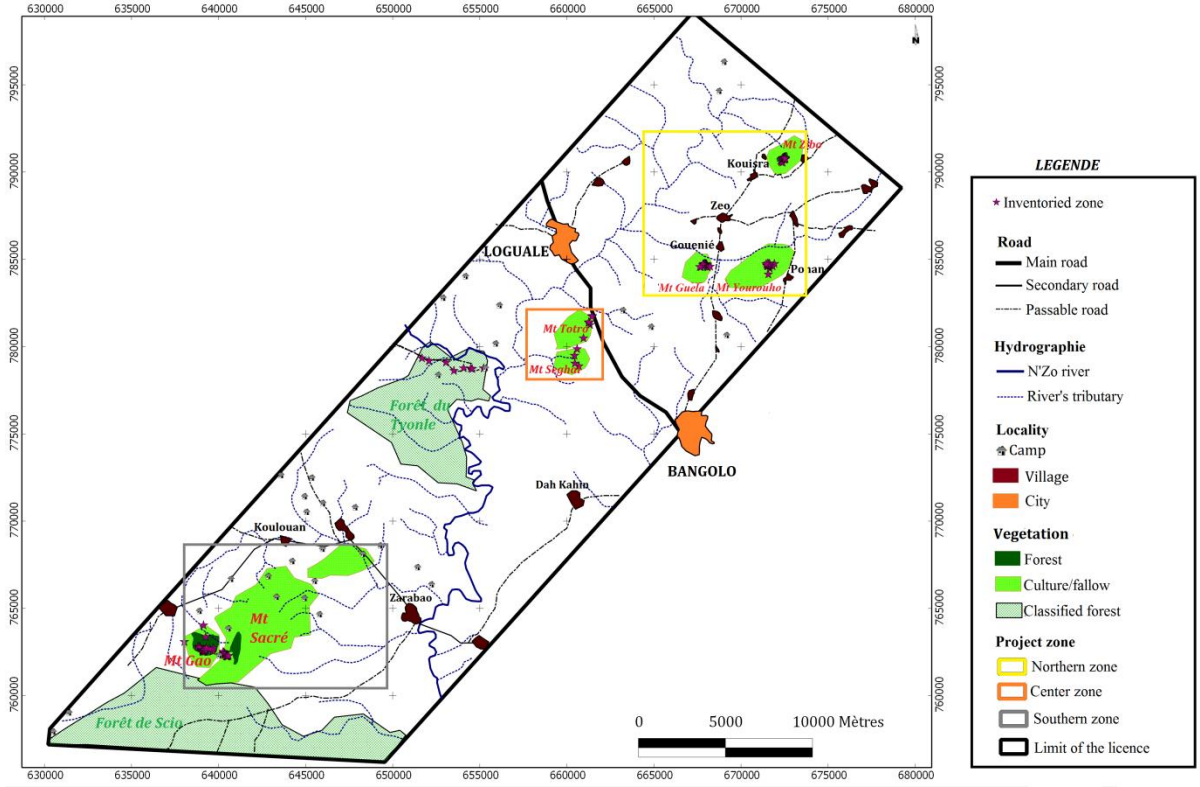

Fig.1: Perimeter exploited for the iron ore extraction

1-1- The sites of floristic inventories

1-1-1 - South of the perimeter of exploitation

The vegetations of the two mountains of the south of the perimeter of exploitation (fig. 2) have a good aspect. On the other hand, certain parts of their sides are exploited at ends agricultural and subjected very often to accidents related to the human activities

1-1-2- Center of the perimeter of exploitation

The Mountains of the center of the perimeter of exploitation comprise many agricultural landscapes (fig. 3). The vegetations inventoried on these mountains are fallow and plantations.

A B

Fig. 2 : Vegetation of the mountains of the south of the perimeter of exploitation

A B

Fig. 3 : Vegetation of the mountains of the Center of the perimeter of exploitation

1-1-3- North of the perimeter of exploitation

The vegetation of the mountains of the north of the perimeter of exploitation (fig. 4) is luxuriant on the tops and fragmented on the slopes. Certain zones are marked by the passage of the bush fires. One also notes, the presence of pieces of food crops in this locality.

A **B**

Fig. 4: Vegetation of the mountains of the North of the perimeter of exploitation

The perimeter of exploitation comprises a zone of transition between the wet dense forest to the south and the semi-décidue dense forest to north. It constituted in the beginning, a zone of strong floristic diversity where several species of the two biogeographic zones were brewed. The flora of this locality presents, today, a gradient of North-South degradation on all the extent of the perimeter. In spite of the presence of some relics floristiquement preserved well, pieces of cultures of revenues and the food ones, fallow are rather well represented. Certain forest vestiges which had escaped up to that point with the human action are seriously started.

Floristic inventory

Two methods were associated during the floristic inventory. It is: itinerant method, of enumeration of species on layouts and the method of the grixels (GAUTIER and al. 1994), which consists in describing the vegetation on "quadrats" of 20 m with dimensions. On each mountain of an average surface of approximately 400 ha, 40 small squares of one hectare (1ha) each one (fig. 5) were delimited. Markers with indelible ink were used to indicate the already inventoried sectors.

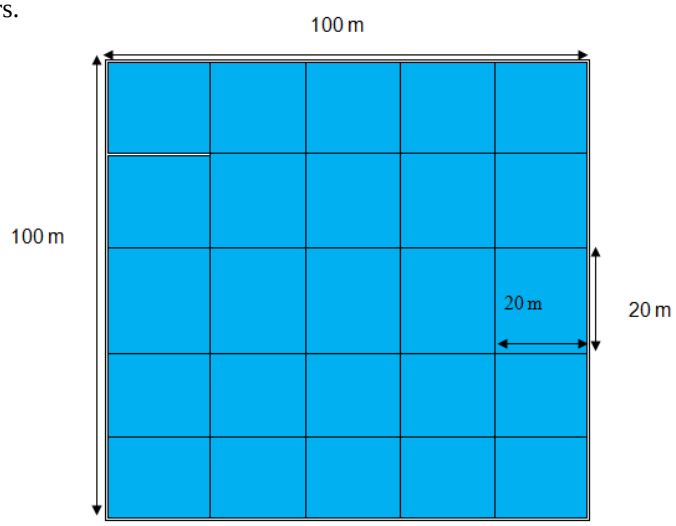

Fig. 5: Configuration of floristic inventory parcels

- Floristic inventory parcel

The small squares were left again of kind to cover all the sides of the mountains (top, sides and low of slope). Thus in each small square of floristic inventory, all species were inventoried and classified according to their statute (endemic, threatened, with risk, vulnerable etc). The list UICN (2012) was used as a basis of data for classification of floristic species analyzed.

The floristic diversity was expressed starting from the index of Shannon-weaver (1948) which is expressed in the following way:

$H = - \sum Pi*Log (pi)$. With, $pi = Fr/N$, NR being the full number of inventoried species; $Fr = F (a)/i$, I = full number of the parcel of inventory; F (a) = number of appearance of a species during the inventory. The values evolve of 0

with log (NR), NR being the full number of inventoried species. The Equitabilité at summer calculated starting from the index of Shannon. It is expressed as follows: E = H/log (NR). E evolves from 0 to 1. The source activities of impacts were identified and codify. The nature of impact (intensity, extent and duration) was evaluated and correlated in a matric table

3- Result and discussion

3-1- Wealth and specific diversity of the Southern zone

286 species were inventoried on the Mountains of the south of the perimeter of exploitation (Table I). The value of the index of diversity calculated in this sector is: H= 5.41. The equitability obtained is: E = 0.66.

23 species with particular status were inventoried there (Table I). Among these species, some are vulnerable or at the risk, others are threatened

Table I: list species with particular status inventoried on the Mountains of the south of the perimeter of exploitation

N°	Espèces	Famille	Statut
1	*Anopyxis klaineana*	Rhizophoraceae	vulnerable (UICN, 2012)
2	*Antrocaryon micraster*	Anacardiaceae	vulnerable (UICN, 2012)
3	*Cleidion gabonicum*	Euphorbiaceae	threatened (AKE ASSI, 2002)
4	*Cordia platythyrsa*	Boraginaceae	vulnerable (UICN, 2012)
5	*Didelotia idea*	Caesalpiniaceae	at the risk (UICN, 2009)
6	*Diospyros vignei*	Ebenaceae	threatened (AKE ASSI, 2002)
7	*Entada gigas*	Mimosaceae	threatened (AKE ASSI, 2002)
8	*Entandrophragma angolense*	Meliaceae	vulnerable (UICN, 2009)
9	*Entandrophragma candollei*	Meliaceae	vulnerable (UICN, 2009)
10	*Entandrophragma cylindricum*	Meliaceeae	vulnerable (UICN, 2009)
11	*Entandrophragma utile*	Meliaceae	Vulnerable (UICN, 2009)
12	*Eribroma oblonga*	Sterculiaceae	Vulnerable (UICN, 2009)
13	*Garcinia cola*	Guttiferae	Vulnérable (UICN, 2009)
14	*Gilbertiodendron splendidum*	Caesalpiniaceae	Vulnerable (UICN, 2009)
15	*Guarea cedrata*	Meliaceae	Vulnerable (UICN, 2009)
16	*Guibourtia ehie*	Caesalpiniaceae	Vulnerable (UICN, 2009)
17	*Gymnostemon zaizou*	Simaroubaceae	Vulnerable (UICN, 2009)
18	*Khaya grandifoliola*	Meliaceae	Vulnerable (UICN, 2009)
19	*Lophira alata*	Ochnaceae	Vulnerable (UICN, 2009)
20	*Microdesmis keayana*	Pandaceae	Vulnerable (UICN, 2009)
21	*Milicia excelsa*	Moraceae	Vulnerable (UICN, 2009)
22	*Nesogordonia papaverifera*	Sterculiaceae	Vulnerable (UICN, 2009)
23	*Solanum terminale*	Solanaceae	threatened (AKE ASSI, 2009)

3-2- Wealth and specific diversity of the center of the perimeter of exploitation

The flora of the mountains of the center is rich approximately 124 species (Table IV). The index of diversity is fairly raised, H = 4.7. On the other hand, the index of Equitabilité is raised, (E = 0.67) in this zone.

11 species with particular status were inventoried in this flora (Table 2). As in the southern part, some are in danger, others are vulnerable or at the risk, others still are threatened.

Table II: list species with particular status met on the Mounts in the center perimeter of exploitation

N°	Espèces	Famille	Statut
1	*Anopyxis klaineana*	Rhizophoraceae	Vulnerable (UICN, 2009)
2	*Cassia aubrevillei*	Caesalpiniaceae	Vulnerable (UICN, 2009)
3	*Cleidion gabonicum*	Euphorbiaceae	threatened (AKE ASSI, 2002)
4	*Cordia platythyrsa*	Boraginaceae	Vulnerable (UICN, 2009)
5	*Milicia excels*	Moraceae	Vulnerable (UICN, 2009)

6	*Nesogordonia papaverifera*	Sterculiaceae	Vulnerable (UICN, 2009)
7	*Placodiscus pseudostipularis*	Sapindaceae	In danger (UICN, 2009)
8	*Pterygota macrocarpa*	Sterculiaceae	at the risk (UICN, 2009)
9	*Rhodognaphalon brevicuspe*	Bombacaceae	Vulnerable (UICN, 2009)
10	*Terminalia ivoriensis*	Combretaceae	Vulnerable (UICN, 2009)
11	*Triplochiton scleroxylon*	Sterculiaceae	at he risk (UICN, 2009)

3-3- Wealth and specific diversity of the north of the perimeter of exploitation

The inventories carried out on the two mountains of north have made it possible to identify 287 species. The indices of diversity obtained on these tops are: H = 4.46 and E = 0.55. This flora comprises 18 species with particular status (Table 3). Following the example of the other zones, some are in danger, others are at the risk or vulnerable, others still are threatened.

Table III: list plant species with particular status inventoried on the Mounts of the Northern zone of the perimeter of exploitation

N°	Espèces	Famille	Statut
1	*Afzelia Africana*	Caesalpiniaceae	Vulnerable (UICN, 2009)
2	*Albizia ferruginea*	Mimosaceae	Vulnerable (UICN, 2009)
3	*Cordia platythyrsa*	Boraginaceae	Vulnerable (UICN, 2009)
4	*Diospyros vignei*	Ebenaceae	threatened (AKE ASSI, 2002)
5	*Entandrophragma angolense*	Meliaceae	Vulnerable (UICN, 2009)
6	*Garcinia afzelii*	Guttiferae	Vulnerable (UICN, 2009)
7	*Garcinia kola*	Guttiferae	Vulnerable (UICN, 2009)
8	*Guarea cedrata*	Meliaceae	Vulnerable (UICN, 2009)
9	*Guibourtia ehie*	Caesalpiniaceae	Vulnerable (UICN, 2009)
10	*Hallea ledermannii*	Rubiaceae	Vulnerable (UICN, 2009)
11	*Irvingia gabonensis*	Inrvigiaceae	at the risk (UICN, 2009)
12	*Khaya grandifoliola*	Meliaceae	Vulnerable (UICN, 2009)
13	*Lannea nigritana*	Anacardiaceae	threatened (AKE ASSI, 2002)
14	*Milicia excels*	Moraceae	Vulnerable (UICN, 2009)
15	*Nesogordonia papaverifera*	Sterculiaceae	Vulnerable (UICN, 2009)
16	*Placodiscus pseudostipularis*	Mimosaceae	in danger (UICN, 2009)
17	*Terminalia ivoriensis*	Combretaceae	vulnerable (UICN, 2009)
18	*Triplochiton scleroxylon*	Euphorbiaceae	at the risk (UICN, 2009)

3-4- Identification, analyzes and evaluation of the impacts

The evolution of the curves (fig. 6) shows the variation of the parameters characteristic of the impacts related to the phases of the prospection, of the exploitation and the closing of the project on the vegetation and the flora of the zones concerned with the exploitation and on that of the contiguous vegetable formations. With the analysis, the maximum intensity (2.33) of the impacts is obtained with the regular maintenance (ERG) of the site of the project. The minimal values (1) are obtained with the opening of the access roads (OVA) to the mountains. Median values (2) are obtained with the fairy-like toxicity (TOF) and the convoie of the machines (CDE). On the other hand, the evolution of the curve of wide of the impacts shows that the maximum values (2) are obtained with the fairy-like toxicity and the convoie of the machines. The median values (1.67) are obtained with, the regular maintenance of the site, the permanent presence of staff on site (PPP). Smallest wide (0.68) is obtained, with the opening of the access roads. In addition, the long duration (2) are obtained, with the fairy-like toxicity and the taking away in flora (pdf). The convoie of the machines, the permanent presence of staff (PPP) and the installation of the site generate average durations (1.67). More short times (0.67; 1) is obtained, with the opening of and the bursting access roads of the rock domes (EDR).

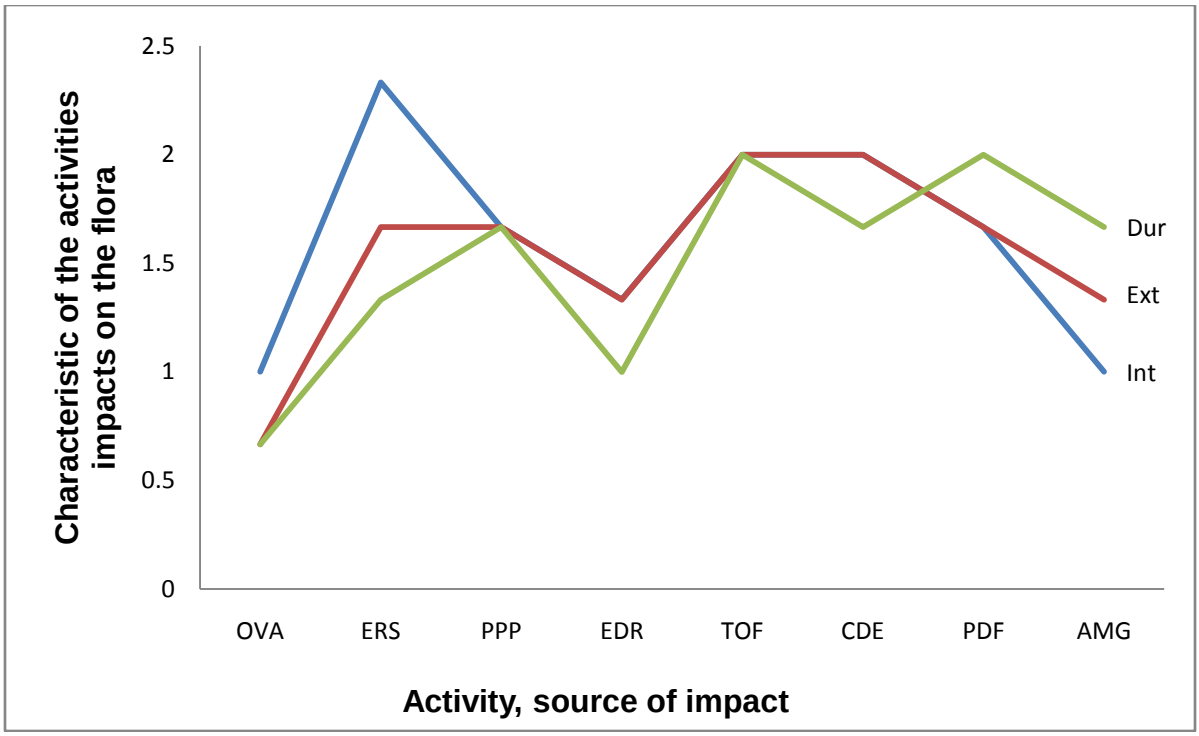

Fig. 6: Characterization of the parameters related to impact according to the sources activities of impacts in the course of time, with (NB: Dur: duration; ext: extended; Int: intensity; OVA: opening of the access roads; ERS: regular maintenance of the site; PPP: permanent presence of staff on the site; EDR: explosion of the rock domes; TOF: fairy-like toxicity; CDE: convoie of the machines; Pdf:cut in the woody flora ; AMG: Installation of the site).

The average curve of the evolution of impact linked activities with the project on the flora (fig. 7) shows high average impact , with fairy-like toxicity (2), the convoie of the machines (1.89), the regular maintenance of the site (1.78), the cut in the flora (1.78) and the permanent presence of staff on the site (1.67). The bursting of the rock domes (1.22) and the installation of the site (1.33) generate median values. The weak one impacts is obtained during the opening of the access roads.

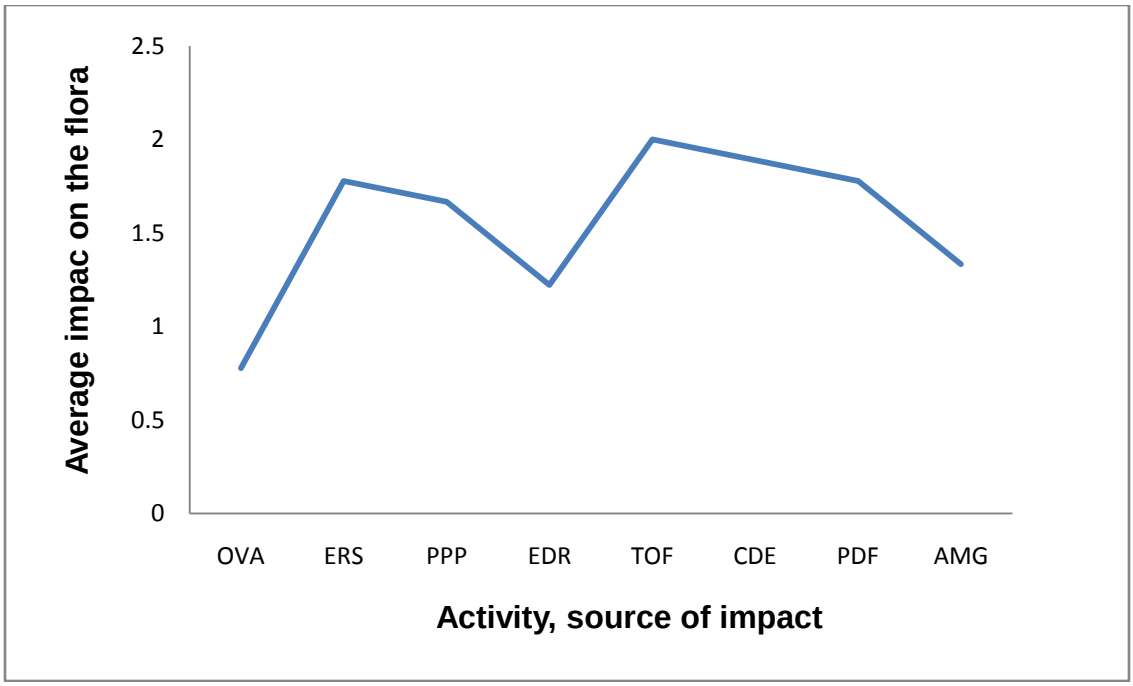

Fig. 7: Evolution of average impact according to the sources activities of impacts in the course of time, with (OVA: opening of the access roads; ERS: regular maintenance of the site; PPP: permanent presence of staff on the site; EDR: explosion of the rock domes; TOF: fairy-like toxicity; CDE: convoie of the machines; Pdf: cut in the woody flora; AMG: Installation of the site).

4- Discussion

4-1- Evolution of the indices of diversity

The analysis of the flora of the south of the perimeter of exploitation shows that it is fairly diversified (H= 5.41) and homogeneous (E = 0.66). The various activities undertaken in this zone were ecological sources of disturbances, and those can be regarded as major disturbances on the floristic diversity of the mountains. But compared to center zone and in the north, this flora is richer and more diversified in species vegetable as shows it the values of the indices of diversity and equitability. The data collected on the mountains of the center shows very important ecological information. With the analysis, this zone less rich and is diversified than the south. The fairly high index of diversity (H = 4.7), indicates that the medium has a mean level of diversity of the flora. On the other hand, the high index of equitability (E = 0.67) shows that the medium is homogeneous and stable on the mountains from the floristic point of view. Indices of diversity and Equitabilité (H = 4.46; E = 0.55) obtained north of perimeter of exploitation show that these mountains are diversified than those of the mountains of the two other zones.

4-2- Evolution of the environmental impacts

The environmental impacts are observed during the phases of exploration, of exploitation, like with the closing of the career. During the phase of exploration, the opening of the access roads and the installation of the platforms involves the destruction of the flora at certain places of the site of the project. Some specimens of trees, shrubs, lianas and herbaceous were destroyed. The openings carried out in the flora contributed to increase to a significant degree the luminosity on the ground in these usually closed formations thus exposing the species of under wood very sensitive to excesses of light. The epiphytes are found on the ground following the demolition of the large trees. All these movements involves an ecological imbalance within the vegetable formations concerned. During the production run, the extent of the disturbances was accentuated. The destruction became more important on the exploitation sites mine because the targeted rock domes were entirely mussed and lost, all their vegetable cover. During this phase, the vegetable formations close to the sites exploited also underwent great disturbances. Indeed, they were, not only stock rooms of enormous quantities of ground pickled on the rocks, but also of the points of fall of large blocks of rocks after the explosions with dynamite, as well as the places of the many frequentations of the workers in search of woody species for utility needs. The regular passages of the heavy machines as well as

excavation work imprisones the seeds, thus disturbing the natural regeneration of the plant species. With the closing of the career, the original vegetation almost disappeared following the destruction from the rocks. The aspect of the vegetation was modified. Species like Hildegardia barteri, whose rocks constitute the natural habitat is very threatened. The primary vegetation rich and diversified in cash and on the spot left a new vegetation mainly made up the herbaceous ones. The surrounding formations have so support the human pressure which they are more degraded. On the whole, the zone lost its diversified and rich forest and biological diversity regressed considerably under the pressures of anthropic origins. The characterization and the evaluation of the impacts on the flora of the site are judicious to bring a thorough lighting on the nature (intensity, extended and lasted) of impact. Thus, impact Them intense are caused by the regular talks of the site, fairy-like toxicity and the convoy of the large front machines, during and at the end of the project. The regular maintenance of the site which comprises demolitions and the clearing of certain ligneous family arborescent intensely have affected all the components of the sometimes compromising flora, its total regeneration like announced by Mitja (1993) in forest zone and Yossi (1996) in zone of savanna. However the intensities of impacts related to the opening of the access roads to the mountains and with the installation of the site are weak probably because of the light cuts made in the flora during these openings. Indeed, the openings carried out are tracks of 7 m width approximately. Also, the beginning of regeneration had been noted, because these roads were not regularly borrowed during the phase of prospection. The intensity of impact caused by installations is weak; that because the afforestations carried out are quantitatively weak and especially of average quality. Moreover, the forest petrols used have a slow growth (Alexandre, 1989, Kouamé, 1998, Ettien, 2005 and Kouadio, 2007) and are often exposed to the blow of the climatic variations. The duration of the impacts related on fairy-like toxicity and the taking away in the flora is long. Because the iron ores present on the site are remanent on the front site, during and at the end of the project, in the same way the cuts in the flora continued at the end of the project because of the land pressure. On the other hand, the opening of the access roads and the bursting of the rock domes with the dynamite are temporary activities of short time.

4-3- Main sources of impact

The main sources of impact are the regular maintenance of the sites and fairy-like toxicity. Indeed, these activities are at the same time intense long and wide. Also, the many cuts in the flora have an additive effect on that of the regular management in the flora. In addition, the convoie of the large machines with its corollaries the compaction of the grounds, the clearing of certain arborescent ligneous family is also source of strong impact. In addition, the opening of the access roads which are a short activity, less intense and not very wide generates certainly disturbances in the flora, but these disturbances cause minor impacts.

Conclusion

The vegetation of the perimeter of exploitation is deeply disturbed. It is strongly degraded in its southern part where the true forest formations are confined on the rocks with more than 400 m of altitude, the rest of the landscape being occupied by orchards of cacao-trees and coffee-trees. The northern part remains preserved relatively better than the south, the original forest is however rare and also localised in altitude. The flora of the site of the project has strongly undergoes the action of the man. However, this perimeter is part of rare spaces in Ivory Coast which still comprise still rich relics in forests species. It presents a floristic homogeneity. This flora comprises many species with particular status. This one was strongly disturbed by mining. However, of measurements of attenuation can be adopted to minimize and or to compensate impact of project. It is inter alia: the protection and with the conservation of the contiguous vegetations, the creation of managed forests and their enrichment in vegetable species with particular status, the protection of the vestiges remaining integrals, to compensate for the losses in biodiversity and to attenuate certain forms of pollution etc

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