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The role of ecosystem services of termites (*Macrotermes bellicosus*) in agriculture in Pendjari region (Benin)

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1. Introduction

There are more than 2500 known species of termites (Pearce & Waite, 1994; Kambhampati & Eggleton, 2000 cited by Ndiaye & al, 2004) in the world. There are at present about 2.290 different species in 258 genera (Korb 1997, Myles and Nutting 1988) well-known, which particularly occur in Africa, Australia and America, but also in most other countries with subtropical to tropical climate and some that have also spread into Mediterranean areas. Termite genera can be grouped according to whether they (1) are epigeal (above ground usually and three-dwelling) or hypogeal (under ground), (2) forage primarily for wood, litter or humus, (3) construct distinct nests, and (4) cultivate fungi. The subfamily Macrotermitinae is most important group of termites in the Old world Tropics, and in Africa they are widespread from Erythrea to South Africa (Wanyonyi 1980 cited by Allen 1990). The Macrotermitinea are hypogeal, feed on dead wood and litter, and cultivate fungi (Termitomyces spp.) in their nest. Macrotermes and Odontotermes spp. construct conspicuous mounds at the centres of distinctly bounded, territorially defended colonies (Collins 1982), whereas other species of Macrotermitinea such as Microtermes spp. frequently construct nests with dispersed chambers (Bouillon 1990 cited by Allen 1990). So Macrotermes are epigeal. Because they feed on litter and cultivate cellulose-decomposing fungi in their mounds, the Macrotermitinea are capable of processing large quantity of litter at up to 80% efficiency (Sands 1969, Wood 1978b cited by Allen 1990). Termites and termite mounds revealed to be multipurpose utilisation for African local communities (termites and mushrooms for human food and chicken feed), mounds for soil fertilisation, fungus and health care plants' nutrition, traditional ceremonies and construction). Termites are known to decompose straw in Burkina-Faso (Mando et al, 1999), to create nutrients for grasses in savannah (Jouquet & al, 2005), to improve soil water availability for plants (Konaté & al, 1999), to high C, N, Ca, P, moisture, microbial biomass (Ekundayo *et al.* 1997, Lavell 1984, Ndiaye *et al.* 2004, Smith *et al.* 1998), to increase root and shoot mass (Smith *et al.* 1998). Termite mounds immobilize a certain amount of soil carbon (0-1.3%) and nitrogen (0-0.15%) (Masanori and Tooru, 2004). Termites concentrate nutrients in their mounds, which may reenter soil through leaching (Rückamp et al, 2009).

The african termite *Macrotermes bellicosus* are particularly impressive. The species build remarkable mounds, which can reach an extent of up to 30 meters and a height of 7 meters. We distinguish the living termite mounds and the dead termite mounds. The living termite mounds are the mounds with red colour in which termite are alive. The dead termite mounds are mound with brown light colour without termite inside them. Recently, researches implemented by BIOTA West Africa teams observed the decreasing of termite mounds in the populated area of Pendjari region.

The present research aims at investigating the relationship between mound population and sorghum yield and the causalities of *Macrotermes bellicosus* mounds' decreasing.

2. Material and Methods

2.1 Site description and farming system

The research was conducted is the zone around the Pendjari Park located in the extreme North West of Benin. The park is located in the Sudanian Zone with a single wet season from April–May to October and one dry season from November until March. Average annual precipitation is 1000 mm, with 60 % falling between July and September. Temperature varies from around 21°C during the night up to around 40°C during the day. The annual mean varies from 25° to 28°C during the cooler period of the dry season and 30° to 33°C during the hot period of the dry season. Relative humidity varies between 17 and 99 %. Agriculture is the most important economic activity in the region. More than 90% of the population's main activity is agriculture. The major crops are sorghum/millet, maize, yam, rice, cotton. Sorghum and yam are grown without chemical fertilizers when cotton, maize and rice are grown with chemical fertilizers which are NPK (16-16-16) and urea (46% N). The quantities of fertilizer used depend on the soil structure, the level of fertility of the soil and the crop. But, usually on cotton, the mean values of quantities of fertilizers used are 150 kg of NPK and 50 kg of urea. On maize and rice, the mean values of quantities of fertilizers used are 100 kg of NPK and 50 kg of urea. But pesticide is used only on cotton. A mean value of 8 liters of pesticide is used per hectare of cotton.

2.2 Sampling

70 farmers are investigated in random in two villages around Pendjari Park (Batia and Dassari). The investigations in 2008 on their farming systems gave the following numbers of plots: 12 maize plots; 55 sorghum plots; 11rice plots; 42 yam plots; 20 bean plots and 9 cotton plots.

2.3 Data collection methods

Field data have been collected through group discussions, individual interviews and observations in cultivated area in the Pendjari region. The group discussion was based on an interview guide to collect data on farming systems at the village level. The individual interview addressed each farmer in the villages and aims at collecting data on the individual farming system, while participatory observations were done to collect data on termite mounds on farmers' crop land.

2.4 Data analysis methods

The methodology used is based on descriptive statistic and regression using SPSS 16.0.

To determine the influence of living termite mound on crop yield, a non-linear input-output regression model is built (equation 1). Derived from equation 2, we built a linear regression in which the dependent variable is the logarithm of sorghum yield and the independent variables are "the logarithm of the density of living mound", "the logarithm of family labour" and "the logarithm of sorghum acreage".

A "living termite mound" (red colour) is a mound with termites living inside while a "dead termite mound" (brown light colour) is a mound without termites.

$$y\_sorg = \beta_0 Fi\_sorg^{\beta 1} fL\_sorg^{\beta 2} acr\_sorg^{\beta 3} \quad (1)$$

y_sorg: sorghum yield in kg/ha (continuous variable)

Fi_sorg: quantity of nitrogen per hectare of sorghum (continuous variable)

fL_sorg: family labour used in human days (continuous variable)

acr_sorg: sorghum acreage in hectare (continuous variable)

β are the coefficients

$$Fi\_sorg=(a*NPK\_sorg)+(b*Urea\_sorg)+(\frac{(t * r)}{100} *lmpha\_sorg*10\text{-}6) \quad (2)$$

a: proportion of nitrogen in NPK =16%

b:proportion of nitrogen in Urea =46%

t: quantity of nitrogen leached from each living mound for each 100 mm of rainfall =250mg (Congdon,Holt and Hicks, 1993)

r : rainfall in Pendjari region =1000mm

NPK_sorg : quantity of NPK on sorghum in kg (continuous variable)

Urea_sorg: quantity of Urea on sorghum in kg (continuous variable)

lmpha: living mound per ha on sorghum (continuous variable)

$$Fi\_sorg=(0.16*NPK\_sorg +0.46*Urea\_sorg+0.0025*lmpha\_sorg) \quad (3)$$

In the study region, sorghum is grown without chemical fertilizer, so NPK_sorg=0 and Urea_sorg=0 and:

$$Fi\_sorg= 0.0025*lmpha\_sorg \quad (4)$$

To determine the influence of cotton farming on living termite mound, a linear regression model is used.

$$lm = \alpha_0 + \alpha_1 cotton + \alpha_2 yam + \alpha_3 acr \quad (5)$$

lm: living mound number (continuous variable)

cotton: cotton in crops in rotation on the plot these last 5 years (binary variable)

yam: yam in the crops in rotation on the plot these last 5 years (binary variable)

acr: crop acreage in ha (continuous variable)

α are the coefficients

In addition, a comparative analysis of the proportion of living termite mound and dead termite mound for cotton and no cotton farming systems is done through a chart.

3. Results and Discussion

3.1 Living termite mounds and sorghum yield

The results of linear regression of logarithm sorghum yield are shown in table 1.

Table 1: Results of regression logarithm quantity of nitrogen

Independent variables	Unstandardized coefficients			
	B	Standard Error	t	Sig.
(Constant)	5.886	1.133	5.195	0.000
Logarithm quantity of nitrogen (*lnFi_sorg*)	0.168**	0.128	1.305	0.100
Logarithm sorghum acreage (*lnacr_sorg*)	-0.404***	0.166	-2.431	0.020
Logarithm family labour (*lnfL_sorg*)	0.185	0.149	1.240	0.224
Dependent variable: logarithm sorghum yield(lny_sorg)				
N= 38			F=4.263	
Adj. R Square=0.209			Sig. F=0.012	

*: significant at 10%; **: significant at 10%; ***: significant at 5%; ****: significant at 0.1%

After calculation and transformation of equation (1), the result is:

$$y\_sorg = 131.556\ lmpha\_sorg^{0.168} fL\_sorg^{0.185} acr\_sorg^{-0.404} \qquad (6)$$

Equation (6) shows a positive coefficient (0.168) for density of living termite mound and reveals a positive influence of living termite mound on sorghum yield. The model is significant at 5% with Adj. R square equals to 20.9% and means that 79% of the variation in sorghum yield is still unexplained. May be ecological conditions (the rainfall, the soil structure) and the seed quality also account significantly for the yield variation.

According to family labour, the regression coefficient is not significant. Therefore, the regression results show a negative influence of acreage on sorghum yield (coefficient – 0.404 significant at 5%). That means that, an increase of the sorghum acreage generates a decrease of sorghum yield.

3.2 Cotton farming and living termite mound

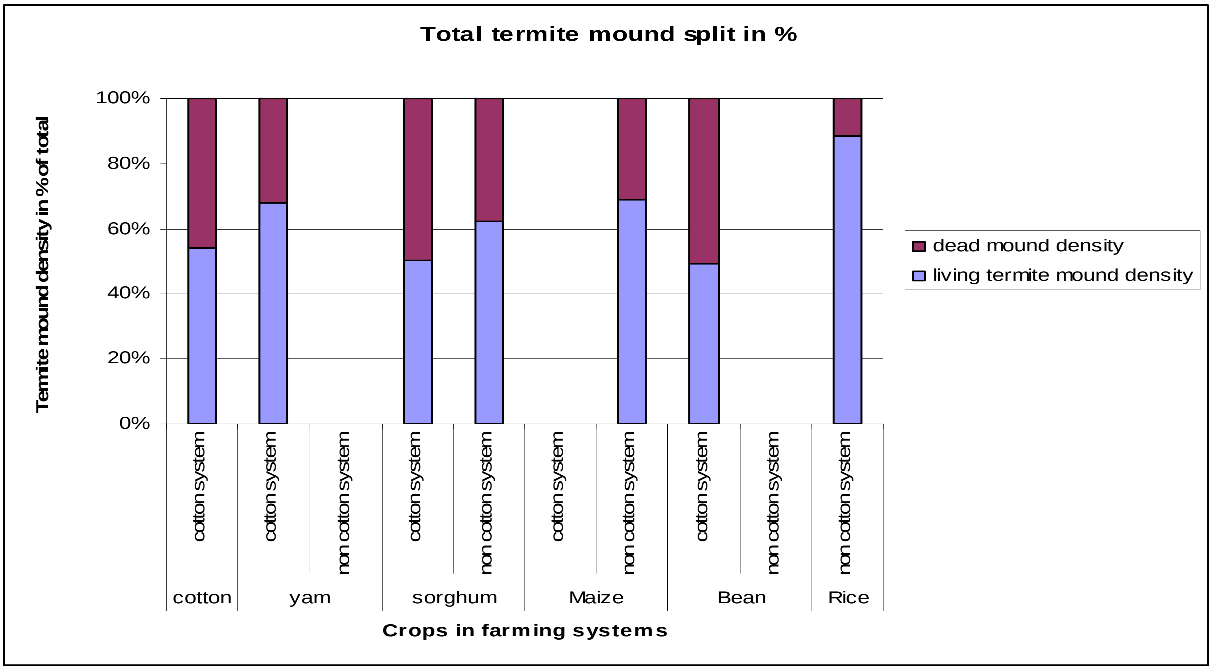

Fig. 1: Proportion of dead and living termite mounds for different farming systems. Shown are the results of the farming system analyses for each crop under cotton and no-cotton farming systems. Missing bars indicate that these analyses still need to be done.

Rice land without cotton hosted more living M. bellicosus termite mounds (90% of the total mounds or 1.8 living mounds/ha) than dead mounds (0.18) (Fig.1). Dead termite mounds had the highest percentage of mounds on beans (cotton system), sorghum (cotton system) and cotton crop land (Fig.1). Otherwise, the highest percentage of dead termite mound is registered in cotton farming system. This might suggest that termites are killed during cotton farming. Indeed, conventional cotton cropping leads to a high use of pesticide; the purpose is for fighting against insects damaging cotton. These pesticides seem to be also dangerous for termite by killing them and transforming living mound to dead mound.

Table 2: Results of regression living termite mound

Independent variables	Unstandardized coefficients			
	B	Standard Error	t	Sig.
(Constant)	1.065****	0.224	4.764	0.000
Cotton in rotation (cotton)	-0.499**	0.207	-2.409	0.017
Yam in rotation (yam)	0.335*	0.194	1.721	0.087
Crop acreage (acr_crop)	0.434****	0.092	4.706	0.000
Dependent variable: living mound(lm)				
N= 151			F=14.005	
Adj. R Square=0.206			Sig. F=0.000	

*: significant at 10%; **: significant at 10%; ***: significant at 5%; ****: significant at 0.1%

Linear regression of the dependent variable “living termite mounds’ population” with its independent variables (table 2) shows that cotton cropping has a negative influence on the density of living termite mounds (coefficient= -0.499). The model is significant at 0.1% (with Adj. R Square equal to 20.6%). This result confirms the one above comparing densities of living termite mound and dead termite mound in cotton and no-cotton farming systems.

At the opposite, yam cropping has a positive influence on the density of living termite mound (coefficient 0.335). Indeed yam cropping doesn’t need pesticide use so the crop is not a danger for termite (*Macrotermes bellicosus*) population.

Conclusions and Outlook

This study shows the relationship between termite mounds and crop yield through the positive influence of living termite mound on sorghum yield despite the termite damage on crops recorded in Southern Africa region by ARC. Indeed, according to the ARC researches results, maize frequently suffers serious damage by termites when cotton is a crop that is frequently damaged by termites, particularly in drier areas of the sub-continent. However, sorghum and millet generally show resistance to termite attack. This gives the idea to investigate same relationship between termite mounds and the other crops such as maize, and cotton. In the case of sorghum, farmers do not use chemical fertilizers and the relationship between termite mounds and sorghum yield was directly established. But in the case of maize and cotton, crops grown with chemical fertilizers, it seams to be possible to establish later the cumulative influence of the termite mound and chemical fertilizers (NPK and Urea) on crop yield. Then we can determine substitution effects between chemical fertilizers and living termite mound.

According to the causalities of mound decreasing, results show opposite effects of cotton (negative impact) and yam (positive impact) cropping on living termite mound. The negative role of cotton cropping on termite population is confirmed by the comparative analysis of density of living termite mound and dead termite mound in cotton and no-cotton system. Results show the increasing of dead termite mound for all crops in cotton system. Indeed, a dead termite mound is a living termite mound from which termites moved or are killed. Finally, cotton is a cause of termite disappearing.

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