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Terrestrial small mammal community structure in a relic forest and anthropogenic habitats in Man region, Western Côte d'Ivoire

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Abstract

Terrestrial small mammals play important ecological roles in tropical ecosystems. They are regularly used to measure the level of habitat disturbance. This study aimed to determine the impacts of human activities on the species composition and relative abundance of terrestrial small mammal communities in Man region. Four types of habitats, including a relic forest, a fallow, rubber and coffee plantations, were sampled using Sherman live traps. With a trapping effort of 2,800 trap-nights, 132 individuals of terrestrial small mammals were collected. These specimens belong to seven species of Muridae family *Grammomys buntingi*, *Hylomyscus simus*, *Lophuromys sikapusi*, *Malacomys edwardsi*, *Mus muscoloides*, *Mus setulosus* and *Praomys rostratus* and one species of Soricidae family, *Crocidura olivieri*. The relic forest and rubber plantation recorded the highest species richness with 7 species each. The lower species richness was obtained in a coffee plantation with 4 species. In the relic forest, *Crocidura olivieri* and *Malacomys edwardsi* were the most abundant (AR = 22.92%) species. *Crocidura olivieri* also dominated in the fallow (RA = 26.83%). *Mus musculoides* (RA = 48%) and *Mus setulosus* (RA = 27.79%) were dominant in rubber and coffee plantations, respectively. The higher Shannon-Wiener Index was obtained in the relic forest (H'= 1.77) and the lower in the coffee plantation (H' = 1.35). Sorensen's similarity coefficient showed great similarity between the species composition of the relic forest and the rubber plantation.

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Introduction

In Côte d'Ivoire, around 80% of the forest cover has been destroyed over the past thirty years (Chatelain *et al.*, 1996). Agricultural activities, mainly cultivation, remain the main causes of this reduction in vegetation cover. Indeed, the establishment of vast monoculture plantations with an absence of a coherent agricultural policy, respectful of biodiversity conservation, has led to a considerable reduction in plant cover by the fragmentation of large intact forest blocks (Chatelain *et al.*, 2010). This fragmentation of natural habitats has resulted in the isolation of populations and decreased species diversity in general and especially that of terrestrial small mammals (Keller *et al.*, 2004). However, terrestrial small mammals (rodents and shrews) play important ecological roles in maintaining the structure as well as the composition of tropical ecosystems. In the food chain, they eat plants and fungi, and are the prey of a large number of predators such as carnivores, raptors and reptiles (Habtamu and Bekele, 2012). They also participate in pollination, seed dispersal and soil aeration through their underground activities (Angelici and Luiselli, 2005).

The diversity and abundance of terrestrial small mammals are strongly influenced by the level of disturbance of natural habitats due to human activities (Wiewel *et al.*, 2007; Sollmann *et al.*, 2015; Negesse *et al.*, 2021).

Therefore, it becomes obvious that the establishment of plantations over large areas poses the problem of maintaining biodiversity. To ensure their socio-economic development, some inhabitants of the rural domain in Côte d'Ivoire, in this case, those of Man in Tonkpi region (western Côte d'Ivoire), have recourse to agrosystems establishment focused on cash crops such as rubber, cocoa, coffee, palm oil plantations, indubitably to the detriment of forests.

The destruction of forests for the establishment of these agrosystems must have caused a modification of the species composition and the community structure of the terrestrial small mammals.

In general, the species composition of the terrestrial small mammals in the western regions of Côte d'Ivoire, particularly those of Man region, is poorly documented. Therefore, the present study proposes to answer the following questions (i) what is the species richness of the terrestrial small mammals in the habitat types of Man region? (ii) Do the diversity and relative abundance of terrestrial small mammals vary between habitat types?

Materials and methods

Study area

The habitat types sampled are located in Man (7°20' - 7°35' N and 7°25' - 7°45' W), which is the headquarters of the Tonkpi region in the western of Côte d'Ivoire. The climate of the Tonkpi region is characterized by two seasons: a rainy season from March to October and a dry season from November to March. Rainfall varies between 1300 and 2400 mm per year. The average temperature is 24 °C (Tiesse, 2020). The soils of this region are of the ferralitic type with medium chemical fertility. Eighty percent (80%) of the vegetation cover was the evergreen forest. Today, part of this forest is transformed into fallow with *Chromolaena odorata*, while another part is exploited in the form of coffee, cocoa and rubber plantations (Tiesse, 2020).

Inventory of terrestrial small mammals

This study was conducted from March to June 2021. Terrestrial small mammals were inventoried in four types of habitats: relic forest, fallow, rubber and coffee plantations (Fig. 1). In each habitat type, two plots of 2500 m² (50x50 m) each were sampled. A total of eight plots prospected during this study. In each plot, five equidistant trap lines of 10 m were arranged. On each trapping line, ten Sherman live traps (7.5x9x23 cm) were installed, spaced 5 m apart (Akpatou *et al.*, 2018a; Ahissa *et al.*, 2020), which makes a total of 50 Sherman live traps per plot.

The traps were baited with palm nuts (*Elaeis guineensis* Jacq.). The traps were marked with fluorescent ribbon to facilitate retrieval. The plots of the same habitat were sampled successively.

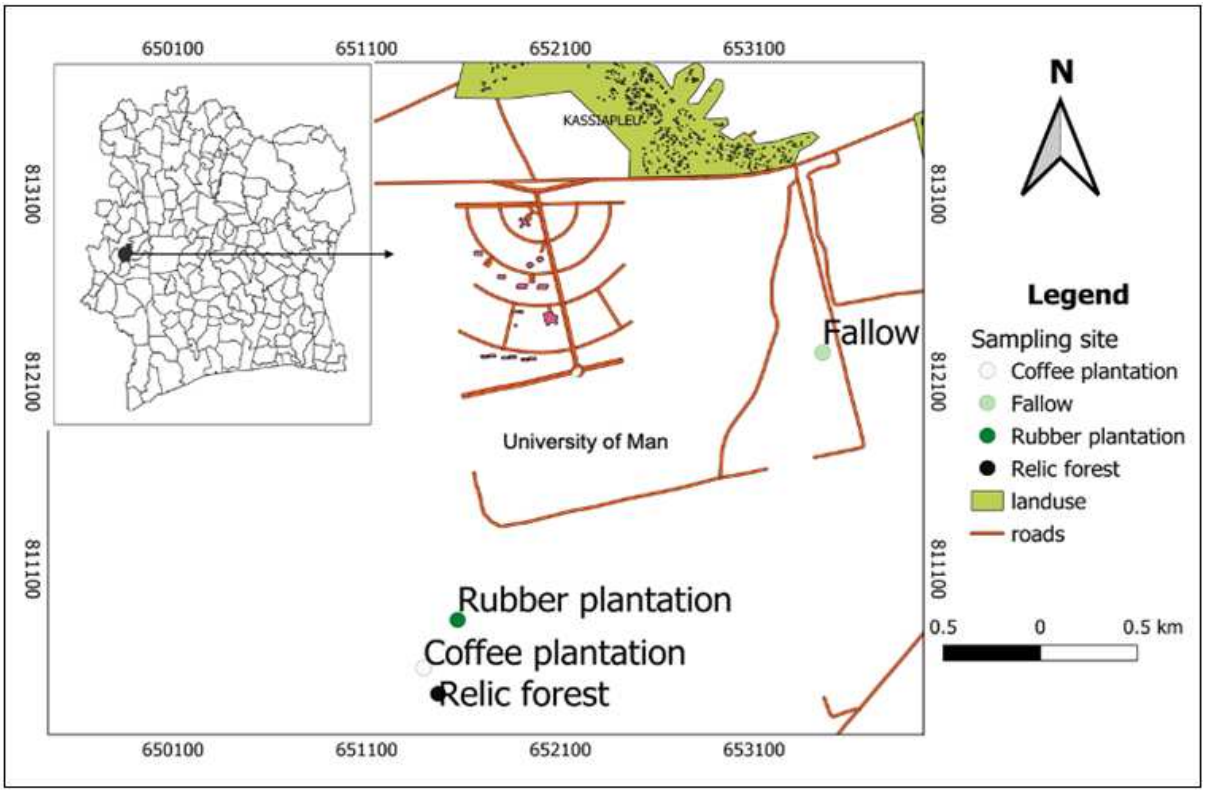

Fig. 1. Map showing the location of the study sites.

The trapping campaign was carried out for 7 consecutive days for a given plot, making a trapping effort of 700 trap-nights per habitat. This gave a trapping effort of 2,800 trap-nights for all four habitats. The traps were visited early in the morning and the baits were renewed as needed. Every three days, the baits of all the traps were systematically renewed.

Identification of terrestrial small mammals

The captured terrestrial small mammals were identified according to the existing taxonomic nomenclature (Happold, 2013; Happold and Happold, 2013). Species identification was based on data from external measurements, specifically head and body length, tail length, hind-foot length, and ear length. All animals were treated in a humane manner, in accordance with the guidelines from the American Society of Mammalogists (Sikes *et al.*, 2016).

Data analysis

The composition and structure of terrestrial small mammal populations in different habitats were described using several ecological variables and indices. For each habitat, the species richness (S), which corresponds to the total number of species sampled, was determined. The Shannon-Wiener index (H') was calculated as follows: $H' = -\Sigma(p_i) (\log_2 p_i)$, where p_i = number of individuals for each species / total number of individuals (Shannon and Weaver, 1949). The Equitability index (J) indicates how the species are distributed in the community and is derived from H' ($J = H'/\log_2 S$). The values range from 0 (one dominant species) to 1 (all species equally represented in the community). H' and J were calculated by habitat. The Simpson index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species. The Simpson's index (D) for each habitat was determined using the formula: $D = \Sigma [n_i (n_i - 1)] / [N (N - 1)]$ whereby, Simpson's Diversity Index = 1- D. Where n_i = the total number of individuals of a particular species, N = the total number of individuals of all species. The trap success (T) was calculated as the ratio of the number of individuals captured to the total trap-nights in a habitat multiplied by 100 (Stanley and Foley, 2008). The relative abundance (RA) of individual species was

computed as the ratio of the number of a particular species to the total number of all individuals captured in a habitat, RA = (ni/N) × 100; with ni = number of individuals of species i, N = total number of individuals captured.

Ecological indices and rarefaction curves were performed using PAST Software Version 4.04 (Hammer *et al.*, 2001). The Mann-Whitney test was used to compare the effects of habitat on the small mammal abundance. A diversity t-test was used to compare the Simpsons and Shannon-Wiener diversity indices between habitats. Sorensen similarity index (S_{xy}) was used to estimate similarities in faunal composition (Tchapgnouo *et al.*, 2012). This index measures the similarity between lists of species from two different sites. For two lists, A and B, with «A» as the number of species of site x, «B» as the number of species of site y and «C» as the number of species common to both sites x and y, $S_{xy} = [2C/(A+B)] \times 100$. S_{xy} varies from 0% to 100%. S_{xy} = 0% when there are no common species between the two sites. S_{xy} reaches 100% when both lists are identical.

Results

Trapping success

A total of 132 specimens of terrestrial small mammals were collected in 2,800 trap nights, which represents a trapping success of 4.71%. The highest trapping success (T = 6.85%) was in the relic forest and the lowest (T = 2.57%) was in the coffee plantation (Table 1).

Table 1. Number and abundance (%) and composition of terrestrial small mammal species in the four sampled habitats at Man region.

Species	Relic forest	Fallow	Rubber plantation	Coffee plantation	Total
Soricidae					
Crocidura olivieri	11 (22.92%)	11 (26.83%)	2 (8%)	3 (16.66%)	27(20.45%)
Muridae					
Grammomys buntingi	1 (2.08%)	-	2 (8%)	-	3 (2.27%)
Hylomyscus simus	4 (8.33%)	1 (2.44%)	2 (8%)	-	7 (5,30%)
Lophuromys sikapusi	10 (20.83%)	-	3 (12%)	4 (22.22%)	17 (12.87%)
Malacomys edwardsi	11 (22.92%)	6 (14.63%)	1 (4%)	-	18 (13.63%)
Mus muscoloides	-	4 (9.75%)	12 (48%)	6 (33.33%)	22 (16.66%)
Mus setulosus	7 (14.58%)	10 (24.40%)	3 (12%)	5 (27.79%)	25 (18.94%)
Praomys rostratus	4 (8.33%)	9 (21.95%)	-	-	13 (9.88%)
Number of individuals	48 (36.36%)	41 (31.06%)	25 (18.94%)	18 (13.64%)	132
Number of species (S)	7	6	7	4	8
Number of trap-nights	700	700	700	700	2 800
Trap success (T%)	6.85	5.8	3.57	2.57	4.71

Species richness and accumulation curves

All of the 132 specimens of terrestrial small mammals collected belong to Muridae family with seven species and Soricidae family with only one species (Table 1). Regarding to the habitats, the highest species richness (S = 7 species) was recorded in relic forest and rubber plantation, while the lowest value of species richness (S = 4 species) was recorded in coffee plantation (Table 1). Species accumulation curves for all the habitat types showed the curves for the relic forest, fallow and rubber plantation were still increasing, while that of the coffee plantation habitat showed a distinct plateau (Fig. 2).

Diversity indices

The Shannon-Wiener index (H') of terrestrial small mammals was high in relic forest (H'= 1.77) and low in coffee plantation (H' = 1.35) (Table 2). There was a significant difference in the Shannon-Wiener index (H') of the relic forest and the coffee plantation (t = -3.56; p = 0.001). The Shannon-Wiener index of the fallow also showed a significant difference (t = -2.27;

p = 0.02) with that of the coffee plantation (Table 3). Regarding, the Simpson's diversity indices, like the Shannon-Wiener indices, the relic forest recorded the highest value (1-D = 0.81). The lowest values (1-D = 0.72) were recorded in rubber plantations (Table 2). No significant difference (p> 0.05) was observed between the Simpson's diversity indices of the four habitat types sampled (Table 3). In general, the value of the Equitability index (J) was high in the four habitat types sampled. However, the highest value (J = 0.97) was found in the coffee plantation and the lowest (J = 0.82) was obtained in the rubber plantation (Table 2).

Table 2. Terrestrial small mammal diversity index from different habitats.

Habitats	Number of species (S)	Shannon-Wiener index (H')	Simpson's diversity index (1-D)	Equitability (J')
Relic forest	7	1.77	0.81	0.91
Fallow	6	1.62	0.78	0.90
Rubber plantation	7	1.59	0.72	0.82
Coffee plantation	4	1.35	0.73	0.97

Relative abundance

Overall, *Crocidura olivieri* was the most abundant species, with 27 individuals, representing 20.45% of the total number of captures. This was followed by *Mus setulosus* with 25 (18.94%) individuals and *Mus muscoloides* with 22 (16.66%) individuals.

The least abundance species was *Grammomys buntingi* with 3 (2.27%) individuals (Table 1). Terrestrial small mammals were collected more in the relic forest (48 individuals, 36.36%) than in the three other habitat types: fallow (41 individuals, 31.06%), rubber plantation (25 individuals, 18.94%) and coffee plantation (18 individuals, 13.64%). There was no significant difference in the abundances of terrestrial small mammal species across the different habitats (H = 3.82; p = 0.28). In the relic forest, the most abundant species were *Crocidura olivieri* and *Malacomys edwardsi* with 11 (22.92%) individuals each. They were followed by *Lophuromys sikapusi* with 10 (20.83) individuals. The species with low relative abundance was *Grammomys buntingi* (2.08%) (Table 1). *Crocidura olivieri* (11 individuals, 26.83%) was the most dominant in the fallow, followed by *Mus setulosus* (10 individuals, 24.40%). With one individual, *Hylomyscus simus* (2.44%) was the least abundant in this habitat (Table 1). *Mus muscoloides* (12 individuals, 48%) dominated the terrestrial small mammal community in the rubber plantation. It was followed by *Lophuromys sikapusi* and *Mus setulosus* with 3 (12%) individuals each. *Mus muscoloides* (6 individuals, 33.33%) was also dominant in the coffee plantation, followed by *Mus setulosus* (5 individuals, 27.79%).

Table 3. Comparative terrestrial small mammal diversity between habitats.

Habitats	Shannon-Wiener index (H')	Simpson index (D)
Relic forest	1.77 ± 0.006	0.18 ± 0.0005
Fallow	1.62 ± 0.006	0.21 ± 0.0004
	t =-1.32 ; df = 87.84 ; p = 0.18	t = - 0.86 ; df = 84.42 ; p = 0.39
Relic forest	1.77 ± 0.006	0.18 ± 0.0004
Rubber plantation	1.59 ± 0.034	0.28 ± 0.006
	t = - 0.90 ; df = 34.11 ; p = 0.37	t = 1.16 ; df = 28.33 ; p = 0.25
Relic forest	1.77 ± 0.006	0.18 ± 0.0004
Coffee plantation	1.35 ± 0.007	0.26 ± 0.002
	t = -3.56 ; df = 45.91 ; p = 0.001	t = 1.64 ; df = 25.79 ; p = 0.11
Fallow	1.62 ± 0.006	0.21 ± 0.0006
Rubber plantation	1.59 ± 0.034	0.28 ± 0.006
	t = -0.16 ; df = 34.68 ; p = 0.87	t = 0.82 ; df = 29.53 ; p = 0.41
Fallow	1.62 ± 0.006	0.21 ± 0.0005
Coffee plantation	1.35 ± 0.007	0.26 ± 0.002
	t = -2.27 ; df = 46.01 ; p = 0.02	t = 1.06 ; df = 28.56 ; p = 0.29
Rubber plantation	1.59 ± 0.034	0.28 ± 0.006
Coffee plantation	1.35 ± 0.007	0.26 ± 0.002
	t = -1.17 ; df = 35.34 ; p = 0.24	t = -0.15 ; df = 38.08 ; p = 0.87

Sorensen's index

The results of the Sorensen's index showed that the species composition of terrestrial small mammals varied between different habitat types. The highest Sorensen's index value (0.85) was observed between the relic forest and the rubber plantation. The lowest Sorensen's index value (0.54) was recorded between the relic forest and the coffee plantation (Table 4).

Table 4. Sorensen similarity coefficient between habitats.

Habitats	Relic forest	Fallow	Rubber plantation	Coffee plantation
Relic forest	-	76%	85%	54%
Fallow	76%	-	76%	60%
Rubber plantation	85%	76%	-	72%
Coffee plantation	54%	60%	72%	-

Discussion

The present study, carried out in four types of habitats in Man region, identified eight species of terrestrial small mammals. The community of the terrestrial small mammals was dominated by Muridae species with seven species (*Grammomys buntingi*, *Hylomyscus simus*, *Lophuromys sikapusi*, *Malacomys edwardsi*, *Mus muscoloides*, *Mus setulosus* and *Praomys rostratus*) and one species of Soricidae (*Crocidura olivieri*). This preponderance of Muridae species has been reported in several previous studies conducted in West Africa. Similar results were obtained in Ghana, where eight species were collected including one Soricidae species and seven Muridae species (Attuquayefio *et al.*, 2017). In Benin, out of 12 species collected, there were 10 Muridae species and two Soricidae species (Nicolas *et al.*, 2020). On the other hand, in Liberia, out of 11 species inventoried, six species belong to the Soricidae family and five species to the Muridae family (Akpatou *et al.*, 2019). The species richness of Soricidae (one species) obtained during this study remains very low, unlike those of Bohoussou *et al.* (2020), who obtained six Soricidae species in anthropogenic relic forests at the western periphery of Taï National Park in Côte d'Ivoire. This low representativeness of Soricidae species could be linked to the types of traps and baits used. Indeed, Soricidae species were found insectivorous than granivorous (Churchfield *et al.*, 2004; Happold and Happold, 2013). Therefore, the palm nuts used as bait could be one of the causes of the low species richness of Soricidae. Furthermore, Kambale (2006) reported that Soricidae species were more captured by pitfall-traps than Sherman live traps. In this study, only Sherman live traps were used.

The species richness (eight species) recorded during this study is similar to that obtained by Akpatou *et al.* (2018a) in the disturbed forest within the Monogaga classified forest in Côte d'Ivoire. However, the species richness of the present study was low compared to those obtained by other studies conducted in the western part of Côte d'Ivoire. Indeed, Akpatou *et al.* (2018b) collected 17 small mammal species in Taï National Park and Bohoussou *et al.* (2020) also inventoried 15 species in relic forest close to this Park. The low species richness recorded during this study could be attributed to the low trapping effort, the number of trap types used and the high level of disturbance.

Diversity indices were higher in the relic forest than those of the other three habitats. This could be explained by the fact that the relic forest is a refuge for several small mammal species, particularly the forest species, in an environment severely degraded by human activities. Also, diversity in plant species could provide a variety of foods that would attract terrestrial small mammals, leading to increased small mammal diversity (Ssuuna *et al.*, 2020). The lower values of the diversity indices observed in fallow,

rubber and coffee plantations could be attributed to human activities, which modify the environmental characteristics of habitats and negatively impact the species composition of terrestrial small mammal communities (Hoffmann and Zeller, 2005; Ssuuna *et al.*, 2020).

In the relic forest, species richness is characterized by small mammal forest species such as *Hylomyscus simus*, *Malacomys edwardsi*, *Mus setulosus*, *Grammomys buntingi* and *Praomys rostratus* (Happold, 2013; Akpatou *et al.*, 2018a), and also by open-habitat species such as *Lophuromys sikapusi* and *Crocidura olivieri*.

In the rubber plantation, forest species such as *Hylomyscus simus*, *Malacomys edwardsi*, *Mus setulosus* and *Grammomys buntingi* were captured. The fact that the rubber plantation is adjacent to a relic forest could explained the presence of the small mammal forest species in this habitat. According to Happold (2013), small mammal forest species were very often captured in plantations close to the forest. The fallow sampled during this study is considered an intermediate habitat between the relic forest and the plantations. The terrestrial small mammal community of this habitat is composed of forest species (*Praomys rostratus*, *Hylomyscus simus*, *Malacomys edwardsi*) and those of open-habitat species (*Crocidura olivieri* and *Mus muscoloides*). The coffee plantation recorded lower species richness. The open-habitat species such as *Crocidura olivieri*, *Lophuromys sikapusi* and *Mus muscoloides* were collected in this coffee plantation.

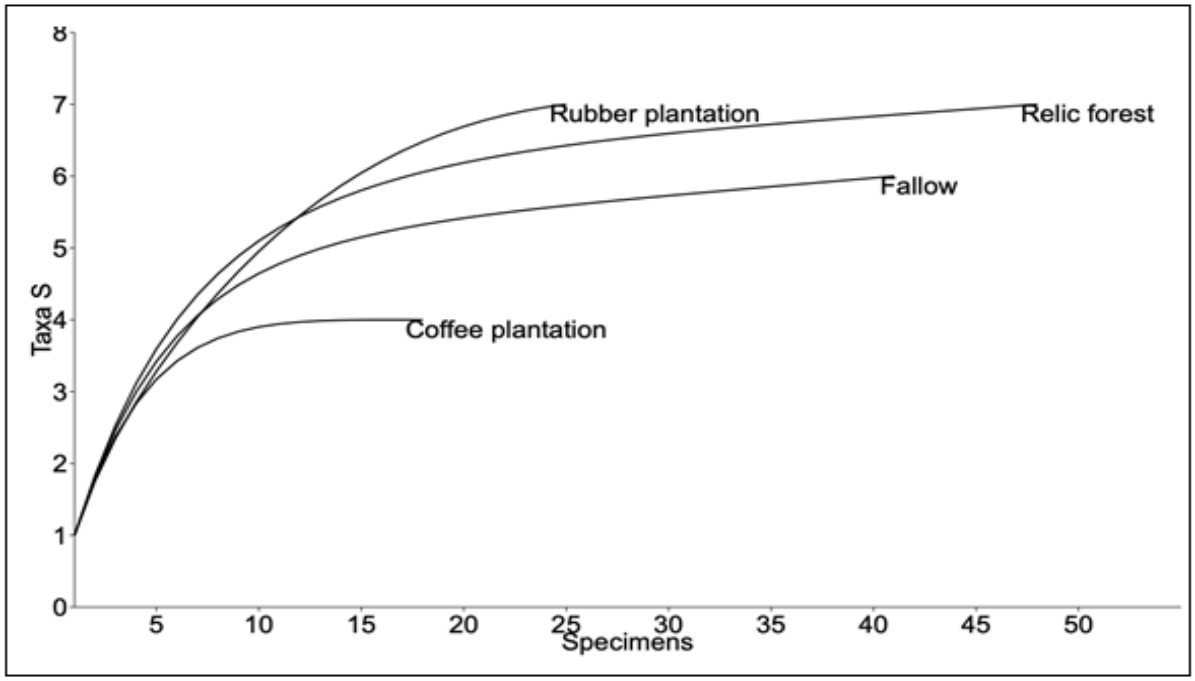

Fig. 2. Rarefaction curves for the four study habitats in Man region.

The species accumulation curves of the studied habitats showed that those of the relic forest, fallow and rubber plantation did not reach the plateau, which meant that this species richness is probably underestimated. So, species richness in these habitats can increase with a higher trapping effort.

The combined trapping success in this study was higher (T = 4.71%) as compared with other studies carried out by Bohoussou *et al.* (2020) in the relics forest in Côte d'Ivoire (T = 1.95%) and by Missoup *et al.* (2006) in the forest of the Cameroon volcanic line (T = 2.26%). Among the four habitats sampled, the trapping success in the relic forest (T = 6.85%) was higher than one of the three other habitats. The great trapping success observed in the relic forest may have been due to the dense vegetation cover and its low disturbance by human activities. Dense vegetation

cover also plays important ecological roles, namely providing a variety of food, and breeding sites and may afford protection from predators (Trejo and Guthman, 2003; Lambert *et al*., 2006), which may attract more small mammals. This could explain the highest trapping success observed in the relic forest compared to habitats with less vegetation cover. Previous studies have shown that the relative abundance of terrestrial small mammal decreases with the level of habitat disturbance (Nicolas *et al*., 2009; Gbogbo *et al*., 2017). This study agrees with this hypothesis. Indeed, the relative abundance of terrestrial small mammal decreased from the relic forest to the plantations.

In the relic forest, the small mammal community was dominated by open-habitat species *Crocidura olivieri* and *Lophuromys sikapusi* and typically forest species *Malacomys edwardsi*. These species are known for their abundance in relic forests (Happold, 2013; Bohoussou *et al*., 2020). In this degraded area, the relic forest represented a good refuge for several small mammal species.

The comparison of habitat types sampling using Sorensen's index showed that there was great similarity between the species compositions of the relic forest and the rubber plantation. This proves that the environmental conditions of the relic forest were similar to those of the rubber plantation. The lowest value of the Sorensen's similarity coefficient was observed between the relic forest and the coffee plantation. This low similarity coefficient would be due to the high level of human activities on the coffee plantation.

Conclusion

This study carried out in four types of habitats shows the first view of the terrestrial small mammal community in Man region. Seven species belonging to Muridae family and one species of Soricidae were collected. The higher species richness was recorded in the relic forest and in the rubber plantation. The forest species *Malacomys edwardsi* and the open-habitat species *Crocidura olivieri* were most abundant in the relic forest. *Mus muscoloides*, an open-habitat species, were dominant in the coffee plantation. *Crocidura olivieri* was also predominant in the fallow. The relative abundances of terrestrial micromammal communities in different habitats decrease from the least disturbed to the most disturbed habitats. Overall, most of the habitat sampling was dominated by an open-habitat species. The relic forest offers a refuge for many small mammal forest species in this area, where most of the fauna habitats were degraded by human activities.

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Conflict of Interest

The authors declare no conflict of interest regarding this article.

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