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To What Extent do Mango Agrosystems (*Mangifera indica,* Anacardiaceae) Contribute to the Restoration of Hypogenous Termites (Insecta: Isoptera) in Korhogo Region (Northern Côte d'Ivoire)?

Tenon Coulibaly[1*], Yalamoussa Tuo[1], Laurince Michel Yapo[1], Akpa Alexander Moïse Akpesse[2], Ahoua Yapi[2] and Kouassi Philippe Kouassi[2]

[1]Department of Animal Biology, UFR Sciences Biologiques, University Peleforo Gon Coulibaly of Korhogo, BP 1328 Korhogo, Côte d'Ivoire.
[2]Laboratoire de Zoologie et de Biologie Animale, UFR-Biosciences, Université Felix Houphouet Boigny de Cocody, 22 BP 582 Abidjan 22, Côte d'Ivoire.

Authors' contributions

This work was carried out in collaboration among all authors. Author TC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors YT and LMY managed the analyses of the study. Author LMY managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The conversion of natural ecosystems to agriculture is recognized as the current major cause of biodiversity loss. Given large expanses of land that is under agriculture worldwide, this study, carried out in 2013, aimed to examine the contribution of mango orchards to the restoration of hypogenous termite in northern Côte d'Ivoire. Using the TSBF (Tropical Soil Biology and Fertility) monolith method of soil macrofauna estimation, termites were collected in seven age classes of mango tree orchards (class 1: <5 years; class 2: 5–9 years; class 3: 10–14 years; class 4: 15–19 years; class 5: 20–24 years; class 6: 25–29 years; class 7: 30 years and over) and compared with

*Corresponding author: E-mail: tenondezana@Gmail.com;

termites collected from the savannah. A total of 16 species of termite were collected in all the study plots. The species richness, low in young orchards of classes 1 and 2 (05 species), increases to reach its maximum in old orchards of more than 30 years (13 species). These old orchards would be even richer and more diversified in termite species than savannah (10 species). Termites were less abundant in young orchard of class 1 (151.33±87.35 Individuals/m^2) and more abundant in the old orchards of class 7 (344.88±119.90 ind./ m^2). In the young orchards of class 1, termites were more prevalent in the 20-30 cm depth (7.92%) and in the old orchards of class 7, termites were found more at the surface between 0-10 cm depth (67.26%). Soil-feeders were absent in the young orchards but were abundant in the old orchard of class 7 (519 individuals). This study showed that in this highly disturbed region, mango orchards are re-colonized by termite communities. These results encourage the establishment of mango orchards to allow natural regeneration after agricultural disturbances.

Keywords: Mango agrosystems; termite diversity; restoration; Côte d'Ivoire.

1. INTRODUCTION

In Côte d'Ivoire, the agricultural and agro-industrial sector is the main source of income for 2/3 of the national working population, including a high proportion of women (54.3%) [1]. Today, after the coffee-cocoa duo, the "fruit" sector occupies an important place. Among the country's fruit crops, the cultivation of mango trees has been very promising in the north of the country for several decades. Indeed, faced with the collapse of world cotton prices, people are more interested in the cultivation of mangos. Thus, from 71 tons in 1981 [2], mango exports from this region reached more than 12,000 tons in 2001 [3]. The mango has become the third exported fruit, after pineapples and bananas [4]. The mango sector generates many services and jobs both in production areas and in non-producing areas. In 2006, this sector brought producers of this region, around 11.2 billion CFA francs [5]. The cultivation of the mango is increasing in popularity, with consequent increases in hectarage. In addition to its remarkable economic importance in the North of the Côte d'Ivoire, the cultivation of the mango tree plays a environmental role by creating micro climates favorable to food crops and by fixing anti-erosion cords which slow down the phenomenon of desertification [4].

Termites constitute one of the major biotic components of the tropical ecosystems where they are, with earthworms and ants, important ecosystem engineers [6-8]. The ecological importance of termites can particularly be observed through their role in trophic networks where they intervene as main decomposers and constitute the prey of numerous other organisms, in the storage and the decomposition of the organic matter of vegetable origin [9] and finally, as bioturbators, modifying the structure of soils [9]. In view of this pivotal role, it is important to understand how some of agricultural practices affect their assemblages.

In northern Côte d'Ivoire, Korhogo region is the main area, for the production of mangos for export. The mango orchards were grown on the old plots that were previously exploited for cotton or food crops for at least 10 years. This research examines the contribution of these mango-cultivated areas to the preservation of soil termite biodiversity since termites are bio-indicators of habitats modified by humans. The main question is: how does the cultivation of mango affect the assembly of termites living in the soil? To answer this question, termites were sampled from mango orchards in northern Côte d'Ivoire.

2. METHODOLOGY

2.1 Study Area

The study was carried out during the local rainy season (April to June) in 2013 in the Korhogo region (9º34′N,5º37′W). The climate is of the dry Sudanese tropical type with two contrasted seasons: the rainy season (monthly rains >50 mm) extends from April to October and the dry season from November to March. The annual average rainfall varies between 1000 and 1600 mm. Rainfall constitutes the most influential climatic factor. The average humidity is 65–70% and the annual average temperature varies between 24 and 36ºC. The natural vegetation is a savannah, with an almost complete cover of high grass dominated by *Panicum* sp. Granites and schists are the main rocks characterizing the substratum of the region and soils are generally average fertility. Seven age classes of orchards were defined and differed in their ages and their management intensity (tillage; weeding; application of pesticides). Age of sampled orchards varied from 1 to >30 years. The planting density for mangos is 100 plants per hectare (10 m between lines and 10 m between plants). Three orchards by age class were sampled with savannah as a reference area. The characteristics of the study plots were as follows:

Young orchards class 1 (<5 years) and class 2 (5-9 years): These mango orchards were made on old plots previously used for cotton or food crops for at least 10 years. Orchards in these classes were virtually devoid of native woody species. To facilitate the weeding of orchards, farmers continue to cultivate various types of plants (rice, groundnuts, maize, cassava, etc.) under the mango trees. The soil was plowed once or twice a year and weeded three or four times a year. Pesticides and chemical fertilizers were regularly used (three to six times a year). The average area of orchards ranged from 1 to 2 ha.

Middle-aged orchards of class 3 (10-14 years) and class 4 (15-19 years): these orchards, canopy increases, gradually reducing the possibility for the cultivation of cotton and food crops below. Orchards are, during these stages, recolonized by fast-growing plants (grasses) and woody plants. Weeding is done once or twice a year and no weed is used. The average area of orchards ranged from 1 to 2 ha.

Old orchards of class 5 (20-24 years), class 6 (25-29 years) and class 7 (30 years and over): In these orchards, canopy closure is almost complete. The species richness of woody plants increases with the orchard age class and includes the regeneration of some native trees. Weeding is done once a year and no pesticides are used. The average area of orchards ranged from 2 to 3 ha.

Savannah (reference area): Three savannah fragments have been studied. These savannas were characteristic of the wet savannah zone. The vegetation consisted mainly of native plants and many shrubs and herbaceous plants. These savanna fragments have been regularly affected by bush fires and grazing livestock.

2.2 Termite Sampling Method

The hypogenous termites were harvested by the TSBF (Tropical Soil Biology and Fertility) monolith method [10] (Fig. 1). A metal quadrat of 1/16 m^2 (25 x 25 x 30 cm) was driven into the ground. A pit was dug around to clear the soil monolith. Once clear, monolith was cut into successive slices (0-10 cm, 10-20 cm and 20-30 cm). Each layer of soil was searched thoroughly. All termites harvested in each stratum were stored in 70% alcohol-labeled. Three monoliths were excavated per plot, totaling 72 monoliths. This technique makes it possible to analyze termite densities and to know their vertical distribution over the first 30 cm of the soil.

Fig. 1. TSBF monoliths

2.3 Identification of Collected Termites

The individuals were first determined to the level of the genus, then of the species under a binocular microscope, using the identification keys [11-17]. In order to increase the chances of being able to correctly determine the problematic species, they were compared to the correctly identified specimens in laboratory of Université Félix Houphouët Boigny in Côte d'Ivoire. After identification, each species was classified into one of the trophic groups (Fungus-growers, Soil-feeders, Wood-feeders and Grass-feeders).

2.4 Data Analysis

Several indices have been calculated to describe the community of termites in the study areas. Using Past software the species richness (S), Shannon index (H') and the equitability (E') were calculated for each habitat type. The Generalized Linear Model (GLM) was done to compare termite densities and to test the effect of the orchard age on the distribution of termites. These statistical analyses were performed using STATISTICA software (version 7.1).

3. RESULTS

3.1 Variation of Termite Diversity According to the Age of Orchards

A total of 16 termite species were collected (Table 1) from all areas. These species were grouped into 5 subfamilies and 13 genera. The termite species richness increased with age, from class 1 (5 species) to older orchards classes 6 and 7, respectively with 11 and 13 species of termites. The specific richness in these old orchards was very close and even superior to that harvested in the savannah.

In general, the Shannon index varies with the age gradient of mango orchards. It is low in young orchards (class 1) (1.88), but increases gradually to reach a maximum value in orchards of class 7 (2.99). Older orchards of classes 5, 6 and 7 had a higher index than that observed in the savannah (2.82). Equitability was greatest in Older orchards of class 6 and 7 (E = 0.93), indicating a good distribution of the species of these areas. The lowest equitability index was recorded in young orchards of class 1 (0.80) and class 2 (0.84) (Table 2).

3.2 Variation in the Density of Termites in Orchards

Termites were present in all horizons of the monolith. The density of termites varied according to the orchard age gradient (GLM, F= 3.48, *P*= 0.05) (Fig. 2). The lowest densities were collected in young orchards of class 1 (90.66± 40.38 ind./m^2) and those of class 2 (232.01±.8 ind./m^2). This density increased with the age of the orchard, to reach the highest values in older orchards, of class 5 (339.55±59.81 ind./m^2), class 6 (341.22±49.64 ind./m^2) and of class 7 (403.55±68.87 ind./m^2). Statistic tests indicates that there was no significant difference between the densities obtained in olds orchards (class 5, 6 and 7) and those recorded in the savannah (312.88±29.90 ind./m^2) (*P*=0.05). However, termite densities observed in old orchards (classes 5, 6 and 7) were significantly different from those obtained in young orchards (class 1 and 2).

3.3 Change in Abundance of Trophic Groups

The abundance of trophic groups varied from one habitat to another (Fig. 3). Fungus-growers were abundant in all habitats with abundances ranging from 400 to 690 individuals. The highest abundance of this group was observed in the savannah. Soil-feeders were absent in the young orchards. However, the abundance of this group increased with the age of the orchards, reaching a maximum of 519 individuals in the orchards of class 7. This abundance was higher than that recorded in the savannah (232 individuals).

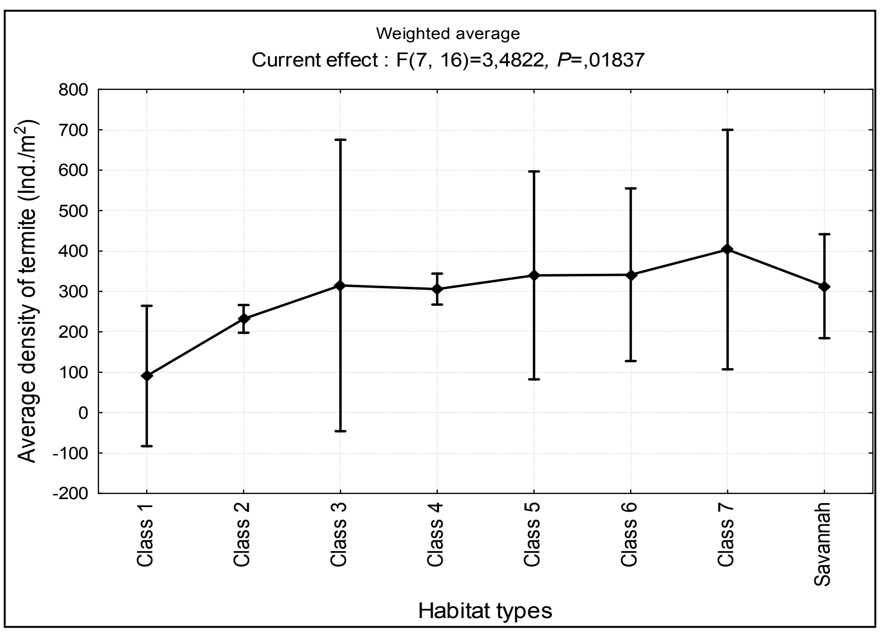

Fig. 2. Average termite densities in the prospected areas
Vertical bars represent confidence intervals at 0.95

Table 1. Variation in species richness of hypogenous termites harvested following the age gradient

Subfamily / Species or morphospecies	FG	Young orchards		Middle-aged orchards		Old orchards			Reference area
		Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Savannah
Macrotermitinae Kemner									
Ancistrotermes cavithorax (Sjöstedt)	f	*	*	*	*	*	*	*	*
Ancistrotermes crucifer (Silvestri)	f				*	*	*		
Microtermes sp1	f	*	*	*					*
Microtermes sp2	f						*	*	*
Odontotermes pauperans (Silvestri)	f	*	*	*	*	*	*	*	*
Pseudacanthotermes militaris (Sjöstedt)	f	*	*	*	*	*	*	*	*
Apicotermitinae Grassé and Noirot									
Astalotermes sp	s			*	*	*	*	*	*
Nasutitermitinae Hare									
Trinervitermes geminatus (Wasmann)	f			*	*				
Cubitermitinae Weidney									
Cubitermes sp	s					*	*	*	*
Procubitermes sjöstedti (von Rosen)	s						*	*	
Basidentitermes potens (Silvestri)	s							*	*
Termitinae Latreille									
Amitermes evuncifer (Silvestri)	w	*	*	*	*	*		*	*
Microcerotermes fuscotibialis (Sjöstedt)	w						*	*	
Microcerotermes sp2	w					*	*	*	*
Pericapritermes urgens (Silvestri)	s						*	*	
Promirotermes holmgren (Silvestri)	s							*	

**=Presence of species, f= Fungus-growers, s= Soil-feeders, w= Wood-feeders, g= Grass-feeders, FG: feeding group*

Table 2. Variability of termite diversity in the prospected areas

Indices	Savanah	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
Species richness	10	5	5	7	7	8	11	13
Shannon (H’)	2.82	1.88	2,17	2.54	2.77	2.86	2.98	2.99
Equitability (E)	0.90	0.80	0.84	0.88	0.91	0.92	0.93	0.93

Wood-feeders were relatively well represented in all areas. The highest abundance of this group was observed in older orchards (classes 6 and 7), which recorded 267 and 229 termite specimens harvested, respectively. Grass-feeders were absent in young orchards of class 1 and old orchards of class 6 and 7. The highest abundance of this group was recorded in middle-aged orchards (classes 3 and 4), which recorded respectively 107 and 52 termite specimens.

3.4 Vertical Distribution of Termites According to the Age of the Orchards

Termites were present in the different sections of the soil whatever the age of the orchards (Fig. 4). Generalized Linear Model survey revealed significantly distribution of termites in different section according to the age of the orchards (GLM: ddl = 7; W =82.83; P<0.05). In the 0-10 cm depth, the lowest density of termites was recorded for young orchards of class 1 (7.92%). The number of termites in this section increases with the age of orchards. The highest proportions of termites in this section were obtained in orchards of class 6 (63.42%) and class 7 orchards (67.26%). At a depth of between 10-20 cm, the proportion of termites was estimated by 26.45 and 28.86%, respectively, in older orchards of class 6 and class 7 orchards. In young orchards (classes 1 and class 2), the proportion of termites was respectively 29.51 and 35.86%. The proportions vary slightly at this depth (10-20 cm) between middle-age orchards classes (classes 3 and class 4). In the 20- 30 cm depth, a lower proportion of termite was observed in orchards of class 7 (3.86%) and those of class 6 (10.11%). The largest proportions of termites in this horizon were obtained in young orchards (class 1 and class 2), with 62.55 and 48.42%, respectively. In the savannah, the proportions of termites vary slightly between the different section.

4. DISCUSSION

4.1 Termite Assemblage in the Young Orchards

The specific richness of hypogenous termites was low in young orchards. This result could be explained by the agricultural practices implemented in these young orchards. In fact, to facilitate the weeding of orchards, farmers grow other crops between mango trees. The consequent weeding, substantial level of pesticide application, and the use of chemical fertilizers probably results in the low species richness of termites by reducing nesting site availability. Several studies carried out elsewhere showed a relationship between the exploitation of the environment and the diversity of the soil macrofauna [18-20]. These studies showed that the exploitation of the soil affects the trophic structure and the species richness of the fauna. These same reasons would also explain the absence of soil-feeders in these young orchards and the abundance of termites in deep within the 20-30 cm. The absence of soil-feeders group was also linked to the destruction of their nests in cultivated plots, as observed in Kenya [21].

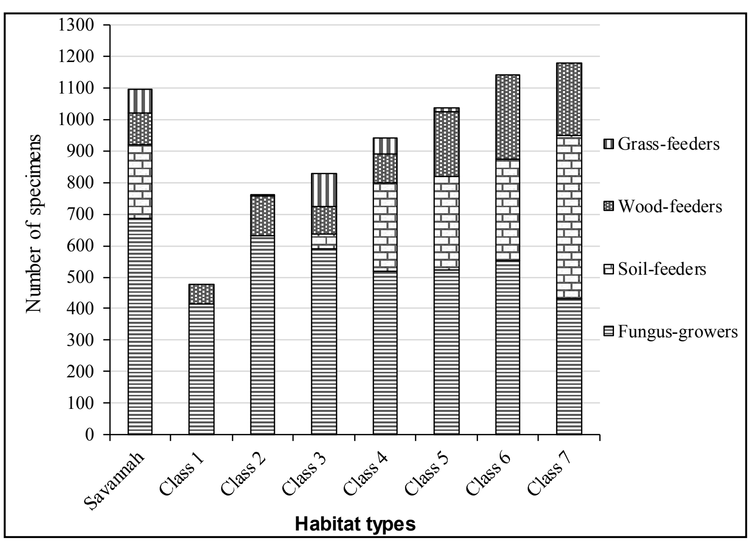

Fig. 3. Abundance of trophic groups according to the age of the orchards

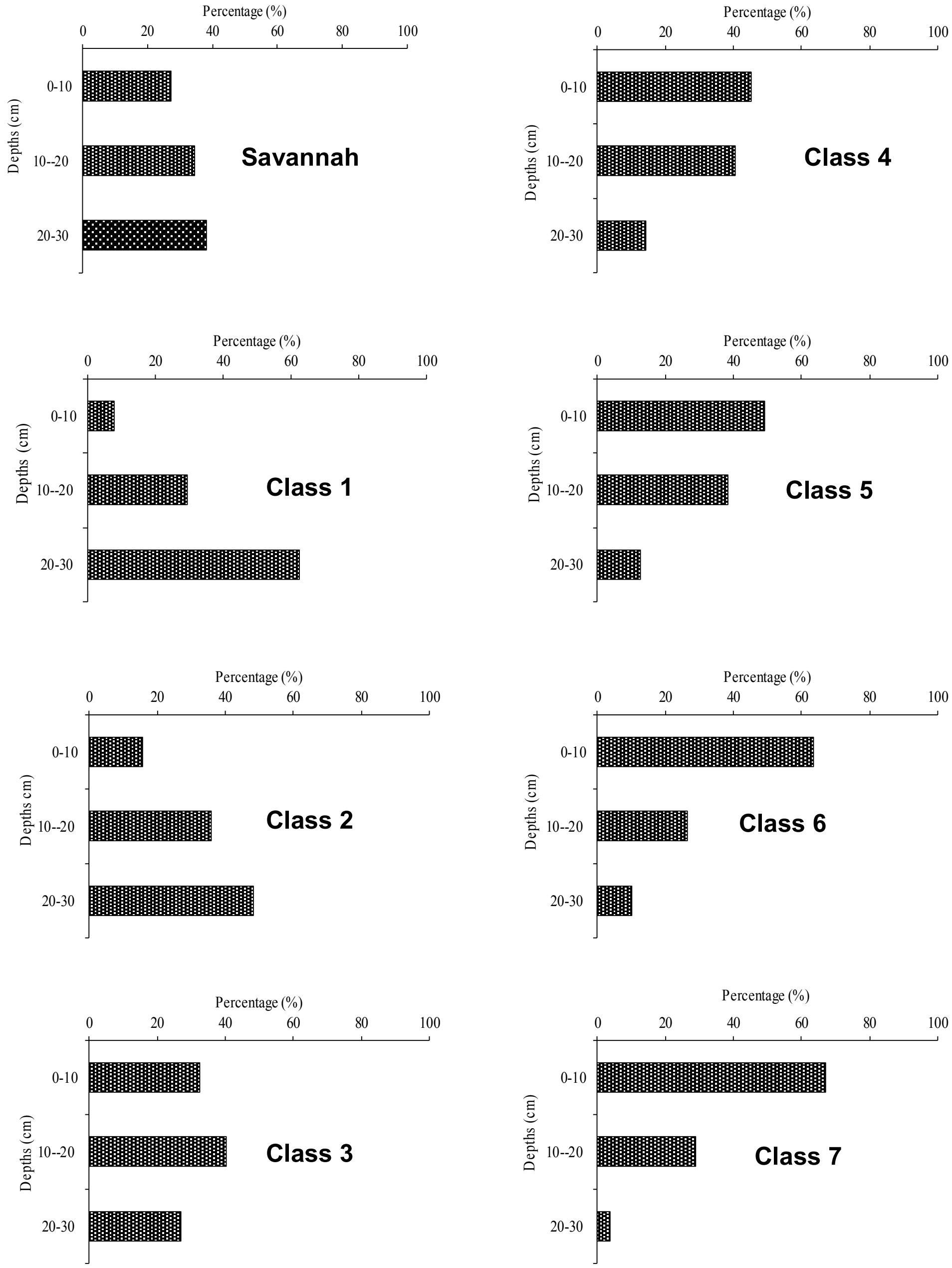

Fig. 4. Vertical distribution of termites according to the age gradient of orchards

4.2 Termite Assemblage in the Old Orchards

The richness and densities of termites increased gradually from class 3, to reach in the old orchards a level comparable or superior to that of the savannah. This could be explained by the fact that in these orchards, the cessation of agricultural activities leaves the soil at rest as in the case of a fallow. It then appears in the orchards a succession of annual plants, herbaceous perennial, then woody. After several years, in the old orchards, the litter accumulates and the canopy develops. Moreover, the presence of dried branches (food sources) that have fallen to the ground and the litter layer provide abundant trophic resources for termites, as well as a more humid microclimate more or less similar to a natural environment. All this would be sufficient assets for the installation of termites in these orchards. Kooyman, et al. [21] have shown that agricultural environments with high diversity and plant densities can maintain a level of biodiversity close to that of natural environments.

The abundance of termites near the surface, 10-20 cm layer depth for old orchards (classes 6 and 7) shows that species have found the suitable conditions for their establishment. Several studies reveal this ability to "heal" soil macrofauna [22,23]. Black and Okwakol [24] and Eggleton, et al. [18] have also shown that the diversity of termites in degraded environments is progressively reconstituted over time. Concerning the vertical migration of termites, Tsukamoto and Sabang [25] showed that 95% of the hypogenous termites of stable area concentrate in the 0-10 cm depth compared 40% in cultivated environments.

The old orchards seem richer in termite species than savannah. This result could be explained by the fact that the old orchards were less disturbed and more likely to offer adequate (and varied) microclimatic conditions for nesting. It should be noted that, during the dry season, mango orchards are protected from bush fires, unlike the savannah [26]. Bush fires could strongly explain the low abundance of termites in savannah compared to older orchards. Indeed, the work of Gimeno-Garcia, et al. [27] showed that during a bush fire, the entire herbaceous layer is destroyed and the soil temperature can reach 200ºC in the first 15 cm of the soil. The less mobile animals, living in the first centimeters of the ground, have no chance of surviving these conditions.

5. CONCLUSION

The study carried out showed that termite communities are strongly linked to agricultural practices in the mango orchards. The results showed that the diversity and density of termites, which is low in young orchards, gradually increases in older orchards, reaching a level comparable to that of the savannah. In this region, which is strongly disturbed by agricultural practices, these old orchards play a role in the restoration of termite biodiversity. The creation of mango orchards would, therefore, be an alternative for the conservation of ground living arthropod communities if the farmers stop agricultural activities, such as crop or cotton cultivation, early in the orchard.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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