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Diversity of termites (Blattodea latreille, 1810) and their damage in the royal court of huts of tiébélé and surrounding areas in Burkina Faso

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Abstract
A comparative study of termite diversity in three different ecosystems (of a royal court huts, *Khaya senegalensis* reserve and agricultural zone) was carried out in the south of Burkina Faso. The overall objective of this study was to assess the diversity of termites and how they get into the huts of the royal court to aid to protect the environment. A standard belt transect method and the systemic search were used for sampling termites. A total of 5 species belonging to 3 sub families (Macrotermitinae Termitinae and Nasutermitinae) and five genera (Ancistrotermes, Macrotermes, Procubitermes, Microcerotermes and Trinervitermes) were recorded. 77 huts in the royal court were examined of which 93.50% had termite attacks with varying intensities. The termites in the huts of the royal court of Tiébélé come from the wood transport areas. This study opens up perspectives for the control of these termites in the habitats.

Keywords: Biodiversity, termites, damages, royal court, Tiébélé

Introduction
Termites are ubiquitous in tropical ecosystems (savannah, forest) and are widespread in Sub-Saharan Africa and play an important role in natural pedogenesis [1]. These insects participate actively in crushing, decomposition, humus production and mineralization of a variety of cellulose-based resources, thus ensuring cycling of organic matter and efficient return of nutrients to soil [2]. Termites affect a structuring role in ecosystems and serve as indicators of their ecological health, and physicochemical processes affecting soil properties [3]. They have availability of resources for other organizations [4].
However, termites are among the main sources of ecosystems nuisance in tropical regions. In Africa, their damage has been observed on various tree species in the Yoko reserves in Congo [5], in the rubber [6] or cocoa [7] in Ivory Coast, on teak trees in Togo [8] and on mango trees in Senegal l[9]. Termite damage has been reported on the cultivation of rice and maize in Ivory Coast [10]. Termites attack the windows and doors of houses in Ghana [11] and buildings in Ase, a rural community in the Niger Delta of Nigeria [12].
In Burkina Faso, some studies have been done on termites which contribute in soil restoration by [13] and those which cause damage to groundnuts [14] and to maize [15]. However, we have little information on the damage caused by termites to timber in general, and cultural heritage in particular. The royal court of Tiébélé, prodigious heritage, of a traditional and exceptional architecture and carefully decorated by the expert hands of women is threatened by natural phenomena and especially termites. It is therefore important and necessary to preserve this heritage. Hence the interest of this study, whose objective was to assess the diversity of termites and how they achieve into the huts of the Tiébélé royal court to aid to protect the environment.
Here we characterised the species richness, relative abundance and damage intensity of termites in three different habitats (royal court huts, *Khaya senegalensis* reserve and the agricultural zone). The reserve of *khaya senegalensis* and the agricultural zone are the places of wood collection for the royal court. Specifically, we sought to address two hypotheses: 1) Termites in the royal court huts of Tiébélé originate from wood collection areas, 2) termite species richness and abundance depend on habitat characteristics.

Materials and Methods

Study area

This study was carried out in the district of Tiébélé located in the south-central region of Burkina Faso ($9^0$34'N-$5^0$37'W). Data were collected in three sites: the royal court, an agricultural zone and a *Khaya senegalensis* reserve (Fig. 1). These last two sites were sampled, because the inhabitants of the royal court collect wood in these areas. The study took place from July to September 2018.

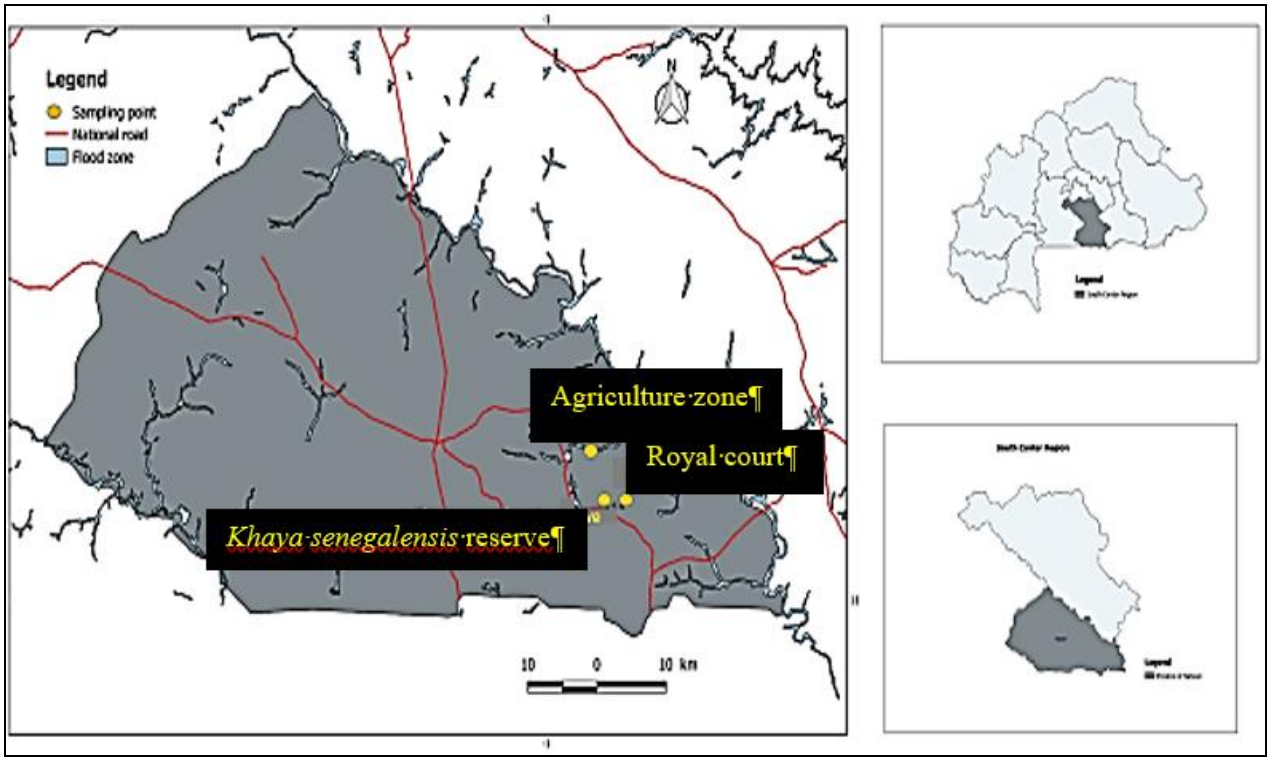

Fig 1: Location map of the study site in Tiébélé (Burkina Faso)

Royal court

This courtyard is located in sector N^01 of the town. It is divided into areas reserved for specific groups. Each area is made up of juxtaposed concessions, where families live. Each concession includes several huts.

K. senegalensis reserve

In this biotope, in from of the royal court this reserve is only *K. Senegalensis* (caïlcedrats tree). It is permitted people to have a rest, shadow and making the storefront beautiful of royal court.

Agricultural zone

This site is located 8 km from the royal court. It is mainly devoted to maize, millet peanut and vegetable production and is dominated by *Vitellaria paradoxa* (shea trees).

Sampling methods and data collection

A standard belt transect method proposed by Jones and Eggleton (2000) [16] was used for termite sampling in *K. senegalensis* reserve and agricultural area. The transect was 1000 m of length, 2 m of width and divided into 20 contiguous sections (each section having dimensions of 5 m x 2 m). In all section, termites' habitats were searched in galleries and veneers on the wall and wood for 1 hour. In the royal court, the systemic research method was used in all 77 huts for sampling termites and was done during raining season. The collected termite was counted, labelled and then conserved in vials containing 90% ethyl alcohol.

Termite damage was assessed using a visual rating scale on 77 huts. It consisted once inside a hut to observe on the timber, the wall and in the ground according to a scale of visual rating of termites' attack employed by Gbenyedji *et al*. (2011) [8] on forest areas. Each hut corresponds to a given type of infestation (Fig. 2) and if there are several types of infestation in a hut, we have noted the predominant infestation type.

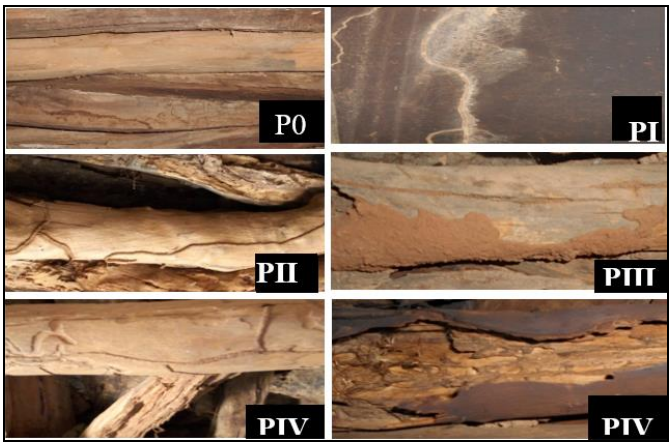

Fig 2: Different types of infestations (P0: Hut with healthy woods, no gallery, no veneers, no termites; PI: Hut with healthy wood with gallery in the ground or wall; PII: Hut with woods with galleries on the wood surface with or without termite; PIII: Hut with wood partially or completely covered with termite veneer; PIV: Hut with wood completely attacked by termites)

Termite's identification

Once at the Laboratoire d'Entomologie Fondamentale et Appliquée in Joseph Ki-Zerbo University, the samples were

sorted by large taxonomic groups for more precise identification. The identifications were later confirmed at the Laboratoire des Invertébrés Terrestres of the Institut Fondamental d'Afrique Noire in Dakar, Senegal. In all cases, termites were morphologically identified using a stereomicroscope and keys of Bouillon and Mathot (1965) [17] based on soldiers' caste specimens.

Data analysis

The following parameters were assessed:

- Frequencies: it expresses by following formula: Fr = ni x 100/N with Fr = Frequencies (%); ni = Number of individuals of each species; N = total number of specimens. The frequency of each species have been codified (Table 1).

Table 1: Codification of frequencies (F) index according to Gbenyedji *et al*. (2011) [8]

Frequency class (%)	Characteristics
F < 10	Rare species
10 < F < 20	Accidental species
20 < F < 40	Ancillary species
40 < F <60	Quite frequent species
60 < F < 80	Frequent species
F > 80	Dominant species

Ecological indexes

The species richness and diversity of termite fauna were calculated and compared using Shannon's diversity index, Simpson's and Pielou Equitability indexes for each biotope.

- Shannon's diversity index (H'): it estimates stand diversity and is determined by the following formula: H' = - Σ ((qi/Q) log2 (qi/Q))

Where *qi* is the number of individuals of a taxon and *Q* is the total number of individuals in the habitat.

Diversity is greater when all taxa observed have the same abundance H' max = log2S where *S* is the total number of taxa in the stand.

- Simpson's diversity index: it estimates stand diversity and is determined by the following formula: D = - Σ (qi (qi-1) / (Q (Q-1))
- Pielou equitability index: (J') it expresses the equipartition of individuals in the habitat. It is calculated using the following formula J' = H'/H' max.

Termite damage

- Rate of hut attacked: it give the percent of hut attacked in royal court by the following formula $R = \frac{na}{NT}$ (na =Number of hut attacked; NT= Total Number of hut).
- Damage Intensification Index (DII) [18]:

It consists to mark the type of infestation inside of each hut of royal court of Tiébélé (Table 2).

DII = [(Ps x 0%) + (P1 x 25%) + (P2 x 50%) + (P3 x 75%) + (P4 x 100%)] / [P0 + P1 + P2 + P3 + P4]

Ps = Number of heathy hut P0; P1 = Number of huts with type damage PI;

P2 = Number of huts with type damage PII,

P3 = Number of huts with type damage PIII,

P4 = Number of huts with type damage PIV.

Functional group classification

Termites were assigned to functional groups based on their feeding preferences according to Donovan *et al*. (2001) [19] method. Group I includes lower termite found in dead wood and grass; group II contains termites with a wide range of feeding habits, including dead wood, grass, leaf litter, and micro-epiphytes; Group III is composed of Termitidae species feeding on the organically rich upper soil layers and group IV represents the true soil-feeder termites, ingesting mineral soil poor in organic matter (Table 2).

Table 2: Qualification of damage intensification indices

GROUP	Damage Intensification Index (%)	Qualification
I	0 ≤ DII) ≥ 20	Low
II	20 ≤ DII) ≥ 40	Average
III	40 ≤ DII) ≥ 50	Strong
IV	50 ≤ DII) ≥ 100	Very strong

In each area of royal court, percent of each type infestation have been calculated. The ANOVA test followed by the t tests was used to compare the mean type of infestations' in the royal court at the significance level of 5 %.

Results

Diversity and taxonomic composition of termites

In total, 1950 specimens belonging to the Termitidae family were identified. They belong to three (03) sub-families, five (05) genera and five (05) species (*Ancistrotermes cavithorax*, *Macrotermes bellicosus*, *Procubitermes* sp., *Microcerotermes* sp., *Trinervitetermes Dispar*). These species are grouped in 4 trophic groups (Mushroom, Humivorous, Xylophagous, Foragers) (Table 3).

Table 3: List of species and their trophic groups

Family	subfamilies	Genera	Species	Trophic group
	Macrotermitinae	Ancistrotermes	*Ancistrotermes cavithorax* (Sjöstedt)	Mushroom
		Macrotermes	*Macrotermes. bellicosus* (Smeanthman,1781)	Mushroom
		Procubitermes	*Procubitermes* sp.	Humivorous
	Termitinae	Microcerotermes	*Microcerotermes* sp.	Xylophagous
Termitidae	Nasutermitinae	Trinervitermes	*Trinervitetermes Dispar* (Sjöstedt)	Foragers

Termites' abundance per biotope

Analysis of species abundance by biotope shows that *A. cavithorax* is the only species present in all three habitats. It is the dominant species in the royal courtyard and the *K. senegalensis* reserve (respectively 95 and 93% of species) and quite frequent in the agricultural zone (46% of species) (Table 4).

Table 4: Species abundance in each biotope.

Characteristic	Royal court	*K. senegalensis* reserve	Agriculture area
Rare species	*Microcerotermes* sp. (5%)	*Microcerotermes* sp. (5%)	*Procubitermes* sp. (4%)
		M. bellicosus (2 %)	*M. bellicosus* (11%)
Accidental species	-	-	-
Ancillary species	-	-	*T. dispar* (39%)
Quite frequent species	-	-	*A. cavithorax* (46%)
Frequent species	-	-	-
Dominant species	*A. cavithorax* (95%)	*A. cavithorax* (93%)	-

Distribution of diversity indices according to biotopes

Analysis of the abundance of species richness per biotope shows that 4 species are found in the agricultural area, 3 in the *K. senegalensis* reserve and 2 in the royal court (Table 5). For the Shannon and Weaver specific diversity index and Simpson's index, the most diversified sampling site was also of agriculture areas while the least diversified are Royal court and *K. senegalensis* reserve. Piélou's fairness shows that the distribution is also more equitable in Agriculture areas (Table 5).

Table 5: Diversity index according to biotopes

Diversity index	Royal court	Agriculture area	*K. senegalensis reserve*
Species richness (SR)	2	4	3
Shannon's Weiner index (H')	0.2	1.09	0.35
Simpson's index (S)	0.09	0.62	0.17
Equitability index (E)	0,28	0,78	0,31

Quantitative analysis of termite damage in huts -

Rate of hut attacked

Of the 77 huts sampled, 93.50% showed signs of termite attack.

Qualification of intensification indices

The intensification index varies from 57.81 to 69.44 and all huts have a very strong infestation in all areas of royal court (Table 6).

Table 6: Intensification index and infestation qualification by area

Areas	Intensification index (%)	Qualification of infestation
Princes	57.81	Very strong
Little brother	67.57	Very strong
Big brother	69.44	Very strong
Others	58.34	Very strong

Mean percent of types of infestation

There is a significant difference between the types of infestations that affected the huts ($P = 9.169.10^{-5}$). Thus, more huts (31.94) have been affected by the PIII infestation. The number of huts affected by PII and PIV infestations is not significantly different from that of type PIII. Compared to types PII, PIII and PIV, type PI affected significantly the fewest number of huts 6, 52 (Fig.3).

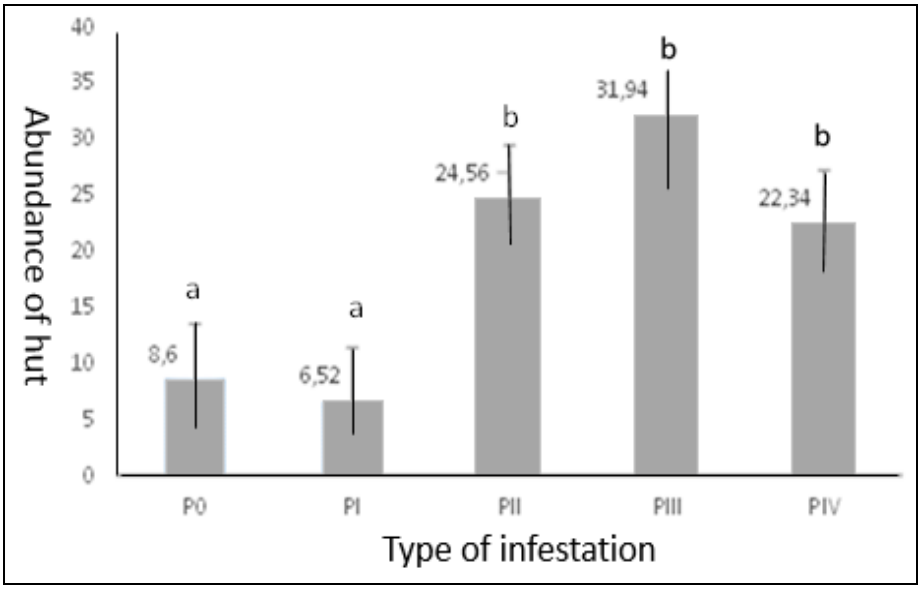

Fig 3: Mean abundance of hut per type of infestation (the average abundances with the same alphabetical letters are not significantly different)

(P0: Hut with healthy woods, no gallery, no veneers, no termites; PI: Hut with healthy wood with gallery in the ground or wall; PII: Hut with woods with galleries on the wood surface with or without termite; PIII: Hut with wood partially

or completely covered with termite veneer; PIV: Hut with wood completely attacked by termites)

Discussion

The present study indicated the diversity of termites in three different habitats. A total of 5 species, 5 genera and 3 sub-families were recorded. The low number of species in this study could be linked to climatic and edaphic factor which can affect the geographical distribution of termites [15]. This low diversity is closely linked to climatic and edaphic hazards which can affect the distribution of *A. cavithorax M.*, *bellicosus Procubitermes* sp., *Microcerotermes* sp., *Trinervitetermes dispar*.

A. cavithorax is very common in the royal court, the of *K. senegalensis* and quite frequent in the agricultural areas because of its diet, its underground nest and its way of life. It is a species found in forests, savannahs and fallows [20]. Previous studies have shown that a *cavithorax* attacks several other plant species, including *Azadirachta indica*, *Acacia auriculiformis, Blighia sapida, Cycas circinalis, Gmelina arborea*, *Terminalia catappa, T. mantaly Mangifera indica* [21]. This mushroom termite belongs to the Macrotermitinae subfamily and to the termitinae family. They live with obligatory exosymbionts, fungi of the genus Termitomyces which develop on grindstones stored in the nest thanks to the workers [22]. In the royal court, in addition to the natural propagation methods, the action of the inhabitants who transport the woods already infested from their fields to their homes favour *A. Cavithorax* propagation [23]. This confirms our first hypothesis, i.e. that the termites in the huts of the royal court of Tiébélé come from the wood transport areas.

This study indicated differences in the species composition in the three different habitats. Three species (*Microcerotermes* sp. *M. bellicosus A. cavithorax*) were recorded in *K. senegalensis* reserve. This low specific richness in the *K. senegalensis* reserve could be explained by the fact that it is the only plant species and constitutes the main food resource for termites. According to Gbenyedji *et al*. (2011) [8], replacing a diversified flora with a monoculture of teak in Togo would result in a reduction in termite species.

In agriculture area, four species (*A. cavithorax, M. bellicosus, Procubitermes sp., T. dispar*) were recorded. The reduction in the number of termite species in the agricultural area could be explained by the disturbance of the natural environment thanks to the intense agriculture activities which are: soil preparation, cutting of woody plants, destruction of weeds and the pesticides use. These results are similar to those of Ponge *et al*. (2013) [24] who report that disturbed environments (cultivation) contain fewer species compared to natural environments.

Two species (*Microcerotermes sp., A. cavithorax*) were recorded in royal court**.** Indeed, Vidyashree *et al*. (2018) [25] have shown that this low specific richness could be due to anthropogenic activities hence increased disturbance had negative effect on species diversity and less decomposed matter or leaf litter.

Species diversity and richness varied across three habitats. Shannon's wiener index shows that the values ranged from 0.2 to 1.09 in the study areas. The index shows that agricultural zone had more species diversity (1.09) followed by reserve of *K. senegalensis* (0.35) and lowest in royal court (0.2). This indicated that in the agricultural zone, the species (*T. dispar, M. bellicosus* and *Procubitermes sp.*) found a place to build their epige nest (termite mound), grass and also the presence of organic matter. These results are closely in confirmation with findings of Shanbhag and Sundarara (2013) [26] who reported higher Shannon's wiener index in forest compared to plantation. This confirms our second hypothesis.

According to our results, in the royal court we obtained an attack rate of 93.50 %. The infestation of which is described as very strong in all areas. This high rate is due to the different modes of attack (galleries, veneer) of the termites. The dominant types of infestation are PII (gallery), PIII (veneer) and PIV (completely degraded wood). Indeed, these termite species encountered build galleries and clayey plating to attack the timber, which would cause the huts to collapse. According to Akpesse *et al*. 2008 [10], these structures protect termites from light, predators and in a special microclimate to attack plants. This favours their very strong damaging actions.

Conclusion

The results of the present study contribute to improving knowledge on the termites and their damage. This study revealed that five species have been identified in Tiébelé. All of These species belong to the family of Termitidae and are distributed in three sub families and five genera. These species belong to four trophic groups namely the Mushroomers, the humivores, the xylophages and the foragers. The termites in the huts of the Tiébélé royal court come from the *K. senegalensis* reserve and the agricultural zone. This is due to the fact that the wood used in the royal court comes from the *K. senegalensis* reserve or from the agricultural zone. *A. cavithorax* is a very common species in the royal court and in the reserve of *K. Senegalensis* but it is quite frequent in the agricultural area. In the royal court, the termite attack rate is high by 93.50% and its infestation is classified as very high. The dominant types of infestations are clay galleries, clay veneers and completely degraded wood. Sustainable means must be developed against these pests in order to better conserve and protect this site with enormous tourist potential. These results draw attention to the control of the wood we bring into our habitats.

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Conflict of interest

All authors declare that there is no conflict of interest.

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