Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(4): 445-451

Received: 07-05-2019
Accepted: 09-06-2019

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Distribution of myriapods (Chilopods and Diplopods) according to four modes of land use (Daloa: Côte d'Ivoire)

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Abstract
Myriapods abound in the tropics specifically in forested areas of Ivory Coast, but little studies has been done on this zoological group. Yet they play important role in litter decomposition and the maintenance of ecosystems. This work aims to study the distribution of Myriapods according to four land use patterns in Daloa (Central West, Côte d'Ivoire). Sampling of Myriapods was carried out by the methods of termite transects and TSBF monoliths. A total, ten (10) genera were harvested from all plots. The study of the distribution of organisms based on diversity indicates that more than 50% of the genera are common (distributed) to all the environments explored. However, an unequal distribution of macroinvertebrates by habitat was observed at the level of abundance. The reforested forest contains most of the population dominated by Myriapods of *Pachybolus* genus.

Keywords: Ecosystems, diversity, abundance, myriapoda, land use management

1. Introduction
Côte d'Ivoire, country has agricultural vocation is confronted by many problems involved in management of cultivable plots.Inter alia difficulties, anarchistic use of the bush fires and weed killers for grubbing of plots.These husbandries contribute effectively of migration and disappearance of ground macrofauna.However, soil arthropods are vital link in the food chain as decomposers (Esenowo, 2014) [1]. In addition, all changes in Arthropod populations have important implications for the functioning of the soil ecosystem (Bedano *et al.*, 2006) [2]. Specifically, Myriapods are one of the least studied arthropods groups (Bedano *et al.*, 2006) [2]. Because of their abundance and diversity, these organisms (Diplopoda and Chilopoda) are the fourth largest invertebrate group accounting for almost 95% of the biomass and total density of soil macroinvertebrates (Iboy, 2000) [3]. They generally live in tropical areas under various habitats where they fulfill essential ecological functions (Mahsberg, 2010) [4]. They affect local communities by various roles in food webs, litter decomposition and nutrient flow. Some of them, such as the Chilopods, are carnivores that maintain ecosystem equilibrium by providing biological control through predation (Iorio, 2006, Houd-Chaker *et al.*, 2012) [5, 6]. On the other hand, other Diplopoda participate in the process of decomposition of organic matter and soil renewal (Kautz and Topp, 1998) [7]. These organisms, moving inside the soil, promote aeration of it. In addition, these organisms are very sensitive to any changes in their habitat (Houd-Chaker *et al.*, 2012) [6]. However, in Daloa, work on Myriapods is almost non-existent. In addition, no study related land use and Myriapods (Chilopoda and Diplopoda). The present work aims to study the distribution and abundance of Chilopoda and Diplopoda in four land use patterns to show the characteristics of soil fertility.

2. Materials and methods
2.1 Study area
Study was conducted in Daloa, city in central-western Cote d Ivoire Coast (6 ° 53'N and 6 ° 27'W). Daloa belongs to the zone of dense semi-deciduous forest at *Triplochiton scleroxylon* (Guillaumet and Adjanohoun, 1969) [8]. Today, this forest has almost disappeared giving way to other types of vegetation such as degraded forests, fallows and cultivated areas. The soil is more or less desaturated ferralitic type (Yao *et al.*, 2012, Anonymous, 2015) [9, 10]. The department of Daloa is characterized by a humid climate marked by relatively low temperatures (24.7 °C to 27.9 °C) and abundant rainfall.

2.2 Sites

Four plots (4) were selected (Figure 1). These have different facies and are subject to various anthropogenic activities: food crops, perennial culture, green area and reforested forest. The perennial crop (06° 54'53.2"N and 06° 26'14.0"W) (Figure 1A). The food crop is located between (06° 55'00.7"N and 06° 26'15.2"W) (Figure 1B). The reforested forest is located between 07 ° 80'03.7"N and (07° 63'14.7"W) (Figure 1C). The green space is located between (06° 54'23.9"N and 06° 26'21"W) (Figure 1D). This is the lawn of the University of Jean Lorougnon Guédé campus.

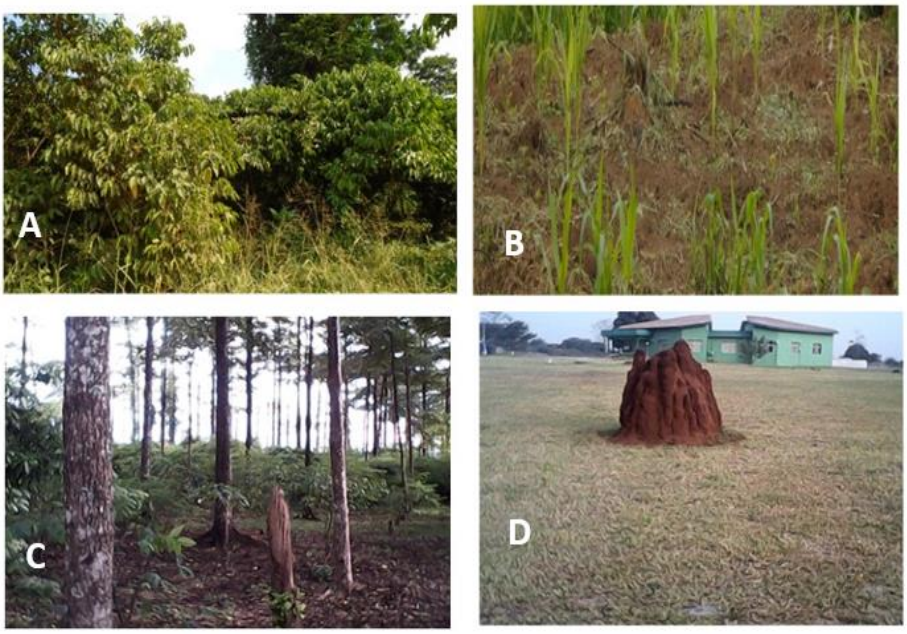

Fig 1: Different study sites **A**: coffee crop (10 year old); **B**: Food crop (2 weeks corn field); **C**: Reforested forest in degradation; **D**: Green area of campus

2.3. Sampling methods

2.3.1 Transect method: Sampling was based on a standardized termite diversity assessment protocol developed by jones and Eggleton (2000) [11]. Straight belt transects, 100 m long by 2 m wide. Each transect was divided into 20 sections, 5 m long. Litter of each section of transect was searched for myriapods. The samples collected were kept in 70% alcohol.

2.3.2 TSBF method: Tropical Soil Biology and Fertility (TSBF) method was recommended by Anderson and Ingram (1989) [12] to compare the abundance of soil macroinvertebrates in natural and antrophized ecosystems. The TSBF monolith is located 20 m from transect. Thus, in each plot, two (2) monoliths 25 cm long and 30 cm deep (25 x 25 x 30 cm) has been installed. Soil monoliths were divided into three layers (0-10 cm; 10-20 cm and 20-30 cm). Clump of soil extracted was sorted in search of Myriapoda. After sorting the different layers, soil was put back in place respecting the order of the successive layers. This is to avoid the disturbance of the environment. The organisms collected were kept in 70 % alcohol and transported to the laboratory for identification. Overall, individuals have been identified to gender.

2.4. Statistical analyses

The relative abundance of Myriapods in transect is the total number of encounters of a kind i harvested in transect divided by the total area of the sections. It is based on incidence (presence = 1 and absence = 0) of genera considered. $A = \Sigma ni / N$; ni = incidence of the individual of genus i in the transect; N = total number of transect sections multiplied by the area of a section (10 m^2). Comparisons tests of the relative abundances of the different taxa by site were carried out by one-way analysis of variance (Anova): Fischer's LSD test at $p < 0.05$ threshold using Statistica software (Version 7.1). Relative abundance of Myriapods and environmental relationships were analyzed using Principal component analysis (PCA). This analysis was performed using R software (Version 2.8).

3. Results and Discussion

3.1. Results

3.1.1 Generic richness of Chilopods and diplopods

The inventory yielded a total of ten (10) genera, eight (8) of which were diplopod genera. They are *Tylodesmus*, *Glomeris*, *Polydesmus*, *Pachybolus*, *Telodeinopus*, *Pelmatojulus*, *Oxydesmus* and *Arhispirostreptus*. As for the Chilopods, they are represented by two (2) genera: *Haplophilus* and *Scolopendra*. Observation of generic richness indicates that all plots are dominated by diplopods. This Sub-class is represented by five (5) families including Glomeridae, Oxydesmidae, Pachybolidae, Spirostreptidae and Polydesmidae. In addition, the coffee and the green area are home to all the two (2) genera of Chilopoda harvested in this study. These are divided into two (2) families: Himantariidae and Scolopendridae (Table 1).

Table 1: List of Myriapods harvested in different area

Family	Genera	Perennial crop	Green area	Food crop	Reforested forest
Glomeridae	*Glomeris*		*	*	*
Himantariidae	*Haplophilus*	*	*	*	*
Scolopendridae	*Scolopendra*	*	*		
Oxydesmidae	*Oxydesmus*			*	*
Pachybolidae	*Pachybolus*	*	*	*	*
	Pelmatojulus	*	*	*	*
Spirostreptidae	*Archispirostreptus*	*			
	Telodeinopus	*			
Polydesmidae	*Polydesmus*	*	*	*	*
	Tylodesmus	*	*		*
Total	**10**	**8**	**7**	**6**	**7**

(*): Presence of genera in the sites

3.1.2 Classification of habitats according to generic richness

A total of four (4) habitat types were prospected: a plot of perennial crop (10 years old coffee), a food crop plot (2 weeks old corn field), a green area and a degraded forest. The analysis of the frequencies of presence of the genera at all the sites combined reveals that perennial culture is home to 28.57 % of the genera. This environment abounds with the majority of the taxa sampled in this study. However, 25 % of genera were found in the green space of the campus and in the restored forest. Finally, 21.43 % of genera were recorded in the food crop plot (Figure 2). There is a slight variation in the frequency of encounters of genera between biotopes.

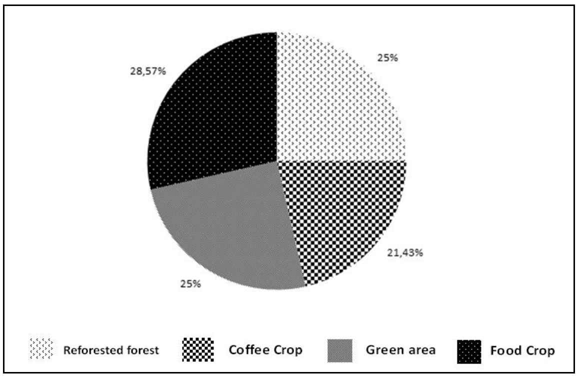

Fig 2: Proportion of genera richness in different sites according their abundance

3.1.3 Relative abundance of Chilopoda and Diplopoda

The distribution of Myriapods according to the habitats shows that the Diplopods are the best represented (Figure 3). The relative abundance of these is 0.18 ind/m^2 in the food crop plot (Maize field). The distribution of this subclass in the perennial crop (10 years old coffee) is substantially similar to that of green space. The results indicate 0.39 and 0.38 ind/m^2 respectively in the perennial crop (10 years old coffee) and in the green area. The degraded forest in degradation shelters most of the individuals of this group with 0.65 ind/m^2 (Figure 3A). In contrast to Diplopoda, the relative abundance of Chilopoda fluctuates between 0.018 ind/m^2 in the deforested reforested forest and 0.065 ind/m^2 in the perennial crop (Figure 3B). The food crop plot and the green space contain respectively 0.032 ind/m^2 and 0.026 ind/m^2 of the Chilopods. The perennial crop plot is home to almost half of the population of the Chilopoda Subclass. A detailed examination of the relative abundance of subclasses shows that the repair of the Diplopoda in the habitats studied does not follow that of the Chilopoda. Except in the 10 years-old coffee plantation, Chilopods are less abundant in environments where there is a strong presence of Diplopoda.

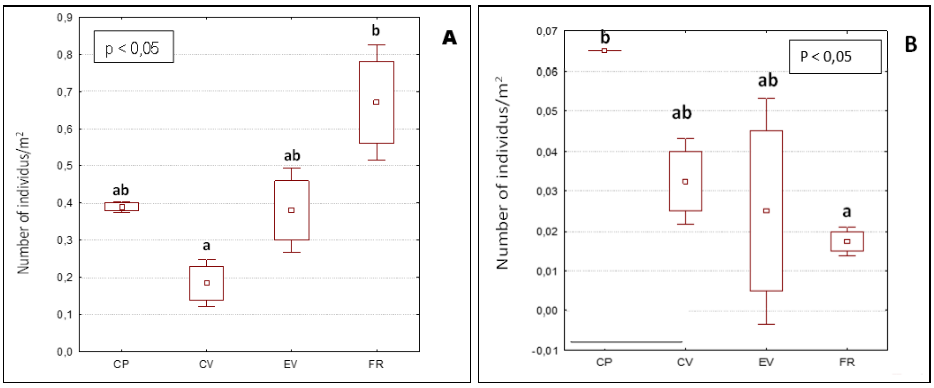

Fig 3: Relative Abundance of Myriapods genera by Habitats **A:** Relative abundance of Diplopoda; **B**: Relative Abundance of Chilopods, **CP**: Perennial Crop; **CV:** food crop; **EV:** green area; **FR:** Reforested forest. Mean with different letters are significantly different at p<0.05 (Anova, Fisher's LSD test).

3.1.4 Distribution of genera by habitat

3.1.4.1 Distribution based on genera richness

The study of distribution based on generic wealth shows great similarities between the sites explored. Thus, more than 50 % of genera are distributed in all biotopes. Almost all the genera present in the food crop are distributed in the reforested forest. The Sorensen similarity index indicates 92 % similarity between these two media. This value represents the greatest similarity in the distribution of organisms in all environments. Similarly, the majority of green space genera are found in the reforested forest. The similarity index between these two plots is 0.85 or 85 % of the genera similar to the two environments (green space and reforested forest). The value of the similarity index between the perennial crop and the reforested forest is 0.66 or 66 % of the genera are common to both environments. In addition, 80% of the genera of the perennial culture have been observed in the green space of the campus. This proportion (80 %) is close to that of the genera of food crops found on the green space (76 %). There are 57 % of the genera of the food crop in the perennial crop (Table 2).

Table 2: Values of Sorensen similarity index relative between habitats.

Sites	Green area	Food crop	Reforested
Perennial crop	080	0, 57	0, 66
Green area	—	0, 76	0, 85
Food crop	—	—	0, 92

A detailed examination of the distribution based on the generic richness of the environments studied reveals that the cultivated parcels (perennial and food crop) show the greatest disparities (43%).

3.1.4.2 Distribution based on relative abundance

Distribution based on relative abundance of genera reveals an uneven distribution of Myriapods in sampled habitats (Figure 4). Diplopoda are present with eight (8) genera. This subclass is dominated by *Pachybolus* in all plots. Of these eight (8) genera, three (3) are common to all surveyed plots with varying relative abundances. These are *Pachybolus* (0.407 ind/m2) in the degraded forest, *Pelmatojulus* with 0.082 ind/m2 on the green area and *Polydesmus* (0.067 ind/m2 in the ten years old coffee).

Chilopods are represented by two (2) genera including *Scolopendra* and *Haplophilus*. This subclass is dominated by *Haplophilus*, which is abundant in the ten-year-old coffee crop (perennial crop). We note 0.06 ind / m2 in this medium. The perennial culture and green space of the campus is full of all genres of this subclass. Scolopendra scores its strongest presence (0.007 ind / m2) on green space. There are only one genus of Chilopoda in the degraded forest and food crop (Figure 4A, Figure 4B, Figure 4C, Figure 4D).

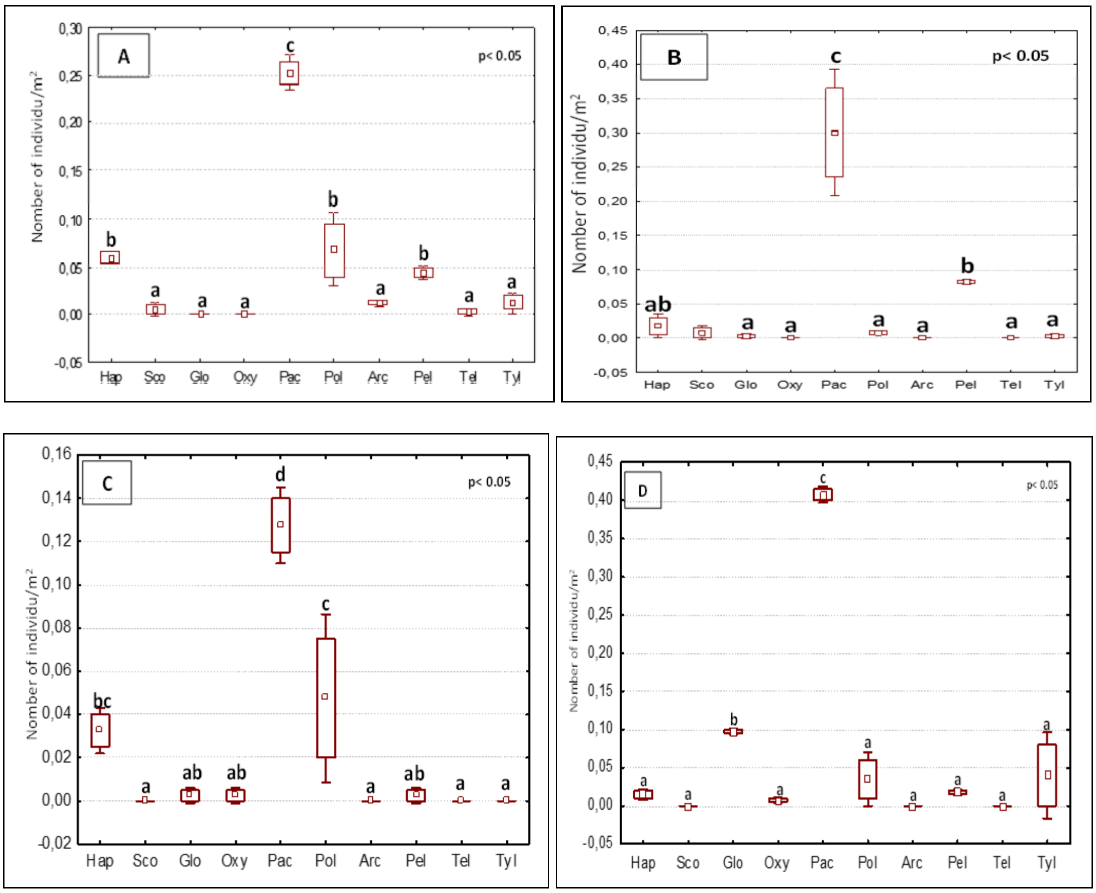

Fig 4: Relative abundance of genera according to four habitats **A**: Coffee crop; **B**: Green area of campus; **C**: Food crop; **D**: Reforested forest; Hap: *Haplophilus*; Sco: *Scolopendra*; Glom: *Glomeris*; Oxy: *Oxydesmus*; Pac: *Pachybolus*; Pol: *Polydesmus*; Pel: *Pelmatojulus*; Arc: *Archispirostreptus*; Telo: *Telodeinopus*: Tylo: *Tylodesmus*. Mean with different letters are significantly different at p<0.05, those with similar letters are note statistical significant (Anova, Fisher's LSD test).

3.1.4.3 Distribution of Myriapods between habitats

Principal component analysis (PCA) was performed based on relative abundance of Myriapoda genera in relationships to environments (Figure 5). The ordination in the factorial plane described by the axes F1 and F2 explains 98.21% of the total variance. The circle of correlation (Figure 5A) indicates that the axis F1 which represents 94.26% opposes two groups: the cultivated environments (food crop and perennial crop) to the environments subjected to no cultural activity (forest reforested and green space of the campus). The projection of Myriapods genera in the factorial plane F1 and F2 (Figure 5B) makes it possible to understand the distribution of these macroinvertebrates according to the prospecting biotopes and to identify the organisms that are most sensitive to different land use patterns. Projections reflects effect of land use on Myriapods fauna. Separation of the genus *Pachybolus* from others could be explained by the fact that this organism is the most abundant in all environments. This shows that with the exception of *Pachybolus*, all genera seem sensitive to land use patterns. In general, the population of Myriapods is affected by these four land use patterns. However, the sensitivity of *Pachybolus* to these land use patterns is less important.

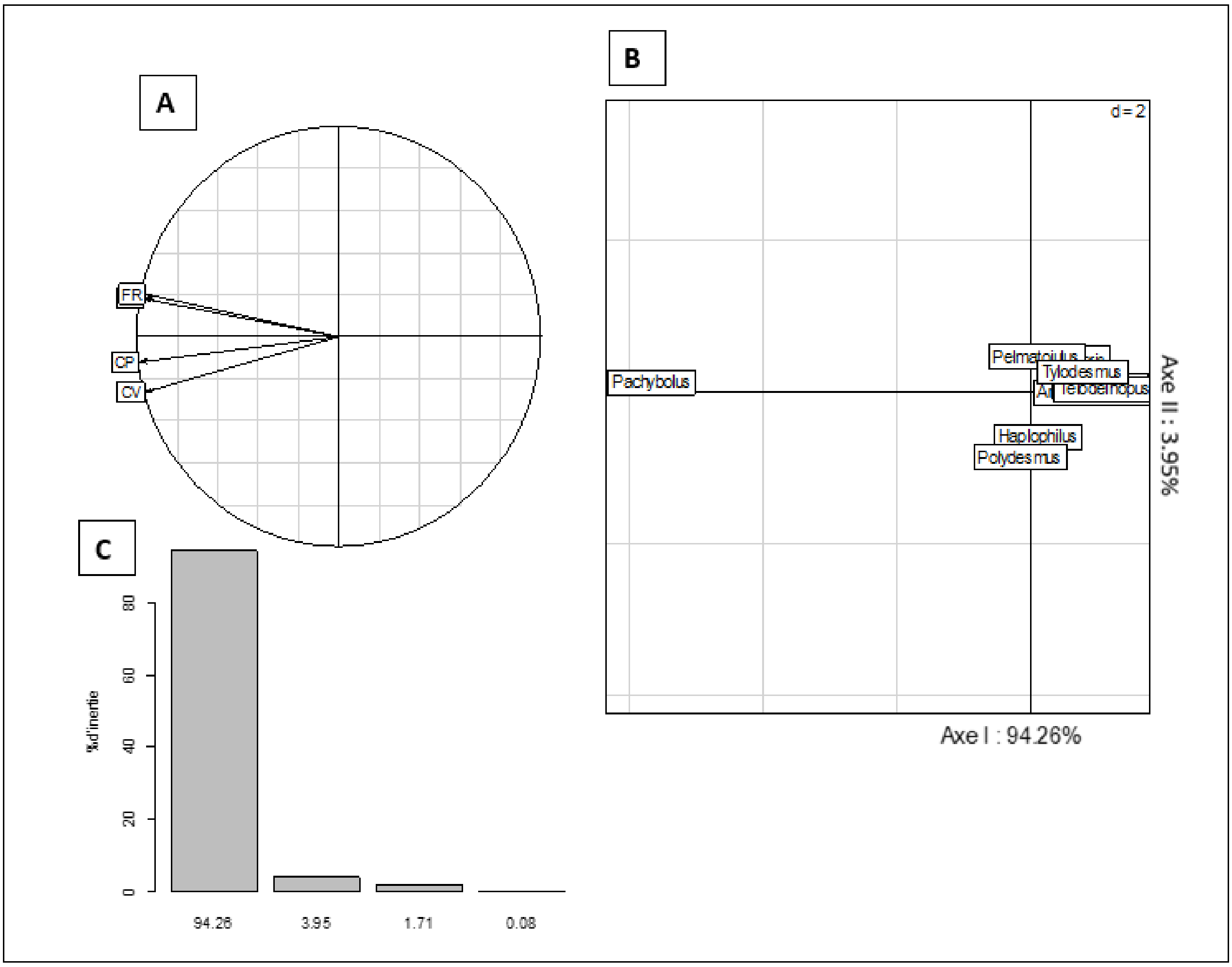

Fig 5: Principal component analysis based on relative abundance of Myriapods genera. **A**: Correlation circle; **B**: Factorial map showing the distribution of Myriapods genera. **C**: eigenvalue of the axes; **CP**: Perennial Crop; **CV**: Food Crop; **EV**: Green area; **FR**: Reforested Forest,

4. Discussion

The use of termite transects and Monoliths favors the sampling of Chilopods and Diplopods, and produces an interesting comparison of the communities of these soil invertebrates. However, some individuals are severed during the collection of clods of land. The analysis of the frequencies of presence of the genera at all the sites combined reveals that the perennial culture abounds the majority of taxa sampled (28.57 % of genera). This regular presence of organisms in this environment is due to the diversity of the litter. Studies report that diversified litter is a positive asset for the installation of Diplopods (primary consumers) (Vicente and Serra, 1992) [13] and provides a greater variety of micro-habitats likely to host a variety of prey available for Chilopoda predators (Iorio, 2008, Idir *et al.*, 2013) [14, 15]. The study of the distribution based on the generic richness shows great similarities between the environments (more than 50 % of the genera are present in all the habitats). This would be due to the proximity of the environments. This trend is similar to that of Idir *et al*. (2013) [15]. These authors obtained a similarity of more than 60% between two close stations subjected to the same climatic conditions. The greatest similarity (92 % of genera) was observed between the food crop (Maize field) and the reforested forest. This observation can be explained, among other things, by the immediate environment of the cornfield. Indeed, the food crop is surrounded on both sides by fallows whose characteristics (undergrowth, trees, shrubs...) are almost identical to those of the reforested forest. Thus during their activities, the Myriapoda present in these fallows would have been found in the corn field.

Ten (10) genera were recorded on all sites studied. Of these, *Haplophilus*, *Pachybolus*, *Polydesmus* and *Pelmatojulus* were simultaneously recorded in all media with varying relative abundances from one habitat to another. In addition, habitat characteristics would be the main cause of their presence. These results are close to those obtained by Sib (2016) [16] who noted the presence of the genera Pachybolus and *Polydesmus* in old fallows and in food crops (maize fields). These organisms would thus have a ubiquitous character. Three environments that are: the forest reforested, the green space of the campus and the coffee house shelter Myriapods of *Glomeris* genera. The diet of this invertebrate could justify its presence in these environments.

Indeed, the campus of the University is regularly grazed by cattle, sheep and goats. These ungulates leave droppings as bait for *Glomeris*. During the sampling campaign, this genus was found nearby and / or on the animal droppings we mentioned earlier. These observations were also made by Ruiz (2004) [17] in France. This author has noted the presence of *Tylodesmus* on campus, in the field of coffee plantations and the restored forest. On the other hand, the genus *Oxydesmus* was recorded in the cornfield and in the restored forest in degradation. These two genera seem to be fond of anthropised environments (Bourdanné, 1988) [18]. On the other hand, most of the stand are dominated by Diplopoda in the reforested forest (David *et al.*, 1998) [19]. These organisms promote the decomposition of leaf litter (Janssen, 1993, Ouedraogo *et al.*, 2004) [20, 21].

Regarding the distribution of Chilopoda and Diplopoda, there is a clear difference in the distribution mode. This, according to the environments prospected. Thus, in general, the Chilopoda seem less abundant in environments dominated by Diplopoda. The ecological requirements of each subclass would justify these observations. Although they belong to the same class of Myriapods, Chilopods and Diplopods differ according to their nutritional mode. Chilopods are predators adapted by environments containts (Iorio, 2008) [14], whereas saprophagous and phytophagous Diplopods remain subservient to closed, moist and cool environments (David *et al.*, 1998) [19].

5. Conclusion

This work aims to study the distribution of Myriapods (Chilopoda and Diplopoda) according to four modes of land use. Regarding diversity, the environments studied have great similarities (more than 50 % of the genera are common to all environments). The genera *Archispirostreptus* and *Telodeinopus* of the family Spirostreptdae seem to be the most affected by the different land use patterns and are therefore very useful in the search for bioindicators. Regarding abundance, an uneven distribution of organisms according to the habitats explored was observed. Indeed, the results reveal that the majority of individuals of the Myriapod population remained confined in the reforested forest (more than one third (1/3) of the Myriapod population). In addition, the Principal Component Analysis clearly indicates that the genus Pachybolus differs from other taxa. This organism seems to be the least influenced by land use patterns, thus constituting the most abundant genus at all sites. In sum, Pachybolus could be used as an indicator of tropical soil quality and would contribute effectively to food security.

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