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Improvement of the Biological Parameters of Sterile Tailings Pits at Ivorian Mining Sites by the Legume *Pueraria Phasoeloides:* Case of the Agbaou Gold Mine (Central-Western Côte d'Ivoire)

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Abstract:-
Objective: The aim of the study is to show the effects of the legume *Pueraria Phasoeloides* on the biological parameters of the waste rock soils (saprolites) at the Agbaou gold mine, in the center-west of Côte d'Ivoire.
Methodology and results: Macroinvertebrates were harvested from the monolytes using the systematic sampling method. The use of the legume *Pueraria Phasoeloides* helped to solve the problems of agricultural land in the area. The inventories carried out in the sterile park 1 of the Agbaou gold mine allowed to discriminate over the three years a total of 1981 specimens from the overall population. We counted 540 individuals (27.25%) on Ramp 1; 743 (37.50%) on Ramp 4, 448 (22.61%) on Ramp 6, and 250 on Ramp 8 (12.61%). Ramps 1 and 6 are the most diversified stations with 540 and 448 taxa respectively, followed by Ramps 4 (743 taxa) and 8 (250 taxa), which are poorly diversified. Shannon's diversity index is less than 3 on the four ramps in this zone (sterile park 1 in Agbaou), thus reflecting a lower biological diversity in these environments. Although mining activity is a threat to the various spheres of the environment, the rehabilitation of the waste rock piles by the *Pueraria Phasoeloides* is a form of compensation for the damage caused by the adverse effects of mining. It appears as an ecosystem that locally increases biological diversity and requires urgent implementation actions.

***Keywords**:- Pueraria Phasoeloides, Rehabilitation, Mine Site, Biological Survey of Microorganisms and Macroorganisms, Agbaou Gold Mine (Central-Western Côte d'Ivoire).*

I. INTRODUCTION

The phenomena of soil degradation are becoming increasingly important from an environmental, health, economic and political point of view. Pollution leads to disturbances at the biotic level (fauna and flora) and fundamental abiotic compartments (water, soil, atmosphere). Most components of the environment can be affected during activities related to a mining project. Water, soil, air, vegetation, fauna and landscape will be affected with more or less impact depending on the size of the site (Christine, 2002).

Mining has always been considered destructive of the landscape and the environment. The impacts are significant and the balance of the environment often changes. Mining often develops to the detriment of local populations who do not always benefit from the economic and financial repercussions, but suffer the effects of land degradation and pollution of all kinds (DIDBY, 1999).

Mining is an important economic activity in the development of countries endowed with mineral resources. However, the development of mining activity has adverse consequences on the environment through its impact on flora, soils and water (GREP, 2012). In Africa, many mining operations have been initiated without any prior environmental impact assessment. Studies conducted in Morocco have highlighted the impacts of mining pollutants on the environment in general and the waters of the Oued Moulouya in particular (Assi, 2001) and (Baghdad et al., 2005). Mining can generate high concentrations of heavy metals through surface mining). The increase in pollutants from mining activity is a source of pollution of ecosystems and a threat to public health (Baghdad et al., 2003 and Tseng et al., 1968).

Côte d'Ivoire's policy is oriented towards the exploitation of subsoil resources in recent decades to increase state revenues. Moreover, mining has been reported in the literature: Making the mining sector a second teat of the Ivorian economy (UNDP, 2011). Geologically, Côte d'Ivoire is part of the Precambrian basement of West Africa (320 to 1600 million years old) with a characteristic NNE-SSW structural alignment that appears as irregular alternating bands of granitoid rocks and metamorphosed volcanic and sedimentary rocks rich in useful mineral resources (SODEMI, 1972).

In order to face the problems of mine site restoration, several solutions have been proposed by research, including: the rehabilitation of sterile verses by the legume *Pueraria Phasoeloides*. It is to make up for the damage caused by

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mining activity that this study was carried out to characterize the composition, diversity and structure of the biological groupings of the tailings pit 1 of the Agbaou gold mine. It constitutes a baseline study to understand the response to the environmental damage caused by mining activity from a sustainable land management perspective.

II. MATERIAL AND METHODS

2.1. Description of the study site

The study was conducted at the Agbaou gold mine in northwestern Côte d'Ivoire, located at approximately 200 km from Abidjan (Figure 1).

The study area is contained within the Agbaou exploration permit, in northwestern Côte d'Ivoire in the southern part of Bandama and the Divo District.

The climate is humid subtropical and transitional equatorial (Tié, 2005). The driest months are January and December, while the wettest month is June, with rainfall of up to 210 mm. The highest annual rainfall is 1,235.4 mm and the lowest 103 mm (SODEXAM, 2000). Maximum temperatures are between 31° and 38°C and minimums between 10° and 21°C.

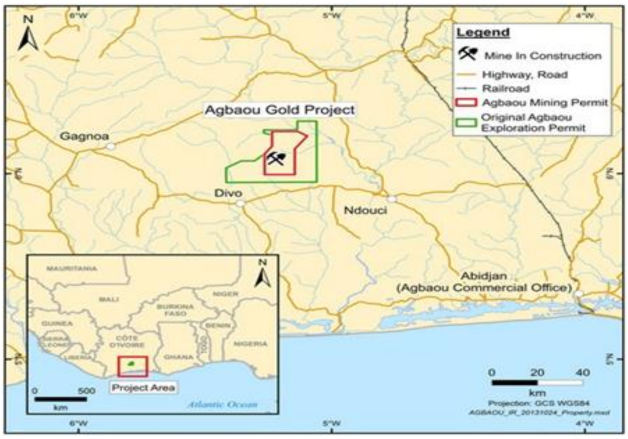

Figure 1: Location of the Agbaou Gold Mine

2.2. DATA COLLECTION

2-2.1 Biological surveys

At the level of each site, the inventory of biological species was carried out using soil monoliths (25 cm *25 cm *10 cm) which were delimited by elementary plots and then water container traps were introduced. Other macro-invertebrates were harvested by hand sorting and preserved in 90° alcohol. The species were identified as follows: The identification of the organisms was carried out using a binocular magnifying glass and a microscope and sometimes with the naked eye. This diagnosis was made using the determination keys published by Elouard (1981), Vergon & Bourgeois (1993), Reynoldson (2000), Tachet et al (1980, 2000), Heidemann & Seidenbusch (2002), Merritt et al (2008) and Bilardo & Rocchi (2008, 2010, 2012, 2013):

- Easily recognizable species are identified in alcohol, otherwise the assembly is required. The species collected during this study were identified either by using determination keys and comparing them with species from large collections deposited in European and American museums.

- All specimens were determined down to the generic level using the keys to the genera of the world (Bolton, 1994). Specimens of the same genus were in turn determined down to the biological species level using various synoptic classification documents or genus review articles in which a species key is always available. In some cases, the original descriptions downloaded from the website << Antbase>> (Agoti and Johson, 2006), were used. In cases where no key was available, species of the same genus were separated into morpho-species (i.e., specimens grouped together based on morphological similarity) as suggested by Lattke (2000) pending their complete determination.

2.2.2. Plant material

Pueraria phaseoloïdes is an herbaceous, coiled legume, with branches up to 15 m long. The stems are cylindrical, equipment with and trifoliate leaves. The number of seeds varies from 8 to 25 per pod, about 3 mm long and dark brown in color (Acevedo-Rodríguez, 2005). It is deeply rooted (up to 2 m depth), with hairy stems that can reach a length between 6 and 15 m and a diameter of 0.6 cm (FAO, 2015; Cook et al., 2005; Halim, 1997). It is a plant species whose systematic position is as follows: Kingdom: plant, Branch: spermatophyte (seed plants), Division : magnoliophyta (flowering plants), Class : magnoliopsida (dicotyledons), Order : Fabales, Family Fabaceae, Genus : Pueraria (kudzu), Species : Pueraria Phaseoloïdes.

2.2.3. Geological material

Rock formations of the Agbaou gold deposit corresponding to the “Sillon de Roches Vertes” Oumé-Fétêkro, of Birrimian age. The rocks encountered are essentially deformed mafic volcanites metamorphosed in the green schist facies. A folded greenstone belt, with deposits located, not far from the anticlinal hinge of the fold on the eastern flank can also be observed. The deposit is located in the northeast-trending shear zone separating meta-volcanites to the east and meta-sediments to the west. Rocks consist of volcanic meta, meta-sediments, tuffs and mylonites (Golder, 2008).

2.3. Soil characteristics

2.3.1. Topsoil

Soils are classified in this area contain coarse materials such as ferruginous gravel, laterite and quartz fragments. Chemical analysis revealed that all soils have a high cation exchange capacity, and that the saturation of these complexes is adequate (Tié, 2005).

2.3.2. Saprolite

It is a thick layer of soil with 10 m of laterite formed above the deposit. A transition zone developed at the lower oxidation limit over the healthy rock. It originates from weathered metavolcanites rokcs. On a regional scale, the saprolite has a typical thickness of 70 to 100 m, which can vary over the deposit from 10 m (west) to 120 m (northeast).

Saprolite thickness varies from 10 to 20 m and is generally found at a depth of 70 m in the Agbaou deposit.

Figure 2: A quarry showing staged ore extraction (saprolite ramps)

2.4. Construction of the sterile park

The waste rock extracted from the open-pit quarries, was transported and stored in a dumping site or waste rock park. The waste rock stockpile is constructed so that the waste rock extracted from the surface of the quarry is placed at the base of the slope and the material extracted further down the quarry is deposited on the top of the ramp hill, in the form of an inverted relief. When a ramp level is constructed, it is covered with a thin layer of "topsoil". Then seeds of Pueraria phaseoloïdes are sown and teak plants (Tectonia grandis) are planted at 10 m intervals to stabilize the slopes of the hill thus constructed.

Figure 3: Hill under construction, with sterile saprolite showing the stairway (ramps) layouts.

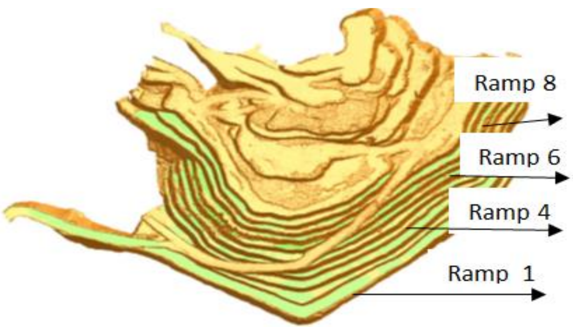

Figure 4: Randomly sampled ramps layont where soil samples were collected.
NB: Ramps 1, 4, 6 and 8 : Ramps where soil samples were collected

2.4. Dendrometric surveys

The dendrometric surveys were carried out from the same soil monoliths (25 cm *25 cm *10 cm) which were delimited by elementary plots. These surveys were carried out on an area of 820,346.765 m2.

2.4.1- Statistical methods of data analysis

The data analyzed in this brief are based on incidence, i.e., the presence or absence of species in the samples. This choice is explained by the social nature of the species, whose distribution of individuals is therefore aggregated. In this case, the choice of incidence instead of the absolute number of individuals should be preferred when estimating the abundance of species (Anderson, 1991). Thus, along a given transect, the most abundant species will have a total incidence of 20 for 200 m and 15 for 150 m transects, while the least abundant will have 1 for all types of transects. The hierarchical classification of the surveys and the calculations were carried out in the R software (Core T, 2017). Correspondence factor analysis (CFA) coupled with hierarchical ascending classification (CAH), carried out using R software version R-3.2.0.2, made it possible to discriminate between animal groupings of the different land use units highlighted by the CCA. For each group highlighted by the dendrograms, the indicator value of all species within the group was calculated using R software version R-3.2.0.2.

2.4.2. Diversity indices

The abundance and species richness of the different macroinvertebrate taxa were calculated. The specific diversity of these organisms in the environments explored was determined by the Shannon index (Shannon, 1948), which allows the heterogeneity of the biodiversity of an environment to be quantified. This index was calculated using the following formula: $H' = -\Sigma ((Ni/N) \times \ln (Ni/N))$; with Ni : number of individuals of a given species and N : total number of individuals. The Simpson's index (Simpson, 1949), which calculates the probability that two randomly selected individuals in a given environment are of the same species, was calculated according to the following formula: $D = \Sigma Ni (Ni-1) / N (N-1)$; with D : Simpson's index, Ni : number of individuals of the given species and N : total number of individuals.

In addition, the equitability of Piélou, which reflects the degree of diversity achieved, was calculated to identify the balance of the stands according to the following formula: $E = H'/H_{max} = H'/Log2\ S$; with S: number of species observed. The Chi-square test (t2) was carried out to understand if there is a significant difference (at the threshold of 0.05) in the distribution of macroinvertebrates according to the surveyed stations.

III. RESULTS AND DISCUSSION

The results show a variation in biological parameters from one ramp to another and from one campaign to another. The figure below shows a sterile park planted with Pueraria phaseoloïdes and Tectonia grandis.

Figure 5: View of a sterile park planted with Pueraria phaseoloïdes and Tectonia grandis and naturally colonized by Panicum maximum, Trema orientalis, etc. species.

Figure 6: View of some species of macro-invertebrates collected on the site.

3.1 Characteristics of macro-invertebrates

3.1.1. Abundance and diversity of macroinvertebrates in the stations of the Agbaou mine tailings impoundment area 1

In the area of the tailing's impoundment area 1 of the Agbaou Gold Mine, the captured macroinvertebrates are shown in Table 1. A total of 1981 specimens were captured over the three years: 540 (27.25%) on Ramp 1; 743 (37.50%) on Ramp 4, 448 (22.61%) on Ramp 6, and 250 on Ramp 8 (12.61%). Ramps 1 and 6 are the most diversified stations with 540 and 448 taxa respectively, followed by Ramps 4 (743 taxa) and 8 (250 taxa), which are poorly diversified.

Shannon's diversity index is less than 3 on the four ramps in this zone (sterile park 1 in Agbaou), thus reflecting a lower biological diversity in these environments. The most diversified station is ramp 1 with a Shannon index of 2.48 bits/ind and the least diversified is ramp 8 (1.94 bits/ind). At the same time, the Simpson's index is between 0.85 and 0.91, with an average of 0.75 for the four stations, indicating an absence of dominant taxa in this zone. The taxa identified are mainly represented by Hymenoptera (42%), Araneids (16%), Coleoptera (16%), Orthoptera (10%), Oligochaete (9%), Dipluracetes (4%) and Diplopoda (3%). The other families are very poorly represented (Figure 7).

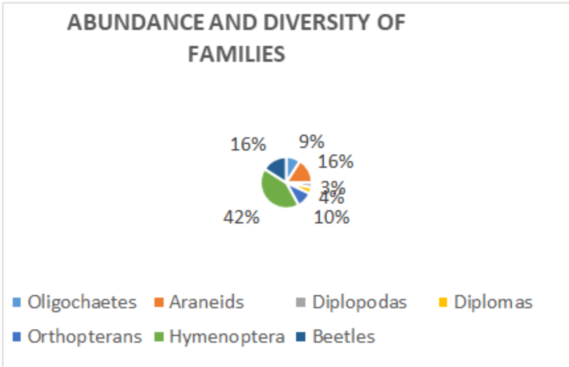

Figure 7: Abundance and diversity of macroinvertebrate families at the Agbaou gold mine tailings impoundment area 1 station.

Table 1: Overall number of macroinvertebrates captured at the Agbaou Gold Mine tailings impoundment area 1.

SHADINGS	Classes	Families	Common Names	Functional Groups	Number of species	Biomass (g/m2)
ANNELIDS	Annelids	Oligochaete	earthworms	Saprophages	172	15,2
MOLLUSKS	Gasteropods	physidae	Phytophagous	snails	18	54
			Slugs	Phytophagous	24	2,4
ARTHROPODS	Crustaceans	Isopods	Sowbugs	Phytophagous	36	3,6
	Arachnids	Aranes	Spiders	Predator	300	30
	Myriapods	Diplopods	Iules	Phytophagus	48	4,8
	Insects	Diplomas	Collemboles	Fungivores	80	24
		Mantidae	Praying mantis	Predator	6	9
		chilopods	Centipede	Predator	8	0,8
		Orthopterans	locusts	Phytophage	174	34,8
		Diptera	Bees	Phytophage	06	0,6
		Isoptera	Termites	saprophage	18	1,8
		Lepidoptera	Butterflies	phytophage	12	2,4
			Caterpillars	phytophage	12	1,2
		Hymenoptera	Ants	saprophage	774	25,8
		Beetles	Beetle	Predator	203	20,3
			Carabous	saprophage	90	9

3.1.2. Composition and specific diversity of macroinvertebrate groupings in the stations of the Agbou gold mine tailings impoundment area 1

3.1.2.1. Evolution of the number of macroinvertebrates as a function of ramps and years

Figure 8 shows the numbers of macro-invertebrates in the ramps. At the end of the first year, there is a significant decrease in the number of macroinvertebrates from ramp 1 (88) to ramp 8 (25). At the end of the second year, there is also a decrease in numbers from ramp 1 (169) to ramp 8 (55). At the end of the third year, there is also a decrease in numbers from Ramp 1 (236) to Ramp 8 (104). From the first season to the third, three years of legume colonization, there is a significant increase in the number of macroinvertebrates, especially at ramps 8, 1 and 6. Values ranged from 104 to 25 for Ramp 8, from 236 to 88 for Ramp 1 and from 175 to 82 for Ramp 6. The highest macroinvertebrate numbers were obtained on ramps 1 and 4 (bottom of the slope) and the lowest on ramp 8 at the top of the hill. The large variations in macroinvertebrate numbers between ramps were obtained between ramps 1 and 6 and between ramps 1 and 8, because of the legume over time. However, non-significant variations in macroinvertebrate numbers were obtained between ramps 8, 1 and 6, and between ramps 4 and 6, over the three years. In general, under the effect of Pueraria phaseoloides, the values of macroinvertebrate numbers of the ramps increased from one year to another and decreased from the lower ramps to the upper ramps.

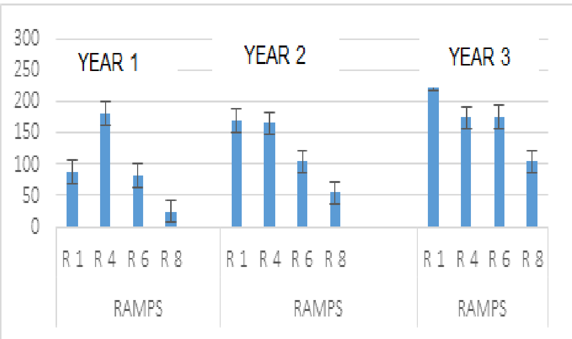

Figure 8: Evolution of the number of macroinvertebrate individuals as a function of ramps and years

R1= Ramp 1 ; R4= Ramp 4 ; R6= Ramp 6 et R8= Ramp 8.

3.1.2.2. Evolution of macroinvertebrate weights as a function of ramps and years

Figure 9 shows the macroinvertebrate weights of the ramps. At the end of the first year, there is a significant decrease in macroinvertebrate weights from ramp 1 (9.3) to ramp 8 (3.7). At the end of the second year, there is also a decrease in the weight from Ramp 1 (12.6) to Ramp 8 (5.7). At the end of the third year, there is also a decrease in weight from Ramp 1 (35.1) to Ramp 8 (25.4). From the first season to the third, i.e., three years of legume colonization, there is a significant increase in macroinvertebrate weight, especially at ramps 8, 1 and 6. Values ranged from 25.4 to 3.7 for ramp 8, from 35.1 to 9.3 for ramp 1 and from 22.5 to 8.1 for ramp 6. The highest macroinvertebrate weight values were obtained on ramps 1 and 4 (bottom of the slope) and the lowest on ramp 8 located at the top of the hill. The large variations in macroinvertebrate weights between ramps were obtained between ramps 8, 1 and 6, because of the legume over time. However, non-significant variations in macroinvertebrate weights were obtained between ramps 6, 4 and 1, over the three years. In general, under the effect of Pueraria phaseoloides, macroinvertebrate weight values of the ramps increased from one year to another and decreased from the lower ramps to the upper ramps.

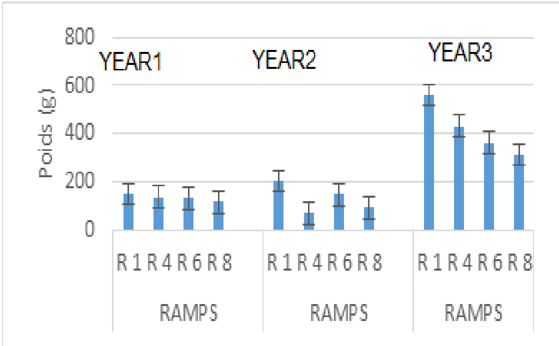

Figure 9 : Evolution of macroinvertebrate weight as a function of ramps and years

R1= Ramp 1 ; R4= Ramp 4 ; R6= Ramp 6 et R8= Ramp 8.

3.1.2.3. Evolution of the Number of individuals per m² of macroinvertebrates as a function of ramps and years

Figure 10 shows the numbers of macro-invertebrates per m² of ramps. At the end of the first year, there is a significant decrease in the number of macroinvertebrates per m² from ramp 1 (1408) to ramp 8 (342.4). At the end of the second year, there is also a decrease in numbers from Ramp 1 (2704) to Ramp 8 (880). At the end of the third year, there is also a decrease in numbers from Ramp 1 (3776) to Ramp 8 (1712). From the first season to the third, i.e., three years of colonization by legumes, there is a significant increase in the number of macroinvertebrates per m², especially at ramps 8, 1 and 6. Values ranged from 342.4 to 1712 for Ramp 8, from 3776 to 1408 for Ramp 1 and from 2800 to 1296 for Ramp 6. The values of the numbers per m² of macroinvertebrates were highest on ramps 1 and 4 (bottom of the slope) and lowest on ramp 8 located at the top of the hill. The large variations in macroinvertebrate numbers between ramps were obtained between ramps 8, 1 and 6, because of the legume over time. However, insignificant variations in the number per m² of macroinvertebrates were obtained between ramps 4, 6 and 1, over the three years. In general, under the effect of Pueraria phaseoloides, the values of macroinvertebrate numbers per m² of the ramps increased from one year to another and decreased from the lower ramps to the upper ramps.

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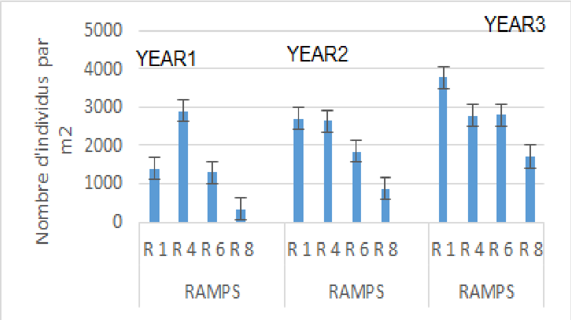

Figure 10 : Evolution of the Number of individuals per m² of macroinvertebrates as a function of ramps and years.
NB : R1= Ramp 1 ; R4= Ramp 4 ; R6= Ramp 6 and R8= Ramp 8.

3.1.2.4. Ecological indices and groupings of macro-invertebrates in the sterile park 1

The composition and diversity of macroinvertebrate groupings in the Agbaou Gold Mine Waste Rock Park 1 area is illustrated in Figures 11, 12, and 13. On Ramp 4 of the barren yard 1 of the Agbaou Gold Mine, 743 specimens were collected, representing 37.50% of the total catch. Of this total, 540 specimens were caught on ramp 1, 448 on ramp 6 and 250 on ramp 8. Ramp 1 is the most diversified station with 743 taxa, followed by Ramp 6 (448taxa) and then Ramp 4 (743). Ramp 6 is the least diversified (250 taxa). Shannon's index thus showed that the station at Ramp 1 (H' = 2.48bits/ind) is the most diversified area while that at Ramp 6 (H' = 1.94bits/ind) is the least diversified. Overall, Simpson's showings obtained from the four stations prospected in the Barren Lands 1 portion of the mine may reflect an absence of dominant taxa in this zone. The highest value of the equitability index is observed at Ramp 8 (0.84) and the lowest is recorded at Ramp 6 (0.8). Equitability at all stations in the park is close to 1, indicating that macroinvertebrate stands are balanced, i.e., all taxa have approximately the same dominance (Figure 11). Macrofaunal populations in this part of the park are dominated by 3 families, namely Hymenoptera (42%), Araneidae (16%) and Coleoptera (16%). The other families are very poorly represented (less than 11%), due to the influence of environmental variables (duration of soil material) on the distribution of macroinvertebrates.

Correspondence factor analysis shows that ramps 1, 4, 6 and 8 have no similarity. However, some macro-invertebrates show a strong correlation of presence in terms of biomass and numbers within the different ramps. Indeed, the ecological requirements of a species, as well as its indicator value, cover all the correspondences between the presence of individuals of this species and the environmental modalities identified at the same locations. Thus, there is a strong correlation of presence between springtails, caterpillars, bees and centipedes within Ramp 1, a strong correlation of presence between ladybugs, earthworms, spiders and locusts within Ramp 4, a strong correlation of presence between ants and snails within Ramp 6 and a strong correlation of presence between ground beetles, iules, sowbugs and termites within Ramp 8. Finally, butterflies and slugs show no correlation of presence within the different ramps, Figure 11. Functional or phylogenetic diversity considers the proximity of species to each other. Generally, the distance between species is evaluated in the space of the traits, an approximation of the niche space, for functional diversity and in a dendrogram representing phylogeny or taxonomy for phylogenetic diversity (Figure 13). A similarity or dissimilarity is any application with numerical values that measures the relationship between individuals in the same set or between variables. For similarity, the stronger the link, the greater the value.

A distance is Euclidean if it can be represented by geometric figures. The most obvious way to define a distance between species is to use taxonomy, by assigning an arbitrary distance (for example 1) to two species of the same genus, another (for example 2) to two species of the same family, etc. The defined distance is ultra metric. Richness is the accumulation of different classes in classical measures. In a phylogenetic tree, the length of the branches represents an evolutionary time: richness is the sum of these. The truncation of the dendrogram (figure 13) allowed to set the number of groups to 2. Comparison of the results between the different groups and consultation of the notes taken in the field revealed that the distribution into 2 groups was close to reality. This grouping of macro-invertebrates considers, on the one hand, the classification by type of vegetation and, on the other hand, the nature of the source rocks and the geographical distribution of each group. Indeed, the soils of group 1 come from the superficial part (topsoil) of the quarry while the soils of group 2 are of deeper origin. The phylogenetic tree in the barren area 1 of the Agbaou gold mine is characterized by branches that are short because it is a rebuilding environment, Figure 13.

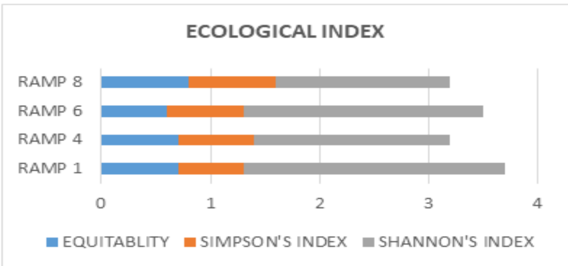

Figure 11: Ecological Indices of Macroinvertebrates on Sterile Park Ramps 1

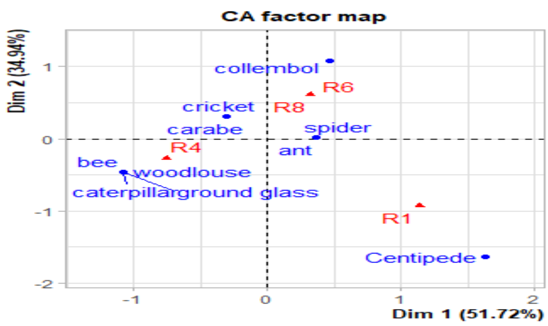

Figure 12 : Ordering of groups of macro-organisms by canonical correspondence analysis : R1 represents ramp 1, R4 represents ramp 4, R6 represents ramp 6 and R8 represents ramp 8.

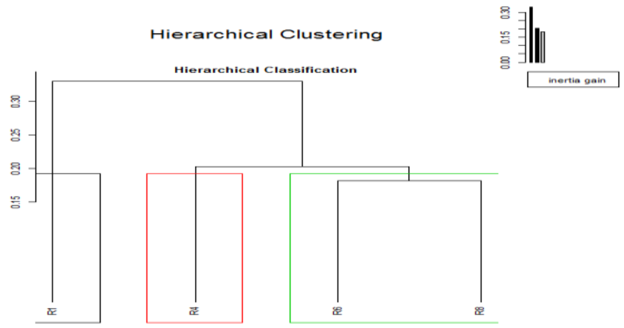

Figure 13: Dendrogram for classifying readings (Distance = Sørensen Bray-curtis): R1 represents ramp 1, R4: ramp 4, R6: ramp 6 and R8: ramp 8.

3.1.3. Structural characteristics of macroinvertebrate groupings

In the Agbaou Gold Mine Waste Rock Park 1 area, the structural characteristics of macroinvertebrate groupings are illustrated in Figure 14. The structural characteristics of the identified groupings do not vary significantly from one animal grouping to another (p value > 0.05; Table 1) indicating a better fit of the groupings observed at the site. The macroinvertebrate predator grouping has the highest mean density (188.33 g/m2) while the macroinvertebrate fungus grouping has the lowest mean density (35.63 g/m2). Macroinvertebrate communities in the tailing's impoundment area 1 of the Agbaou Gold Mine were evenly distributed over the study area. In general, the number of individuals in the different macroinvertebrate groups increases from one year to the next, because of leguminous plants.

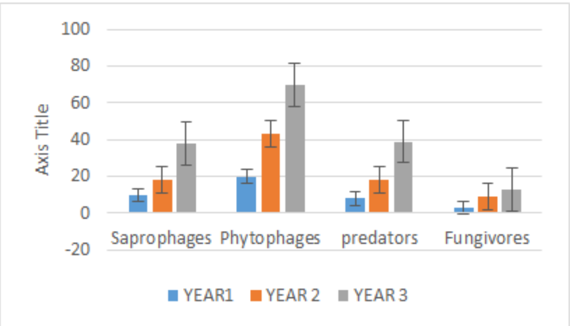

Figure 14: Changes in macroinvertebrate groupings as a function of years in the sterile yard 1

IV. DISCUSSION

4-1. Effects of improved fallowing of the legume *Pueraria Phasoeloides* on overall macrofaunal diversity and abundance

The different spheres of the environment are undergoing strong degradation due to mining activity. The rehabilitation of the sterile verses by the leguminous Pueraria Phasoeloides comes to fill the void left by this activity. Indeed, the results obtained during this study show the abundance of certain taxonomic groups including annelids, gastropods, crustaceans, arachnids, myriapods and insects on the sterile park 1 of the Agbaou gold mine. Hymenoptera are the most abundant order in terms of individuals. The other taxa including annelids, gastropods, crustaceans, diptera, beetles, arachnids and myriapods are poorly represented. The total taxonomic richness is 1981 taxa of which 743 were caught on Ramp 4, 540 on Ramp 1, 448 on Ramp 6 and 250 on Ramp 8. The calculated equitabilities reveal the balanced character of the ramps studied. This reflects the fact that the macroinvertebrates are distributed equitably over the site. The important effect of the improved fallow on the soil macrofauna was demonstrated by a contrasting comparison of the different groupings over many years. The most important contrast was established within the ramps of the study area on the one hand and within the macrofauna groupings on the other hand. For the macrofauna groupings, the diversity and density of the groups as a whole was higher within the phytophagous and saprophagous species, showing the favourable effect of the presence of a permanent ground vegetation cover, playing both a role in regulating abiotic conditions (soil temperature and humidity) and a constant supply of organic matter (Blanchart et al., 2006; Ratnadass et al., 2007; Rabary et al., 2011). This confirms previous studies showing the interest of no-till cropping systems with direct seeding on the plant cover to increase biodiversity (density and taxonomic diversity) of the macrofauna. For the different ramps in the study area, the highest density of macrofauna was observed in the plots of Ramp 4 in connection with a particular functional group (phytophages), whereas greater diversity was observed in the plots of Ramp 1. In these parts of the study area, the fallowing by the legume PuerariaPhaseoloides of the mine site tailings slopes seems to have favoured the development of soil macrofauna.

V. CONCLUSION

This work allowed to characterize the terrestrial macrofauna of the barren park 1 of the Agbaou gold mine and to appreciate their richness. In addition, it allowed to make a biological characterization of the soils present in the barren park 1 of the Agbaou gold mine. In general, these soils have improved biological parameters because of the legume P. phaseoloides. These soils are marked by good improvement in biological values because of the legume P. phaseoloides. The preliminary inventory of macroinvertebrates in this sterile park 1 has highlighted 6 classes divided into 14 families and 17 orders. Among these different classes, insects constituted the most abundant and diversified taxonomic group.

More in-depth studies on these parameters are essential to improve knowledge on the different biological parameters that improve the soils of the waste rock piles of the mining sites. In order to better preserve biodiversity, it is essential that all actors involved in the management of Ivorian mining sites pay particular attention to the harmful effects of mining activity on the various spheres of the environment and propose solutions such as the improvement of tailings pits by the legume P. phaseoloides.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest between them or between parties regarding this article.

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