SPATIAL DISTRIBUTION AND DENSITY OF TERMITE MOUNDS IN A PROTECTED HABITAT IN THE SOUTH OF COTE D'IVOIRE: CASE OF NATIONAL FLORISTIC CENTER (CNF) OF UFHB OF ABIDJAN

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Abstract

The spatial distribution and termite mounds density and their activity were studies in order to assess to the biological restoration level in a protected area, knowing that termites are considered as tropical ecosystem engineers. The CNF area was subdivided into 4 sectors (SW, SE, NW and NE). In every sector of 1.75 ha, 20 transects (5 m x 100 m) were sampled. Termite nests were counted. Their dimensions and geographical coordinates were recorded. The superposition of spatial distribution maps of the 3 types of termite mounds showed an impressive abundance of termite mounds in all CNF area. In total, there were recorded 165 termite mounds. They were composed of 119 epigeal termite mounds and 46 tree-dwelling termite mounds. The average density of the 3 types of termite mounds on the CNF area was 23.57 mounds/ha with a dispersion coefficient of 0.07. The average density of *Macrotermes* mounds (8.99 mounds/ha), *Cubitermes* mounds (8.00 mounds/ha) and that of arboreal termite mounds (6.57 mounds/ha), with respective dispersion coefficient of 0.10, 0.08 and 0.07, showed no significant difference between them (p> 0.05). The epigeal termite mounds moved 297.42 tons of soil to build their nests. *Macrotermes* only, moved 297.03 tons (99.87%) of soil. On the CNF area, *Macrotermes* mounds have occupied a base area of 373.3 m^2 and a volume of 264.99 m^3. *Cubitermes* mounds covered a total base area of 2.08 m^2 and a volume of 0.42 m^3. These results are the reflection of a strong activity of the termite colonies, gradually restored in this protected habitat for 51 years.

Keywords: Spatial distribution, termite mounds density, *macrotermes*, *cubitermes*, protected habitat

Introduction

Termites are the dominant Macroarthropod decomposers in many tropical soils, and are particularly diverse and abundant in lowland equatorial forests (Collins 1983; Eggleton *et al.*, 1999; Eggleton 2000). They are major agents of decomposition, and play an important part in nutrient and carbon fluxes (Lawton *et al.,* 1996; Bignell *et al.,* 1997; Tayasu *et al.,* 1997), redistribute organic matter, improve soil stability and it's physical and chemical properties, and improve water absorbing and storing capacity (Lee and Wood 1971; Holt and Lepage 2000, Jude and Ayo, 2008, Boga, 2007; Garnier-Sillam *et al*., 1991). The termites are a source of vegetation heterogeneity and tree diversity (Traoré *et al.,* 2008; Sileshi *et al*., 2010; moe *et al*., 2009; Asawalam *et al*., 1999). Beyond all these important roles of termites in the nature, they are considered as good bio-indicators and real ecosystem engineers in tropical ecosystems. Their sensitivity to habitat disturbance causes changes in their species richness, composition and functional characteristics (Davies, 1997, Eggleton *et al.,* 2002, Konaté *et al.,* 2005, Thomas F., 2006, Dosso *et al*., 2013).

Indeed, these last years, in international scientific conferences, many debates revolve around the loss of biodiversity in the disturbed habitats, and the need to preserve some area with the aim to favorise plant and animal species diversity restoration; among others, termites, playing a key role in the tropical ecosystem evolution.

The National Floristic Center (CNF) is an artificial botanic forest set up by Professor Ake Assi in 1963, in order to recreate and preserve the diversity of endangered plant species. Today, in addition to the conservation and preservation of plant species diversity, the CNF has almost become an ecological niche of some insect species including termites (Boga *et al*., 2015). The CNF is an academic site, and therefore, the need for a reliable database in all areas of research arises. For this purpose, it seemed necessary (i) to map the epigeal termite mounds and the tree-dwelling termite spatial distribution and (ii) assess termite activity in this environment. Thus, epigeal termite mounds and trees inhabited by termites have been identified. Their dimensions and geographical coordinates were recorded. Density, area, volume occupied by the epigeal termite mounds and the mass of soil mobilized by termites were determined.

Materiel and methods

Study site

The study was carried out in the region of Abidjan, in the CNF area. The CNF is located at the Félix Houphouët-Boigny University (UFHB) of Cocody (3°57 N - 5°20 W). The CNF covers 11 hectares. The investigations were made on 7 hectares. The climate is equatorial, with an average inter-annual rainfall exceeding 1800 mm. The climate is characterized by four seasons, two rainy and two dry seasons. The average temperature ranges from 24 °C to 30 °C, with an average value of 26 °C. The soils are mostly ferralitic desaturated (Perraud, 1971) with low organic matter content (2-3%). The CNF is composed of two parts: a fallow (Unauthorized access: (4ha)) and an arboretum (7 ha) comprised of plant species from different countries. These plants give an appearance of humid forest (Kouakou, 2009).

Sampling procedure

Three (3) types of termite mounds were encountered in CNF: *Cubitermes* mounds (Fig. 1A), tree-dwelling termite mounds (Fig. 1B) and *Macrotermes bellicosus* mounds (Fig. 1C).

To list all of the termite mounds, the CNF area was subdivided into 4 sectors named as follows: South-West (SW), South-East (SE), North-West (NW) and North-East (NE) (Fig. 2). In every sector of 1.75 ha, 20 transects (5 m x 100 m) were sampled. The same transect is successively inspected by 3 technicians in search of termites' nests. Termite nests were counted. The base perimeter (BP), the perimeter to 2/3 of the height (MP), height (H) and the distance between the termite mounds were recorded. Then, nests' status (active or inactive) and their geographic coordinates were also recorded.

Cubitermes sp mound (BP:39,1 cm x H:25,8 cm) | *Anoplotermes'* mound (BP:20 cm x H:15 cm) | *M. bellicosus'* mound (BP:820 cm x H:310 cm)

Fig. 1: different types of termite mounds listed in the cnf area

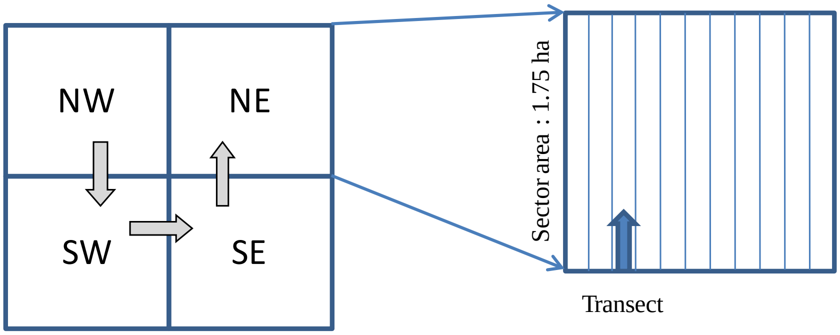

Fig. 2: Investigation device and sectors exploration chronology

As for the tree-dwelling termites, taken into account was only the perimeter of the inhabited trees in order to mark the geographic position of the nest. Because of the height of the trees (at least 10 meters), tree-dwelling termite mounds are not accessible. The status of these termite mounds was confirmed by the presence of termites in veneers adjoining trees.

Mounds density and dispersion coefficient

The dispersion coefficient (i) and the density (ii) of termite mounds were calculated on the entire CNF and in every sector. The method used by Collins (1981) and Lepage (1984) for determining spatial distribution using the dispersion coefficient was employed in the study for the determination of spatial distribution of the mounds. The dispersion coefficient of the mounds was calculated using the Clark and Evans (1954) formula for assessing the dispersion coefficient;

(i) $\mathbf{a = m.d^2}$

Where, **a** is the dispersion coefficient, **m** is the real density and **d** is the average distance between mounds. The real density was determined using the formula;

(ii) $\mathbf{d} = n/s$

Where, **n** is the number of mounds sampled and **s** is the area sampled in m^2 as applied by Meyer (1997). Values where a=0 are described as having clump distribution, a= 0.25 as random distribution and a= 1.158 as regular distribution (Collins, 1981).

Estimation of epigeal termites' mounds dimensions

To estimate the average base area covered by nests, the total volume occupied and the weight of soil moved to build nests, it was necessary to adopt some simplifications to estimate these irregular volumes.

- Macrotermes

To determine the BP and BS of mounds, the base was considered as a circle. The formula of circle perimeter ($P = 2\pi R$) and surface ($SB = \pi R2$) were applied. To calculate the volume of *Macrotermes'* mound, as Collins (1983) and Lepage (1984), mound was likened to a cone. The diameter D was calculated from measurements of the base perimeter (V = volume, H = height and R the circle radius). The formula used is as follows:

$$V = 1/3\pi R^2 H$$

Note that this is an estimate of the external volume, because the total volume of internal galleries is not considered.

- Cubitermes

To estimate the volume, the nest of *Cubitermes* was likened to a cylinder topped by a cone or not. The volume of the basal part is assimilated to a cylinder:

$$V_{cy} = \pi R_{cy}^2 H_{cy}$$

Where V_{cy} = cylinder volume, R_{cy} = cylinder radius and H_{cy} = the height of the cylinder.

The hat was the second part of the nest comparable to a cone. The following formula was used: $V_{total} = V_{cylinder} + V_{cone}$, soit :

$$V_{total} = 1/3\pi R_{co}^2 H_{co} + \pi R_{cy}^2 H_{cy}$$

Where V_{total} = total volume, R_{co} = cylinder cone and H_{co} = the height of the cone.

Note: The base surface and the geographic references of each termite mound were used for mapping termite mounds on the CNF area.

Estimation of mound soil mass

After determining the base areas and volumes, the total weight of termite mounds was calculated to estimate the total soil mass moved per hectare. Ten (10) samples of termite mounds soil were weighted in a container of 11 liters. Soil weighed mass was obtained by deducting to the total weight of the container filled with *Macrotermes* or *Cubitermes* mounds soil. Taking into account the density of nests (1.35 *Macrotermes* and 1.25 *Cubitermes*), it was determined the mass of the mound, knowing the equivalent weight of the volume of the soil weighed and the volume of each nest. By this method of empirical calculation, volume and mass of the nests are overestimated. This calculation does not take into account internal galleries of the nest. To correct the estimated value of the weight of the termite mounds, the formula of Tilahun *et al.* (2012) according to whom the mass of the termites' nest is overestimated by 10 % was applied. They used regression lines ($Y = 0.87X - 37.11$ ($R^2 = 0.99$ or 0.97 depending on the site) to determine the degree of overestimation of the total weight of the nest. In this equation, Y is the true weighed mass of mound and X the mass in $Kgha^{-1}$ calculated from the mounds' average density bulk density.

Statistical analyses

STATISTICA 7.0 software was used for data analysis. Data generated were subjected to one-way analysis of variance using Newman Keuls test at 0.05% level. The mapping of epigenous mounds and the Tree-dwelling nests network was performed using ArcGIS 6.3 software.

Results and Discussion

Results

Distribution and comparison of the average densities of termite mounds between sectors

Hundred and sixty-five (165) termite mounds were recorded over the entire CNF area. They include 139 active and 26 inactive termite mounds (**Table 1**)

Macrotermes mounds

A total of 63 *Macrotermes* mounds were listed on the whole CNF area. Among them, 76.2 % (48 termite mounds) were active and 23.8 % (15 termite mounds) inactivate (**Table 1**).

The *Macrotermes* mounds were distributed over the entire surface of CNF, but unevenly (**Fig. 3**).

Table 1: rate of active or inactive termite mounds

Type of mounds	Number of termite mounds collected	Active mounds	Inactive mounds
Macrotermes	63	76.20 (48)	23.80 (15)
Cubitermes	56	80.36 (45)	19.64 (11)
Arboreal	46	100 (46)	0
Total	**165**	**(139)**	**(26)**

The total density of *Macrotermes* mounds was 8.99 mounds / ha with a dispersion coefficient of 0.10 on the entire CNF area (Table II). The density of *Macrotermes* mounds was significantly represented in the sectors NW (12.00±0.2 mounds/ha) and NE (10.28±0.2 mounds/ha) compared to that of the sectors SW and SE ($p = 0.034$). Average densities of *Macrotermes* mounds were almost identical in the sectors NW and NE (**Table 2**). The dispersion coefficient was lower in the sector SW (0.05) and was located between 0.12 and 0.13 for sectors NW, NE and SE.

The map of cathedrals termite mounds distribution showed that the sector NE (33.3%) and the sector SW (26.7%) contained the highest rate of active mounds (**Fig. 3**).

Cubitermes mounds

Cubitermes mounds were present on all the CNF area, but with varying densities (**Fig. 4**). The most significant *Cubitermes* mounds densities were obtained in the sectors SW (10.28 ± 0.3 mounds/ha) and NE (9.14 ± 0.2 mounds/ha) with dispersion coefficients of 0.10 and 0.06 respectively. These two sectors showed significant densities compared to those of the sectors SE (6.28 ± 0.1 mounds /ha) and NW (5.71 ± 0.1 mounds/ha) with the probability p = 0.042 (Table II). The dispersion coefficients of *Cubitermes* nests noted in the sectors SE and NW were 0.10 and 0.04 respectively. Sectors SE and NW had statistically equivalent termite mounds densities. Over the whole CNF area, 56 *Cubitermes* mounds were counted. The 80.36% (45 termite mounds) of these termite mounds were active. The sector NW grouped the largest number of inactive mounds (54.55%) and lowest rate 0% was recorded in the sector NE.

Table 2: number, distance between neighboring termites' mounds, density and dispersion coefficient in the cnf and by sampling sector

Termite mounds	Sectors	Number of nests	Distance between nearest neighbors nests (m)	Areas 10^4 (m^2)	Density/ Sector (ha)	Density on all the CNF (ha)	Disp.coef/ Sector	Disp.coef. On all the CNF
	NW	21	10.40	1.75	12.00±0.2a		0.13	
Macrotermes	NE	18	11.33	1.75	10.28±0.2a	8.99±0.1a	0.13	0.10
	SE	14	12.22	1.75	8.00±0.2b		0.12	
	SW	10	8.93	1.75	5.71±0.2b		0.05	
Probability					**0.035**			
	NW	10	8.00	1.75	5.71±0.1b		0.04	
Cubitermes	NE	16	8.40	1.75	9.14±0.2a	8.00±0.2a	0.06	0.08
	SE	11	12.33	1.75	6.28±0.1b		0.10	
	SW	18	10.20	1.75	10.28±0.3a		0.11	
Probability					**0.042**			
	NW	10	9.00	1.75	5.71±0.1b		0.05	
Arboreals	NE	8	14.00	1.75	4.57±0.1b		0.09	0.07
	SE	20	9.20	1.75	11.42±0.3a	6.57±0.2a	0.10	
	SW	8	10.29	1.75	4.57±0.2b		0.05	
Probability					**0.017**	**> 0.05**		
MCA	MCA	165	5.58	7.00	-	23.57	-	0.07

Note: values followed by the same letters are not statistically different at 0.05% level according to the test of newman keuls. **Mca**: the three types of termites' mounds (*macrotermes*, *cubitermes* and tree-dwelling termites' nests), **disp.coef**. (dispersion coefficient)

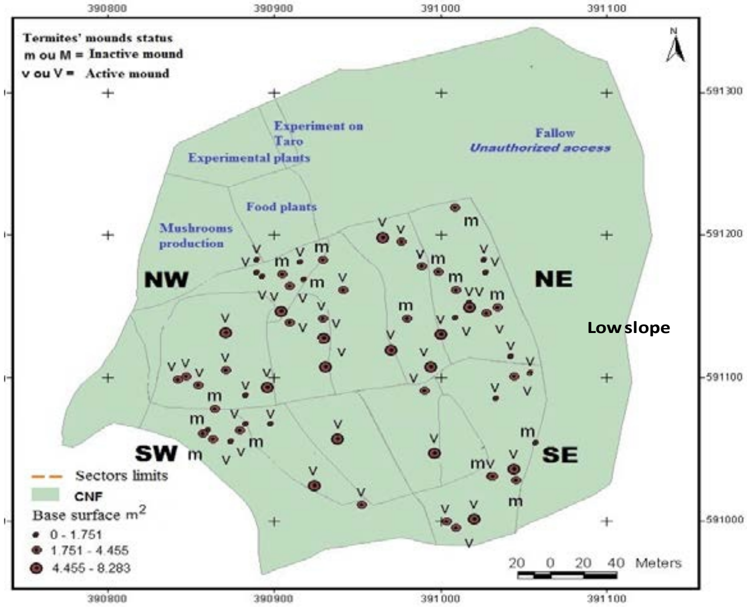

Fig. 3: Spatial distribution map of *Macrotermes* mounds on CNF
NB. Comparison of the densities between sectors (p = 0,034)

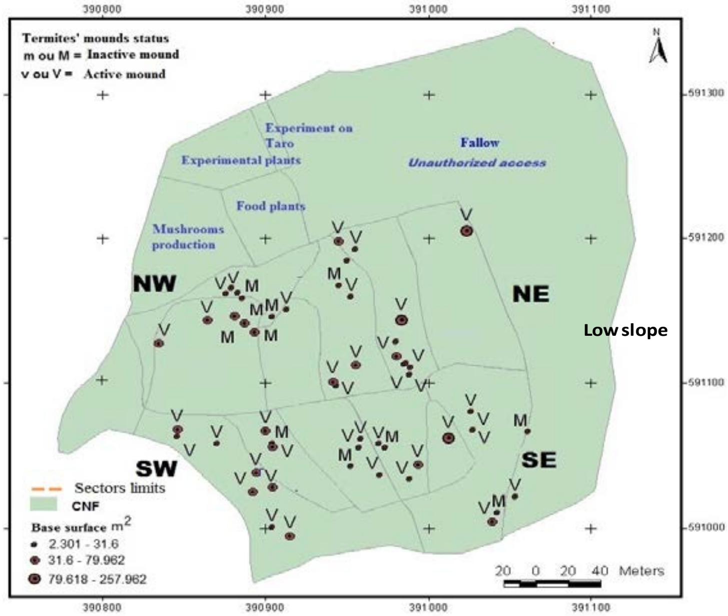

Fig. 4: Spatial distribution map of *Cubitermes* mounds on CNF
NB. Comparison of the densities between sectors (p = 0,042)

Arboreal termite mounds

Forty six (46) arboreal termite nests were listed in CNF. The spatial distribution map of these termite mounds showed that they were differently distributed in the different explored sectors (**Fig. 5**).

The sector SE had the highest density of trees inhabited by termite mounds (11.42 ± 0.3 Mounds / ha) compared to the sectors SW, NW and NE. The concentration ratio of arboreal mounds between this sector SE and the other was statistically different (p = 0.017) (**Table 2**).

The number of arboreal mounds by hectare was sensibly similar in sectors SW (4.57 ± 0.2 Mounds / ha), NW (5.71 ± 0.1 mounds / ha) and NE (4.57 ± 0.1 mounds / ha). Dispersion coefficients of arboreal termite mounds by sector were between 0.05 and 0.10. The lowest coefficients (0.05) are recorded on the sectors NW and SW.

Comparison of termites' mounds densities inside of each sector

The data analysis showed that inside each sector, the different types of termite mounds are represented to variable densities (**Fig. 6**). In the sector NW, *Macrotermes* density was twice higher than those of *Cubitermes* mounds and tree-dwelling termite mounds with a probability of p=0.013. The comparative test of Newman and Keuls at 0.05% level revealed a significant difference between the densities of *Cubitermes* mounds (10.28±0.3 mounds/ha) and those of the two other types of termite mounds in the sector SW (p = 0.022) (**Fig. 6**). The sector SE was dominated by a higher rate of arboreal termite mounds (11.42 ± 0.3 mounds / ha). On the other hand, the arboreal termite mounds were statistically less represented in the sector NE p=0.032

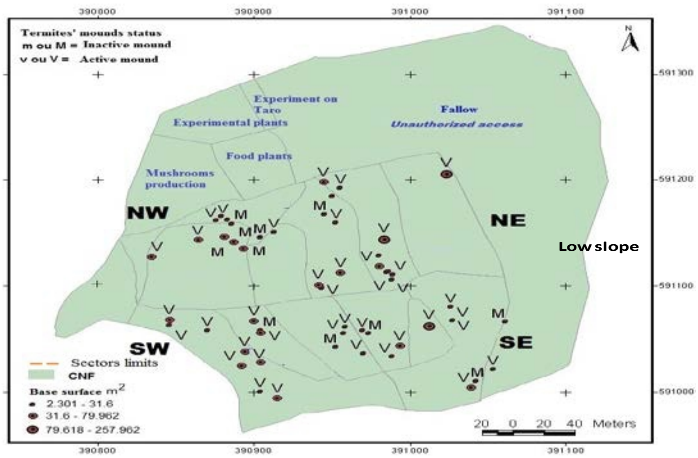

Fig. 5: Spatial distribution map of arboreal termite mounds on CNF
NB. Comparison of the densities between sectors (p = 0.017)

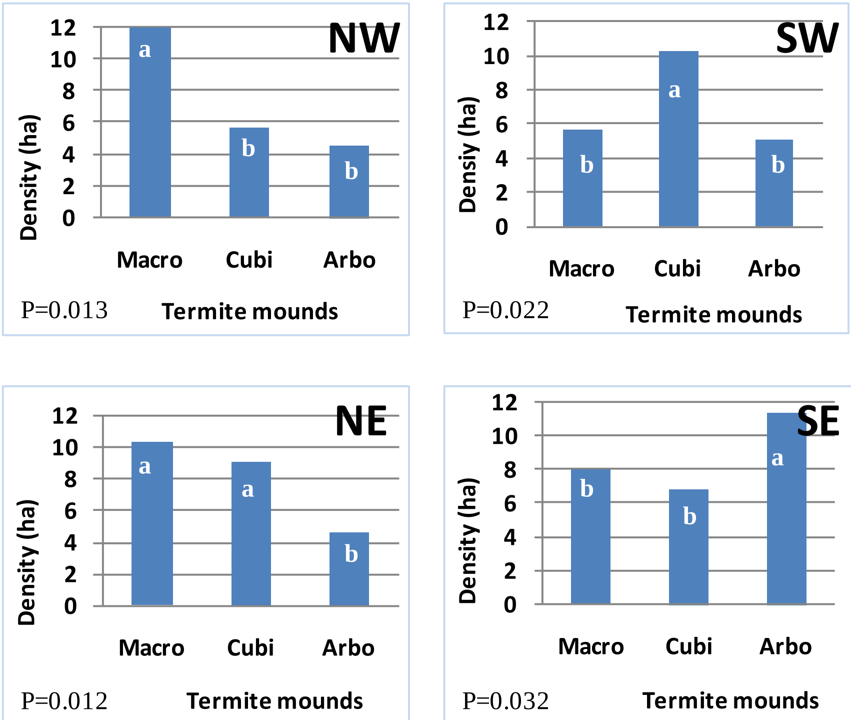

Fig. 6: Comparison of densities of termite mounds in each sector
N.B: **Macro**: *Macrotermes* mounds; **Cubi**: *Cubitermes* mounds; **Arbo**: arboreal termite mounds; p: probability. Values followed by the same letters are not statistically different at 0.05% level according to the test of Newman and Keul.

Comparison of densities of termite mounds between sectors

The superposition of spatial distribution maps of the 3 types of termite mounds revealed an impressive abundance of termite mounds in all CNF areas (**Fig. 7**).

In each sampled sector, when calculating the densities of the 3 types of termite mounds (ie d_{SW} = (n.$_{Macro}$ + n.$_{Cubi}$ + n.$_{arbo}$) / the area of sector SW (ha)) and compared these densities (d_{SW} # d_{SE} # d_{NE} # d_{NW}) between sectors, observations clearly showed significantly high levels (**Fig. 8**).

The sector SE had the highest density of termite mounds (d_{SE} = 26.28 mounds / ha) compared to that of sector SW (d_{SW} = 20.56 mounds / ha) with $p < 0.05$ (**Fig. 8**). Furthermore, NE and NW presented a significant grouping of termite mounds compared to that of the sector SW ($p < 0.05$). Termite mounds density was statistically equilibrated between sectors SE, NW and NE (**Fig. 8**).

Base surface, volume and weight of termite mounds

The epigeal termite mounds moved 297.42 tons of soil to build their nests. *Macrotermes* only, moved 297.03 tons (99.87%) of soil (**Table 3**). On the CNF area, *Macrotermes* mounds have occupied a base area of 373.3 m^2 and a volume of 264.99 m^3. *Macrotermes* mounds reach a maximum height of 3.8 m, a base area of 8.12 m^2 and a volume of 10.29 m^3 corresponding to a weight of 1281.28 kg. *Cubitermes* mounds covered a total base area of 2.08 m^2 and a volume of 0.42 m^3. They used 0.43 tons kg to build their nests (**Table 3**). This weight was 763 times less than that of *Macrotermes* mounds.

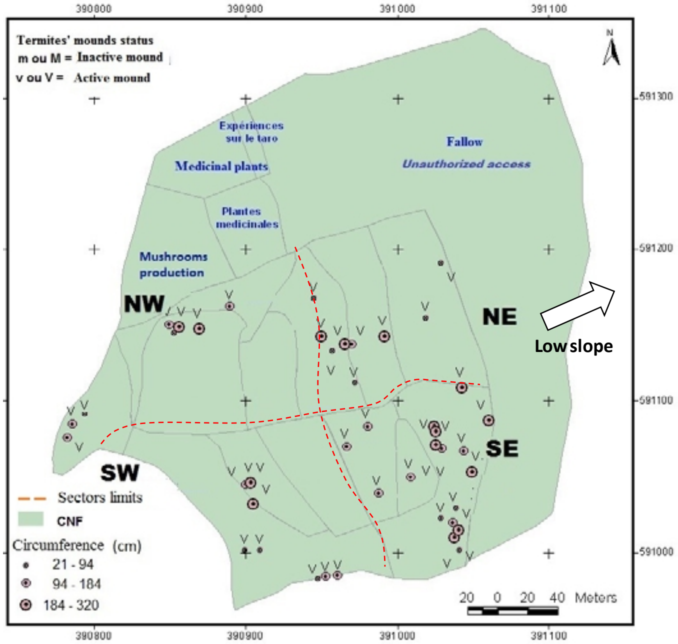

Fig. 7: Spatial distribution map of epigeal termite mounds and arboreal termite mounds on the CNF area ($p < 0.05$)

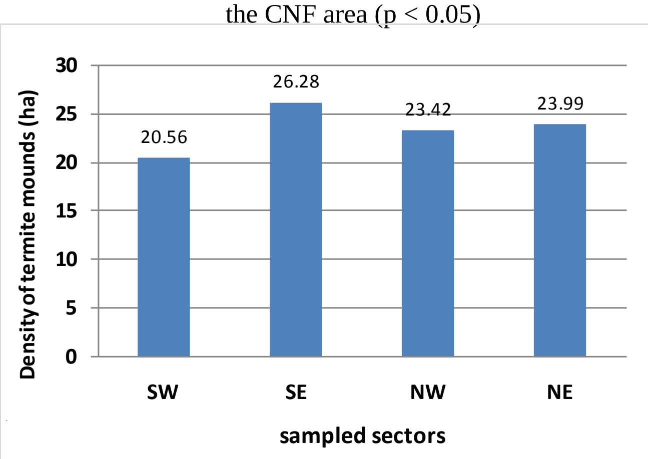

Fig. 8: Comparison of termites' mounds total densities between the 4 sectors
NB: Bars followed by the same letter at the top were not significantly different at 0.05% level according to the test of Newman and Keuls ($p < 0.05$).

Trees which perimeter was greater than 160 cm were most inhabited by termites (**Table 3**). Trees colonization by termites may be positively correlated to the diameter and thus, to the age of trees.

Table 3: Base surface, volume and weight of the termite mounds in CNF

Termite mouds	Base surface (m^2)	Volume (m^3)	Weight (kg)	Corrected weight (ton)
Macrotermes	373.05	264.99	330037.06	297. 03
Cubitermes	2.08	0.42	432.49	0.39
Arboreal	-	-	-	-
Total	**375.13**	**265.42**	**330469.56**	**297.42**

Discussion

Spatial representation on different types of termite mounds

In all, there were 165 termite mounds recorded. They were composed of 119 epigeal termite mounds and 46 arboreal termite mounds.

The spatial distribution maps of *Macrotermes* (Fig. 4), *Cubitermes* (Fig. 5) and arboreal termite mounds (Fig. 6) were performed using field measurement with GPS. These three distribution maps were then merged into a single (Fig. 7) in order to appreciate the overall distribution of termite mounds identified in the CNF area. The superposition of spatial distribution maps of the 3 types of termite mounds shows an impressive abundance of termite mounds in all CNF areas, giving the impression that its entire surface is dotted with termite mounds and all the floor swarms with termites. These mapping would constitute an important database of the CNF. They could serve as guide in locating termites' nests during studies visits for the students, but also for all the visitors.

Similarly, previous studies (Schuurman and Dangerfield (1997) and Linsenmair Korb, (2001), Lepage, 1984) used fields' measurements to map the distribution of the termite mounds. But recently, Muyinya *et al*. (2014) have used high resolution satellite imagery to map *Macrotermes falciger* mounds in the Upper Katanga, R.D Congo.

Indeed, these maps of termites' nests distribution are very scalable according to the rhythm of the turnover of the mapped termites' nests. Tano (1993), has noted a very high turnover of *Macrotermes bellicosus* nests, with an annual mortality rate of 50 to 55% (49.3% the first year and 56.8% the second year) in the North West of Côte d'Ivoire. Collins (1983) on the same species in Nigeria, and Pomeroy (1983) in the savannas of Kenya, noted significant changes in the density of nests according to years. These studies clearly demonstrate the high instability of the termite mounds density and their spatial distribution mapping. The need to update the maps would arise at least every 2 years if they are to be useful.

Density and dispersion coefficient of the mapped termite mounds

In this study, the average density of each type of termite mounds, and the density of the 3 types of termite mounds grouped were calculated. The density of the 3 different types of termite mounds grouped, is very high by sector (20.56 - 26.28 mounds / ha) and in all the CNF area (23.57 mounds / ha). These densities were higher compared to those reported in previous studies. These values are high because they reflect the combination of 3 types of termite mounds while previous studies reported only the density of a single type of termite mounds. The individual average density of *Macrotermes* mounds found in this study was 8.99 mounds / ha in all the CNF area and varied between 5.71-12 mounds/ha inside the sectors.

This average density of 8.99 mounds/ha observed in all CNF area appeared to be lower than earlier reports of Bandiya *et al.* (2012) which recorded a density of 10.08 mounds/ha in a Semi-arid Zone of Nigeria. In the same order, mounds density ranked in the highest densities were recorded by Tilahun *et al.* (2012) in Borana in the southern Ethiopia which indicated an average mound density of 10-14 mounds/ha. For the same species *Macrotermes subhyalinus*, Abdulrahman (1990) found 12 mounds/ha in western Ethiopia.

Macrotermes mounds density found in this study appeared similar to earlier reports of Lee and Wood (1971) which indicated that large mounds of Macrotermitinae are usually less than 10 mounds/ha. In the other hand, this value of *Macrotermes mounds* density seems to be higher than those indicated in several earlier studies:

Hesse (1977) indicated a density of 3-4 mounds/ha in East Africa, Pomeroy (1978) reported a density of 1- 4 mounds ha^{-1} for *Macrotermes* in Uganda, Trapnell *et al.* (1976) also, estimated a density of 3- 4 mounds ha^{-1} in Zambia for Macrotermitinae and Abe *et al.* (2009) reported a density of 3-10 mounds ha^{-1} for *M. bellicosus* in an upland site of central Nigeria and attributed the variation to anthropogenic disturbance. Similarly, Mujinya *et al.* (2014) recorded in the Uppeer Katanga, D.R Congo, a density of *Macrotermes falciger* mounds of 2.6-3.6 mounds/ha. Also, Schuurman and Dangerfield (1997) noted 0.1-6 mounds/ha.

These densities previously reported by these authors were much lower than those of *Macrotermes* mounds (5.71-12 mounds/ha) obtained in the CNF area and therefore, could be classified among the highest densities recorded to this date. The dispersion coefficient of the nearest neighboring termite mounds was 0.07 for the entire CNF. The dispersion coefficient of *Macrotermes* mounds, *Cubitermes* mounds and the arboreal termite was located between (0.07 - 0.10) in the Entire CNF (Table II). This was in line with Collins (1981) which reported a random distribution pattern of *M. bellicosus* in Southern Guinea Savanna of Nigeria. These high densities of termite mounds and the randomized distribution reported in the CNF area could be explained mainly by the stability of this habitat protected from human activities since 51 years.

Termite mounds are preserved. Nutritive factors and soil quality seem not to be a limiting factor in the development of termite colonies. This spatial distribution of termite mounds in different sectors, although random (according to the distribution coefficients calculated), seems to be in certain areas, the result of inter-specific competition as it has been previously noted by (Grohmann et *al.* (2010), Korb and Linsenmair, (2001), Lee and Wood (1971) and Pomery (2005). Indeed, the distribution map of cathedrals termite mounds (Fig. 3) shows that the sector NE contains the most important rate (33.3%) of inactive nests. It also has the lowest density of the arboreal termite mounds. In this sector, it has been particularly noted the abundant presence of ants (*Oecophylla smaragdina*) in the trees and on the ground, the presence of a nest of black ants hunters (*Dorylus nigricans*). One might therefore think that these ants hunt, and decimate populations of termites and so, prevent their abundant installation in this area (NE). This would explain the lowest density of arboreal termite mounds and the higher rate of inactive *Macrotermes* mounds in the sector NE. These observations imply a perpetual struggle between the different colonies of termites and ants. This observation was also noted by Hauser (1976) who showed that certain populations of termites are hunted and decimated by ants.

Regarding *Cubitermes* nests, they are more represented in the sector SW (10.28 mounds / ha). This result is in line with that of Tano (1993) who found significant densities of *Cubitermes* nests (10-11 mounds / ha) in shrub savannas in the catchment of Booro-Borotou, in the North West Côte d'Ivoire. Indeed, *Cubitermes* genus is a soil feeding termite that consumes organic matter. Generally, the stable environments promote termite’s development; However, the CNF is a preserved environment where abound humic substrate serving food to *Cubitermes* termites. The stability of this habitat could explain the recolonization and restoration of *Cubitermes* and *Macrotermes* termites in the CNF. This observation was also reported by Lepage and Tano (1986, 1988) who showed that only the fallows of approximately 30-40 years regain an important termite populating and that, the highly wooded areas recorded a maximum density of *Macrotermes*.

Base surface, volume and weight of termite mounds

The epigeal termite mounds moved 297.42 tons of soil to build their nests. *Macrotermes* only, moved 297.03 tons (99.87%) of soil. On the CNF area, *Macrotermes* mounds have occupied a base area of 373.3 m^2 and a volume of 264.99 m^3. *Macrotermes* bellicosus mounds atteining average height of 1.70 m, a base area of 3.29 m^2 and a volume of 2.31 m^3

corresponding to an average weight of 2873.84 kg. Similar studies reported for *M. Subhylinus* an average height of 2.52 m and a volume of 2.19 m^3 in southern Ethiopia (Tilahun *et al*. 2012). In northern Namibia, Tuner (2000) also reported similar dimensions for *M. Subhylinus* mounds (Height 2.16 m and a volume of 3.41 m^3). *Macrotermes* mounds reach a maximum height of 3.8 m, a base area of 8.12 m^2 and a volume of 10.29 m^3 corresponding to a weight of 1281.28 kg.

Conclusion

Hundred and sixty-five (165) termite mounds were recorded over the entire CNF area. They include 139 active and 26 inactive termite mounds (**Table 1**). A total of 63 *Macrotermes* mounds, 56 *Cubitermes* mounds and 46 arboreal termite mounds were listed in all the CNF area. Among them, 76.2 % of *Macrotermes* and 80.36% of *Cubitermes* mounds were active (**Table 1**).

The spatial distribution maps of *Macrotermes*, *Cubitermes* and arboreal termite mounds were performed. These mapping would constitute an important database of the CNF; and they could serve as guide in locating termites' nests during studies visits for the students.

The density of the 3 different types of termite mounds grouped, was very high by sector (20.56 - 26.28 mounds / ha) and in all the CNF area (23.57 mounds / ha). The individual average density of *Macrotermes* mounds (8.99 mounds/ha), *Cubitermes* mounds (8.00 mounds/ha) and that of arboreal termite mounds (6.57 mounds/ha), with respective dispersion coefficient of 0.10, 0.08 and 0.07, showed no significant difference between them ($p > 0.05$). Therefore, they could be classified among the highest densities recorded to this date. The termite mounds were randomly distributed in the sectors (NW, SW, NE and SE), but also in the whole CNF area.

The epigeal termite mounds moved 297.42 tons of soil to build their nests. *Macrotermes* only, moved 297.03 tons (99.87%) of soil (**Table 3**) and *Cubitermes* used 0.39 tons to build their nests. *Macrotermes* mounds have occupied a base area of 373.3 m^2 and a volume of 264.99 and Cubitermes mounds covered a total base area of 2.08 m^2 with a volume of 0.42 m^3. Concerning the arboreal termites, they preferentially seem to colonize trees which perimeter was greater than 160 cm. Trees colonization by termites may be positively correlated to the diameter and thus, to the age of trees.

These results revealed a strong termite activity in the CNF, and seem to indicate that the diversity of termites is virtually restored in this preserved habitat.

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