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Inventory of Soil Invertebrate Macrofauna, Bioindicator of Soil Quality, Along a Toposequence in an Agro-Ecological Area of Ahoue (southern Côte d'Ivoire)

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Abstract: ***The spatial variation of the soil macrofauna (> 2 mm) is one of the major determining factors of soil quality. The objective of this work is to examine the spatial typology of soil invertebrate macrofauna, along a toposequence in Ahoue an agroecological zone (southern Ivory Coast). The sampling method used was performed according to the monoliths method of dimensions 25x25x30 cm as defined by the method of Tropical Soil Biology and Fertility / UNESCO (TSBF). Multivariate analyzes showed significant differences in the distribution of soil invertebrate macrofauna, based on level of soil degradation according to topographic positions. The statistical analysis method of the principal component analysis (PCA) and redundancy analysis (RDA) enable to classify, predict and select the best set of descriptive variables in the different topographical positions. This study contributes to the knowledge of bio-indicators in the topographic positions, based on soil invertebrate macrofauna. This knowledge is very important for maintaining soil quality, which is essential for sustainable ecosystems management.***

Keywords: macroinvertebrates, soil, toposequence, Ahoue, Côte d'Ivoire

1. Introduction

Lacking sufficient financial means to acquire agricultural inputs such as mineral fertilizers, local farmers practice shifting cultivation. This practice is characterized by a "nomadic" system, permanently in search for fertile land, along the different topographical segments, after exhausting those under cultivation. With the present situation of scarcity of cultivable lands, we are witnessing soil degradation and sometimes reduced soil production capacity in our ecosystem. This capacity is defined by Doran and Parkin (1994), as the (soil quality – soil health) capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant, animal and human health. In order to react to environmental degradation, it is important to try to assess at both levels, local and national, the quality of soil in order to ensure sustainable land management practices. This assessment requires indicators that could reflect, if possible from a single measurement, the main existing living conditions in this environment, particularly in carbon sequestration in the form of organic matter and maintenance of biodiversity.

The soil quality indicators as explained in the literature generally describe the physical and chemical characteristics. However, the measurements of these parameters, although relevant and necessary, come with some problems in the rapid assessment of soil quality and management. In addition, these analyzes in the laboratory unfortunately are very expensive, time to get the results can be very long (M'Biandoun *et al*., 2003). Soil organisms, soil macrofauna (> 2mm) live in the soil, its organic matter and the solution that fills its porosity (Eglin *et al*., 2010) gives a more reliable and relevant measure of ecological risk, because they integrate all the physical and chemical conditions of the soil (Lavelle and Spain, 2001).

The soil macro-invertebrates taken together, represent an interesting potential indicator (Lavelle *et al*., 2006) since they include a significant number of taxonomic units with very different responses to different types of disturbances due to the diversity of habitats (bedding, soil) and diet (plant-eating, wood boring, humivores, saproxylic etc.) (Ruiz-Camacho, 2004). Despite their relevance, the assessment of soil quality based on the groups of soil macro-invertebrate remains poorly documented. To take advantage of all the bioindicator potential of all macro-invertebrate groups, we propose the analysis of all soil macro-invertebrate population; to replace the one group e.g earthworms focused method (Guei, 2013).The objective of this study is to identify the useful potential of the soil. In the course of our study, (1) we have tried to identified the morphological and biological characteristics of soils in connection with the three topographical positions; higher slope (HV), mid-slope (MV) and lower slope (BV), (2) identify biological indicators of soil quality based on macro-fauna and the state of organic matter (degradation level) along a toposequence.

2. Materials and Methods

2.1 Study site

The study site is located in the village of Ahoue (5 ° 26' and 5 ° 29' north latitude, and 3 ° 50' and 3 ° 56'). It covers an area of 1.3 hectares, located along the Abidjan – Alépé road, in the north of the district of Abidjan (Southern part of Côte d'Ivoire) (**Figure 1**). The site corresponds to a plateau of about 50 to 100 m above sea level overlooking the river valley. The District of Abidjan is characterized by equatorial climate having two raining seasons and two dry seasons. The average monthly temperature is above 20 ° C. The annual precipitation exceeds 1200 mm. The rainfall is characterized by: (i) a long rainy season from May to July; (Ii) a short dry season from July to August; (Iii) a short rainy season from September to October; (Iv) a long dry season from December to April (Koffi *et al*., 2013).

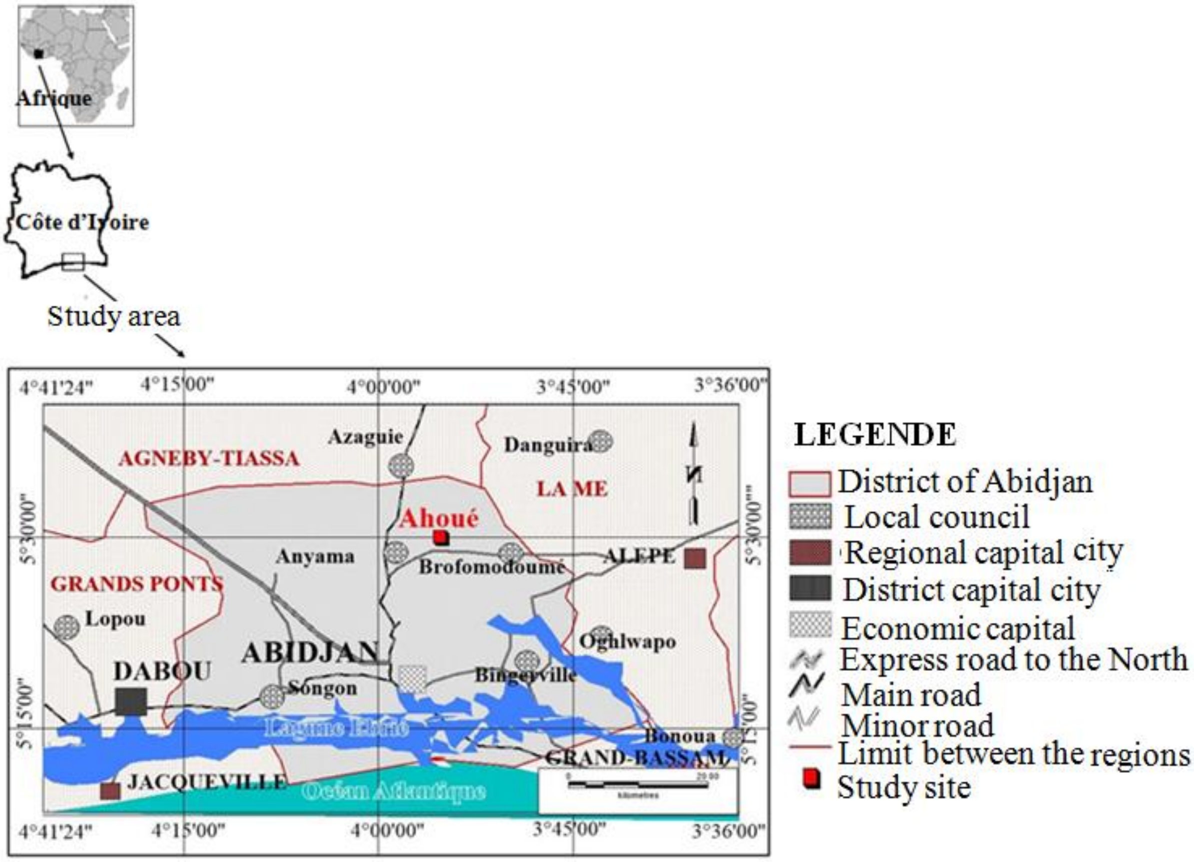


Figure 1: Geographic localization and main characteristics of the study site

2.2 Biological and technical equipment

Technical equipment used consisted of a measuring tape, a GPS receiver (Global Positioning System) type Garmin, a clinometer, spades shovels, picks, scissors, flexible clamps, storage vials, indelible markers, alcohol 70 %, formaldehyde 4 %, a topographic map 1/50000 and a compass of the type TOPOCHAIX. The environment observatory equipment and description of soil profiles was made with cutlasses, milestones, poles, geologist's hammer, soil scientist's knife, plastic bags, a 50m measuring tape, a carpenter meter rule 3m, a Munsell, guides and description sheets of soil glossary IRD (ex ORSTOM) and a digital camera. The biological materials studied consisted of macroinvertebrates.

2.3 Sampling Methods

2.3.1 Morpho-pedological characterisation

The method used involves the digging of ditches and their description by toposequence method (Yao-Kouame, 2008), and the interpretation of their morphological observations. Three soil pits were opened up in toposequence (three equidistant toposequences 45 m). The pits are located at the higher slope, mid-slope and at the lower slope separated at least by 200 m (**Figure 2**) .The scientific classification used is the one adopted by IUSS Working Group WRB (2014) .The following parameters are reported:

- The structure, which is a parameter that reflects the activity of living organisms in the soil;
- Organic matter and humus, which will gradually break down under the influence of soil organisms;
- The soil pH, which is estimated through pH strips. The signification of pH is based on the classification of Landon (1991).
- The sand / silt / clay composition of soil, which was determined through "pudding": (i) not pudding (presence of a lot of sand); (ii) breaking pudding (presence of silt); (iii) flexible pudding (presence of clay).

Vegetation, topography, land use and its possible history were described by a set of standardized qualitative and quantitative variables. Field forms including variables like (percentage of vegetation cover and type, soil texture, presence of large roots, pebbles percentage and the degree of the slope) have been filled on the field for each sampling point.

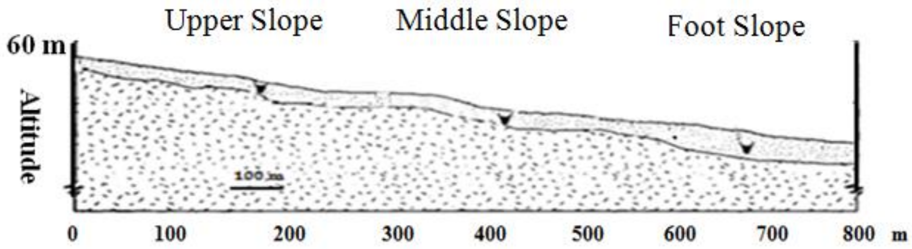


Figure 2: Structure of toposequence found in the landscape of Ahoue

2.3.2 Sampling of soil macro-invertebrates

Soil living organism has been taken out from the soil monoliths, 25x25x30 cm dimensions placed side by side in every 20 m along the toposequence. The classical sampling method is recommended, by the International Tropical Soil Biology and Fertility / UNESCO program (Lavelle, 1988; Anderson and Ingram, 1993). It allows for comparing the abundance of soil macroinvertebrate and / or its density in natural and anthropogenic ecosystems. Five monoliths were taken from each different topographic positions (15 along the toposequence). Soil macro-invertebrates are then removed by manual sorting from soil portion of 10 cm and kept in formalin 4 % (earthworms) or alcohol at 70 % (other organism). The identification by taxonomical group and counting were conducted in the laboratory of entomology of Nangui Abrogoua University, Cote D'ivoire. Seven groups have been identified they are morphotypes: Isoptera (Termites), Myriapoda, Hymenoptera (ants), earthworms, beetles, Arachnids and Others (**Table I**). Sampling was carried out between 7am and 11am.

Table 1: Classification of soil invertebrates found in the study site

Groups	Taxons, families entry a defined group
Arachnida (Arachnid)	Mites, spiders
Isoptera (isopter)	Termites
Hymenoptera	Ants
Coleoptera (Beetle)	Larves or adultes beetles
Clitellata (Annelid)	Young or adultes earthworms
Myriapoda (Myriapode)	Chilopodes (Centipedes, Centipedes, geophilics), Diplopodes (Millipedes)
Others	Dermoptera, Heteroptera, Hemiptera, Orthoptera, Lepidoptera larvae, larvae and undetermined pupae

2.4 Data-Analysis

The density is calculated on an area of 0.0625 m^2. It is expressed in average number of individuals per unit area ($indm^{-2}$). The assessment of vital environmental attributes was conducted using the Shannon-Weaver index (H ') and evenness was measured using Pielou (E) (Dajoz 1985).

- The Shannon-Weaver index $H' = -\sum_{i=1}^{S} Pi \times \log_2 P_i$ (1) where S is the total number of species and Pi is the probability that a randomly selected animal belongs to the specie. This index is a measure of diversity taking into accounts not only the richness but also the proportion represented by each species within the community. It shows some sensitivity to rare species. H 'closer to 0 when the group is poorly diversified (contains very few species), while H' is maximum when the number of species is very high. In nature Shannon index is 0.5 (very low diversity) and 4.5 (in the case of complex community).
- The index E = H '/ H'max (2), with H'max being the maximum Diversity (Log_2S) where S is the number of species. It tends towards 0 when almost the entire population is focused on a single species and towards 1 when all species have the same abundance. An evenness index below 60% characterizes a disturbed environment (**Guedje *et al*., 2002**).

2.5 Data Processing

The various measurements performed were then subjected to analysis of variance supplemented by tests reflecting the spatial structure parameters (Kruskall-Wallis test, test of Student Newman-Keuls: SNK). The "p-value" obtained, which corresponds to the probability that there are significant differences, is compared to the risk $\alpha = 5\%$. A principal component analysis (PCA) was performed to determine the taxonomic groups most susceptible to degradation. The relationship between the macroinvertebrate families, evenness index of Pielou, Shannon index and organic matter were assessed by means of a redundancy analysis (RDA). The data were processed using the software XLSTAT, 2007 www.xlstat.com.2007.

3. Results

3.1 Characterization of the study site Ahoue

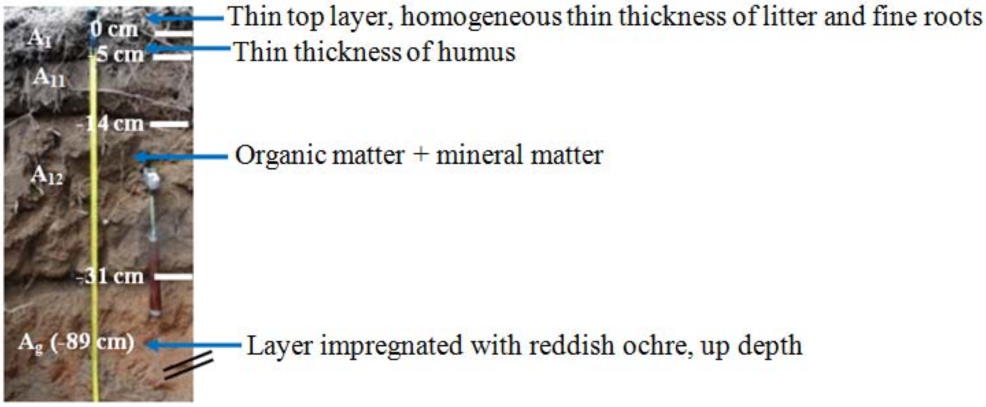
Upper slope profiles show thick topsoil and clear separations between horizons. Macroscopic observations of the profiles shows: absence of visible traces of plant debris, indicating a well-decomposed segment and black color testifying presence of organic matter, slightly thick. The soil is strongly acidic, with an average pH of 4.5. The biological activity of the soil is poor. Texture tests indicate a strong presence of sand (**Figure 3a**).

In the middle-slope, the topsoil is very thin. The profile analysis shows a non-homogeneous mixture of inorganic and organic matter (strong presence of traces of organic debris), indicating poor decomposition of organic matter. The soil is slightly acidic, with a pH of 5.5. Macroinvertebrates are much more abundant than the previous segment (due to the effect of pH) and the presence of worm castings shows a pretty good biological activity in the sandy -loamy soil (**Figure 3b**).

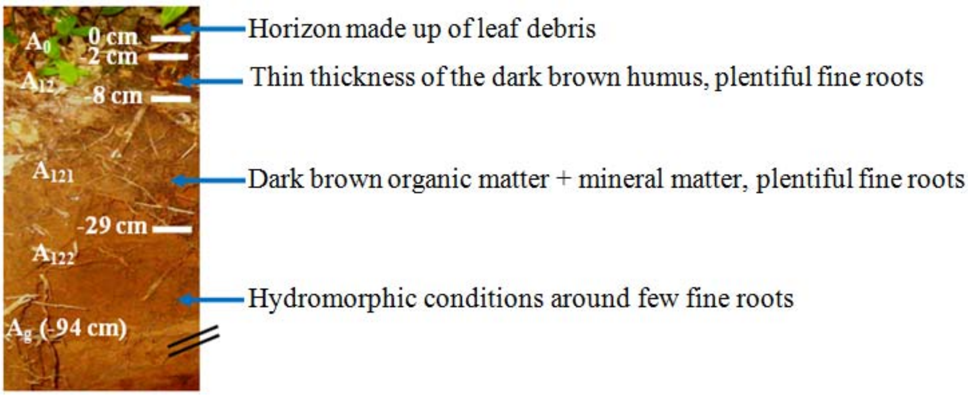
Soil profiles of lower-slope show: a litter, a thick humus horizon, the presence of traces of organic debris, indicating a fairly good decomposition of organic matter. The soil is slightly acidic, with a pH of 6. The biological activity is more pronounced than in the previous two segments. The water table is less than 20 cm (**Figure 3c**). All the land parcels observed has a gradient water logging related to the soil topography and specifically, to the position of the soil profiles with well-drained soil in the surface horizon, Pseudogley soil in deeper horizon (upper slope and mid-slope) and Gley horizons of shallow depth, at the lower slope.

3.2 Population of soil macrofauna in different topographic positions

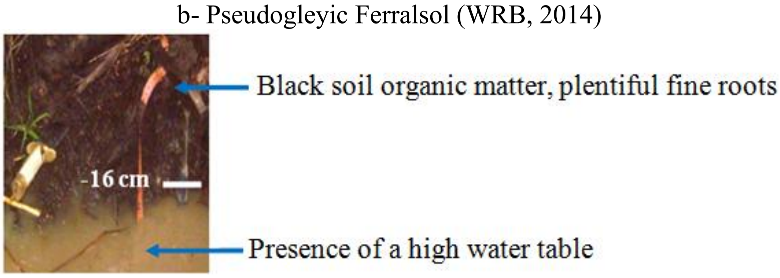
A total of 20 families have been identified belonging to the classes of Arachnida (arachnid), Chilopoda (centipede), Clitellata (annelid), Diplopoda (millipedes) and Hexapoda (insect), (**Table II**). Insects are represented by 15 families, distributed in seven orders. All identified termites species belong to the family of Termitidae, while those of Earthworms belong to the family of Lumbricidae and those of ants to the family of Formicidae. The densities recorded for the seven groups identified are shown in **Table III**. Apart from the Arachnida, densities of the remaining soil macroinvertebrates are significantly different in various topographic positions. Middle-slope positions (covered areas) have significantly more favorable conditions for termites and ants than lower slope positions (Gley horizon) and upper slope (disturbed by successive cultivation of soil). This highlights the positive effect of perennial shrub cover. The lower slopes have the most favorable conditions for the growth of Earthworms and Myriapoda (Chilopoda and Diplopoda), while the upper slope is associated with Beetles. The Kruskal-Wallis test expresses a significant difference in the densities of Arachnids and Termites [Kruskal-Wallis (p = 0.016)]. Arachnids clearly appear less dense.



a- Pseudogleyic Ferralsol (WRB, 2014)



b- Pseudogleyic Ferralsol (WRB, 2014)



c- Vertisolic Gleyic Petroplinthic Cambisol (WRB, 2014)

Figure 3: Soil profile in the 0-30 cm topsoil, along toposequence in Ahoue site study. (a) Upper slope; (b) Middle slope; (c) Lower slope

Table 2: List of soil macro-invertebrates in the study site of Ahoué

Class	Order	Family
Arachnida	Araneae	Larves
	Acarida	Acaridae
Chilopoda	Geophilomorpha	Geophilidae
Clitellata	Haplotaxida	Lumbricidae
Diplopoda	Glomerida	Glomeridae
	Julida	Julidae
Hexapoda	Beetles	Tenebrionidae
		Scarabaeidae
		Cucujidae
		Trogidae
		Carabidae
		Chrysomelidae
		Elateridae
	Dermaptera	Forficulidae
	Dictyoptera	Blattidae
	Arthropds	Cydnidae
		Reduviidae
	Homoptera	Cicadellidae
	Hymenoptera	Formicidae
	Isoptera	Termitidae
Total	13	20

Table 3: Total density of macrofauna according to their morphotypes along the toposequence

	Density (indm^{-2})			
Morphotypes	**US**	**MS**	**LS**	**Total**
Arachnida*	32^{a}	32^{a}	0^{b}	64
Clitellata (Earthworms)***	96^{c}	288^{b}	672^{a}	1056
Myriapoda***	496^{b}	336^{c}	592^{a}	1424
Coleoptera***	608^{a}	400^{b}	304^{c}	1312
Hymenoptera (Ants)***	704^{b}	1232^{a}	576^{c}	2512
Isoptera (Termites)***	1088^{c}	2704^{a}	1696^{b}	5488
Others ***	64^{b}	16^{c}	448^{a}	528
Total	3088^{c}	5008^{a}	4288^{b}	12384

Different letters indicate significant differences between treatments (Newman-Keuls test). * Significant at threshold p = 0.05; ** Very significant at threshold p = 0,01and *** highly significant at threshold p = 0.001.

3.3 Population of soil macrofauna in different topographic positions and deepness

The analysis of variance using two factors (topographic positions and deepness) applied to densities of soil macro-invertebrates, is summarized in **Table IV**. The results allow us to identify the influence of the deepness and topographic segment on the vertical distribution of soil macro-invertebrate communities. The statistical values are: F = 4.86, p = 0.01; 83, p <0,0001and 33.27, p = 0.02, topographical segments (highly significant differences), deepness (very highly significant difference) and their interactions (significant difference) respectively.

The produced histogram shows that high concentrations densities are obtained in the 0-10 cm layer and this, in whatever topographical positions. The lower slope is characterized by higher biological activity (**Figure 4**). Vertical distribution of macrofauna appears to be an indicator of topographic segment fertility. Therefore, it is used as one of the factors in the description of soil macrofauna communities.

3.4 Characteristics of the soil macrofaune population: Principal Component Analysis (PCA) and redundancy analysis (RDA)

3.4.1- Comparison of populations and their distribution in group significantly different by principal component Analysis (PCA)

The correlation circle of the principal component analysis (PCA) revealed that the axis 1 of the correlation circle explains 65.41 % of the total inertia and the second axis 34.59 % (Figure 5a). He reveals, based on the relative contribution of each species on the axes, the positive side of the axis 1 is mainly characterized by earthworms, myriapodes and the others, while the negative side is the arachnids and ants.

Axis 2 is shown in its positive side by termites, and positive side by beetles. La projection topographic segments In the 1-2 factorial plan has revealed the effect of the intensified cultivation of the soil gradient on the population of the soil macro-invertebrates along topographic segments. Indeed, the axis 1 opposes the lower slope segments to the mid-slope. In other words, the axis 1 oppose natural to cultivated environments, respectively. Axis 2 is principally represented by high slope segments (secondary forest under reconstitution) **(Figure 5b).**

Table 4: Variance analysis of densities of soil macro-invertebrates between topographic segments, soil depths (in toposequences) and their interactions

Source	*Type III : sum of squares*	*DDL*		*F*	*Pr > F*
Model	2790400	8	348800	23,6	< 0,0001
Seg. togr	143598,93	2	71799,47	4,86	0,01
Depth	2453640,53	2	1226820,27	83	< 0,0001
Interactions	193160,53	4	48290,13	3,27	0,02
Errors	532100,8	36	14780,58		
Total corrected	3322500,8	44			

togr = Segment topographic, DF :Degree of freedom, F = Fischer, Pr = probability

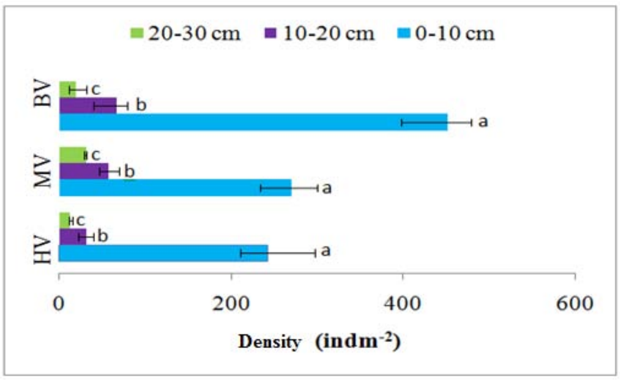


Figure 4: Underground vertical distributions of Macrofauna in Ahoué, according to the depth and topographic segments. BV = Lower slope, MV = mid-slope, HV = upper slope. Different letters indicate significant differences between treatments at a given depth in different topographic positions (ANOVA and Newman-Keuls)

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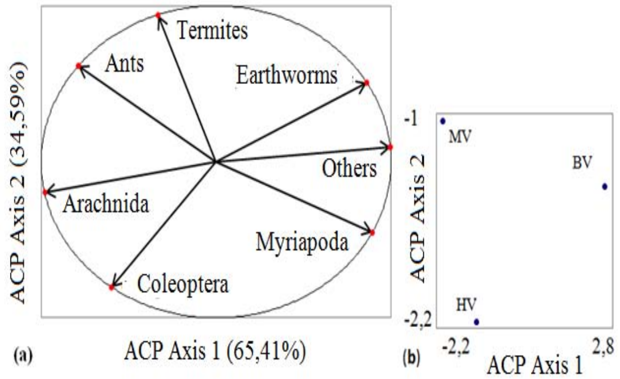

Figure 5: Principal Component Analysis carried out on the density of macro invertebrates stand in F1 × F2 shots. (A) Correlation circle of variables and (b) factorial 1-2.p.c. match percentage

The position of the Earthworms, Myriapoda and others along the axe 1 of the PCA can be explained due to the fact that their density is particularly high in the lower slope because the ecosystem their in is not often disturbed.

Variables selected are those whose relative contribution (in absolute value) are greater than or equal to half of the maximum contribution to the first two axes defined by the ACP (Table V). It is clear from this analysis that all these taxonomic groups considered discriminate all topographic positions and may constitute "potential bio-indicators" of soil quality.

To do this, a redundancy analysis (RDA) was done to establish grouping indicators.

Table 5: Relative contributions of macro-invertebrates on the factors (F) 1 and 2 of the PCA.

Variables	Factor	
	F1	F2
Arachnida *	21,0026	1,5857
Clitellata (Earthworms)*	16,2460	10,5793
Myriapoda*	17,3665	8,4607
Coleoptera*	7,7975	26,5534
Hymenoptera (Ants)*	13,5279	15,7186
Isoptera (Termites)*	2,4178	36,7252
Others*	21,6418	0,3770
	21,6418/2 =10,8209	36,7252/2 = 18,3626

(*) Selected species that better differentiates the types of land use

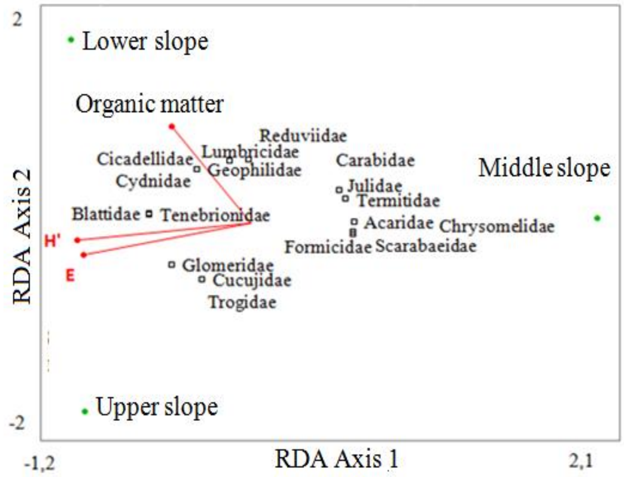

Figure 6: Ordination of redundancy analysis illustrating the relationship between the characteristics of biodiversity, organic matter and distribution of macro-invertebrate families. H ': Shannon-Weaver diversity index; E: evenness index Pielou; RDA: redundancy analysis

The Shannon index is strong (2.7 bits), indicating high diversity and a good reconstitution of the diversity of soil macro-invertebrate population. These parameters depends on an increase or decrease in soil organic matter, good drainage conditions and increase in the overall density of soil macro-invertebrates .Two subgroups clearly emerge depending on the content of soil organic matter. The first subgroup includes macroinvertebrates mostly found in the environments rich in organic matter, thick. They are: earthworms (Lumbricidae), millipedes (Geophilidae) and others (Cicadellidae, Reduviidae and Carabidae). The second subgroup consists of Tenebrionidae et Blattidae found mostly on dry environments, less sensitive to lower organic matter (**Figure 6**).

The second group consists of the family dominating the upper slope positions. They have optimum evenness in the order of 0.8; indicating an ecosystems that have not been disrupted. The Shannon index is strong (2.9 bits), indicating great diversity and a good reconstitution of the diversity of soil macro invertebrates' population. These parameters signify poor soil organic matter, sandy and reduced overall density of soil macro invertebrates' .The macro invertebrates' family, indicators of environment under reconstitution and poor in organic matter are Myriapodes of types Glomeridae and Coleoptera the types Cucujidae and Trogidae (**Figure 6**).

The third group consists of macro invertebrates found in the Middle slope position which recorded lower evenness value (0.5). These low values reflect the population dominance by some species; they can also indicate stress or transient state of the ecosystem. The values of the Shannon index is very weak (1,94 bit) compared to those obtained in BV and HV, indicating a low diversity and a poor reconstruction of the soil macro invertebrates population. These parameters indicate poor soil organic matter, rich in sand and increased overall density of soil macro invertebrates. The macro invertebrates families associated with these fragile environments, concern the whole family of termites (Termitidae) and ants (Formicidae) millipedes (Julidae) coleoptera, phytophages of the family Chrysomelidae, Scarabaeidae, predatory beetles of the Carabidae family and arachnids (Acaridae). Their densities are characterized either by an increase, or a reduction (**Figure 6**).

Redundancy Analysis carried out has shown that invertebrates collected from these slopes, which has been weakened by farming, are ubiquitous (dominates all sides). This is the case of termites.

If these environments evolve, groupings of macro invertebrates will likewise change also. This property therefore makes them good indicators of the state and changes in the natural environment which constantly undergoes human transformation.

4. Discussion

In this study, it is not a question of an inventory of all potentially useful bio-indicators or that have already been used. The first bioindicator quality noted here is one that is consistent with the loss of soil fertility due to their degradation. So to determine the sustainability of farming system, in this study priority has been given to an indicator connected more or less directly to the organic matter as reported by Doran and Parkin (1994). Indeed, these global indicators are generally, inventories and annual value of organic matter that is of great importance to soil quality, especially in fragile ecosystems (Andreux et al., 1994).

The use of soil macro-invertebrates as a good indicator according to their roles in the soil. Their roles reflect the changes, potentially having an impact in the functioning of the soil. Soil macro-invertebrates are in permanent contact with the soil **(Ruiz-Camacho, 2004. Eglin et al, 2010).** It is also sensitive enough to quickly detect imbalances before it causes irreversible damage .Specifically, our study focused on the population responsible for these functions.

The sampling method used TSBF allowed the capture of several thousand individuals (**Table III).** The density of soil macro invertebrates studied varies between 3088 indm^{-2} and 5008 indm^{-2}. Our results differ slightly from those obtained by Gilot et al. (1995) in the evergreen forests of the wetland (5750 indm^{-2}) Southern CoteDivoire .This tendency of reduction in density is as a result of degradation, and cultivation of the forest studied. This result join, those obtained by Tondoh (2007) in secondary forestsaverage (3308.8 indm^{-2}) of the savanna forest zone Cote d'Ivoire or in plantain plantation area (3278indm^{-2}) Ahoue.

Reduction in the density and diversity of soil macro invertebrate communities can be explained by the effects of tillage on these soil organisms. Indeed, there is a direct effect of tillage on organisms (displacement: exposure to predators, mortality), a modification of their habitat (water content, porosity, temperature), and a change in the spatial distribution of organic and mineral resources (ADEME, 2007).

Comparison of different landscape taking into account the depth of the sampling depths showed significant differences. The 7 groups of soil macro invertebrates are differently affected by the topographic positions, depending on their vertical distribution, their mobility and ability to dispersion, or sensitivity to compaction. Our results reflect the fact that organisms spread according to the availability of their nutrients resources, are subdivided into ecological niches in highly specialized habitats. This reduces competition between species while allowing the greatest number of them to coexist in a reduced density. This is, moreover, supported by the activity of soil macrofauna which strongly influences the spatial and temporal distribution of food resources used by all soil organisms as demonstrated by Lavelle (1998) and (**Lemercier and Walter, 2011**) on the role of earthworms, Myriapoda, beetles and termites in tropical zone on soil health in France. It has been demonstrated a stronger presence of organisms in the top 10 cm of sol. All organisms feed on decomposed organic matter.

The study site Ahoué was firstly subjected to biological action. Biological action relates to the density of soil macro-invertebrates and associated parameters, as they are the only action that can be easily done at that moment.

At the lower slope, redundancy analysis showed a positive relationship with the organic matter content of the soils. The Lumbricidae family reflects the existence of a significant and constant humidity in the soil. Indeed, earthworms of this family are recognized as experts in humid habitats (**Lapied 2000**). The association earthworms with decomposers of the family Geophilidae confirm the rich in organic matter in this landscape position (Ruiz-Camacho, 2004). The soil macrofaunal group in the lower slope: earthworms (Lumbricidae), Arthropods (Cydnidae and Reduviidae), Homoptera (Cicadellidae) are indicators of the "highest quality" of dead organic matter and a high degree of moisture in the soil. Our results are similar to those of Frouz (1999).

On the upper slope, acidic natures of soils are characterized by a decrease in stocks of organic matter and soil macro-invertebrates. The significant reduction in soil macro-invertebrates in the upper slope positions is explained by the sensitivity of the soil macro-invertebrates populations to the action of the intensive cultivation of the land becoming secondary forest.

This is confirmed by the results of the work of Tondoh (2007). Thus, practices, traditional or not, suspected to cause chemical degradation, will lead to the reduction of organic matter in the soil (Chaussod 1996). Furthermore, the acidity discourage the growth of macro-invertebrates but enhance fungi growth; which enhances the process of acidification. The abondance of beetles, saproxylic like Cucujidae, Tenebrionidae and trogidae, is indicative of the existence of fungi on these slopes. Saproxylic species depend, during part of their life cycle, on dead or dying wood (Speight, 1989). However, mushrooms are less effective decomposers than soil organisms (s. Faurieet, 2011), hence lower soil organic matter is obtained. Glomeridae, Cucujidae, Tenebrionidae and trogidae are bio-indicators in such environment (in reconstruction and depleted soil organic matter) .Moreover the soil quality bio-indicators nature of Cucujidae and Trogidaea was reported by Calmont (2011) . However, the presence of Glomeridae contradicts the results of Ruiz-

Camacho (2004) who indicated that these decomposers characterized sites rich in organic matter.

The mid-slope segments recorded weak evenness value. These low values reflect not only the dominance of the population by some other species, including termites, but also indicate the state of stress or transforming situation of the segments. Les observed values for density are naturally élevées.La size densitémacrofaunique is a function of carbon input (dead organic matter) .These entries are higher under covered vegetation for example cocoa plantation and other associated vegetation. The quality of plant residues, main source of food, is the cause of re colonization of macro-invertebrates. These results confirm the observations made by Tondoh (2007) who reported that culture of Arachishypogaea and Chromolaenaodorata has increased macro-invertebrate.The group of soil macro-invertebrates collected are Myriapoda (millipedes), ants, termites, Carabidae, Scarabaeidae and Chrysomelidae. These organisms are distributed widely,they are Bio-indicators of soil quality (Doube and Schmidt, 1997). In tropical areas, particularly in this present study, the density of termites and ants dominant in cultivated areas (**Tondoh, 2007**). Their relative abundance reflects the environmental conditions. Indeed, as soil-borne insects (fixed by the nest), ants and termites are subjected to the full environmental factors. As social insect, each individual is subjected throughout his life span, from egg to adult, to these factors. These are the most common species that might be interesting to characterize because their abundance reflects their adaptation to the environment. Practically, these organisms are relatively easy to identify and count. But to define a species as bioindicator, the first concept to consider is "scarcity" in relation to the study zone (**Calmont, 2011**).Although the ants and termites are considered as "ecosystem engineers" but cannot be considered as good bio-indicators of soil quality. Our results are in consistent to that of Doube and Schmidt (1997).

It is good to note, however, that functional groups within termites such as humivores termites (géophages) are known as good indicators of tropical soils fertility (Yapi 2010). Brown et al. (2002) reported that the risk of underestimation of these invertebrates by the monolith method is immense. In addition, the redundancy analysis showed that species in the mid-slope position seem not to be too demanding when it comes to environmental conditions. The group of soil macro-invertebrate including millipedes (millipedes), ants, termites, Carabidae, Scarabaeidae and Chrysomelidae can not be accepted as reliable bio-indicators of soil quality.

5. Conclusion

It is clear from this study that the topography influences the quality of the soil. In the lower slope, our results confirm the importance of Lumbricidae, ecosystem engineers, in improving soil quality. The soil macrofaunal found consisted of Lumbricidae, Geophilidae, Cydnidae, Reduviidae and Cicadellidae. These organisms are bio-indicators of dead organic matter and high degree of moisture in the soil. In the upper slope, bio-indicators identified are saproxylic beetles: Cucujidae and Trogidae to which are associated Glomeridae, Tenebrionidae and Blattidae. These segments are less endowed in organic matter, but very sandy. The mid-slope positions, weakened by regular farming, are characterized by the growth of the population of Termitidae, Formicidae, Julidae, Carabidae, Scarabaeidae and Chrysomelidae. By accepting the risks of underestimation of the invertebrates', social insects when using TSBF method, and common characteristics that these organisms have, this group has not been retained as reliable indicator of soil quality. It would be interesting to continue our study by extending to functional group, in other to develop a multifunctional indicator of soil quality from the macro-invertebrate populations.

References

[1] ADEME (2007). Impacts environnementaux des techniques culturales sans labour en France. ARVALIS - Institut du végétal. 40 p.
[2] Anderson et Ingram J.,1993. Tropical Soil Biology and Fertility.A handbook ofmethods CAB.Oxford (2nd edition), 221 p.
[3] Andreux, F., Dutartre P., Guillet B., Choné T., Desjardins T., 1994 - The status of soil organic matter in selected fragile ecosystems. In : Humic sub- stances in the global environment and implications on human health, N. Senesi et T.M. Miano, Eds., Elsevier Science B.V., pp 389-403.
[4] Brown G., Passini A., Benito N.P., De Aquino andCorreira M., 2002.Diversity and functional role of soil macrofauna communities in brasilian no-tillage agroecosystems: a preliminary analysis. Paper based on an oral presentation at the international symposium on managing biodiversity in agricultural ecosystems ". Montréal, Canada 8-10 November 2001. 8p.
[5] Calmont B., 2011. Étude des « Coléoptères saproxyliques » bio-indicateurs de qualité des forêts françaisesdans les châtaigneraies ardéchoises. Commanditaire : Parc Naturel Régional des Monts d'Ardèche. 129 p.
[6] Chaussod R. 1996. La qualité biologique des sols : évaluation et implications. Etude etGestion des Sols, 3,pp 261-278.
[7] Dajoz R. 1985. Precis d'ecologie. Paris, Dunod, 5e ed., 505 p.
[8] Doran J.W., Parkin T.B., 1994 - Defining and assessing soil quality.In : Defining soil quality for a sustainable environment. J.W. Doran et al., Eds., SSSA Special Publication n• 35, pp 3-21.
[9] Doube B.M. and Schmidt O., 1997.Can the abundance or activity of soil macrofaunabe used to indicate the biological health of soils?. In: CAB International, *BiologicalIndicators of soil health.* C.E. Pankhurst, B.M. Doube and V.V.S.R. Gupta (edts).pp.265-295.
[10] Eglin T., Blanchart E., Berthelin J., de Cara S., Grolleau G., Lavelle P., Richaume-Jolion A., BardyM., Bispo A., 2010. La vie cachée des sols, MEEDDM, 20 p.
[11] Faurie C., Ferra C., Médori P., Dévaux J., Hemptinne J.-L., 2011. Ecologie: Approche scientifiqueet pratique. Tec & Doc Lavoisier, 531 p.
[12] Frouz J.,1999. Use of soil dwelling Diptera (Insecta, Diptera) as bioindicators: a review ofecological requirements and response to disturbance. *Agriculture, Ecosystems andEnvironment* 74, 167-86.

[13] Gilot C., Lavelle P., Blanchart E., Keli J., KouassiP. & Guillaume G., 1995. Biological activity of soilunder rubber plantations in Côte d'Ivoire.ActaZool. Fennica 196: 186-189.
[14] Guedje M.N., Nkongmeneck B.A. &Lejoly J., 2002.Composition floristique et structure des formations àGarcinia lucida dans la region de Bipindi, Akom II (SudCameroun). Acta Bot. Gallica, 149(2), 157-178.
[15] Guéi A. M. 2013.diversite biologique et services ecosystemiquesdes peuplements de vers de terre en zone deforêt semi-decidue de côte d'ivoire. Thèse Unique de Doctorat. Université NanguiAbrogoua de Côte d'Ivoire, 196 p.
[16] IUSS Working Group WRB, 2014. World reference base for soil resources 2014. International Soil Classification System for Naming Soils and Creating Legends for Soil Maps World Soil Resources Reports no. 106. FAO, Rome. 203 p.
[17] Koffi Y. B., Ahoussi K. E.,Aké G. E., Kouassi A. M.,Biémi J. 2013.Étude de l'environnement géologique, hydrogéologique et géophysique d'un site destine a l'implantation d'un centre d'enfouissement technique a attiékoi dans le district d'Abidjan (sud de la Côte d'Ivoire). Journal of AsianScientificResearch, 3(7):762-774.
[18] Landon, J.R. 1991. Booker tropical soil manual.A handbook for soil survey and agriculturalland evaluation in the tropics and sub tropics. John Wiley and Sons, New York. pp.94-95.
[19] Lapied, E., 2000. A case of temperate earthworms (Lumbricidae) invasion in a lowland tropicalrainforest of French Guiana, in: Rusek, J. (Ed.), Book of Abstracts. XIII InternationalColloquium on Soil Zoology and Ecology, 14-18 August. p. 177
[20] Lavelle P. 1988.Assessing the abundance and role of invertebrate communities in tropical soils: Aims and methods.J AfrZool 102:275–283.
[21] Lavelle P., Pashanasi B., Charpentier F., Gilot C., Rossi J.P., Derourard L., Andre L., Ponge J.F., Bernier N. 1998. Large-scale effects of earthworms on soil organic matter and nutrient dynamics. Earthworm Ecology 103-122.
[22] Lavelle P. et Spain A. V. 2001. Soil Ecology.Kluwer Academic Publishers.Dordrecht, TheNetherlands. 654 pages.
[23] Lavelle P., Decaëns T., Aubert M., Barota S., Blouina M., Bureau F. 2006. Soil invertebrates and ecosystem services.European Journal of Soil Biology, 42, S3-S15.
[24] Lemercier B. et Walter C. 2011. L'´etat des sols de France. Groupement d'intérêt scientifique sur les sols, 188 p.<hal-00729367>
[25] M'Biandoun M., Guibert H., Olina J.-P., 2003.Caractérisation de la fertilitédu sol en fonction des mauvaises herbes présentes. Jean-Yves Jamin, L. SeinyBoukar, Christian Floret. 2003, Cirad - Prasac, 8 p., 2003. <hal-00140820>.
[26] Ruiz-Camacho N., 2004 - Mise au point d'un système de bioindication de laqualité du sol base sur l'étude des peuplements de macro-invertébrés.Thèse de Doctorat de l'Université Paris 6, Spécialité Science de la Vie,14 septembre 2004, Bondy: 327 p.
[27] Sébillote M., 1982. Fertilité du milieu et agriculture. Bulletin technique d'information, n°370-372, 327-599ok
[28] Speight M.C.D., 1989. - Les invertébrés saproxyliques et leur protection. Collection Sauvegarde de la Nature,N°42, Conseil de l'Europe, Strasbourg, 77 p.
[29] Tondoh E. J. 2007.Effet de la mise en culture des forêts secondaires sur les peuplements de macroinvertébrés du sol dans la zone de contact forêt-savane de Côte d'Ivoire.Sciences & Nature. 4 (2) : 197 – 204.
[30] XLSTAT, 2007, www.xlstat.com.2007
[31] Yao-Kouamé A.2008. Etude des sols brunifiés dérivés des matériaux volcano-sédimentaires de Toumodi en moyenne Côte d'Ivoire. Thèse de Doctorat d'état es Sciences naturelles, Université de Cocody/ UFR STRM, 210 p.
[32] Yapi A. 2010. Facteurs biogéochimiques fins des sols et répartition des termites humivores : cas de *Cubitermes* dans les savanes de Dabou et de Toumodi, Côte d'Ivoire. Thèse de Doctorat d'état es Sciences naturelles, Université de Cocody/ UFR Biosciences, 164p.