African Journal of Ecology and Ecosystems Vol. 1 (2) pp. 029-036, November, 2014. Available online at www.Internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Agriculturists' ethno-biological learning of the termite issue in semi-parched Nakasongola

***John E. Milton, Bhasker V. Patel and Sudkir Mukwaya**

Department of Ecology and Evolutionary Biology, Faculty of life Sciences, Ndejje University, Ndejje Hill, Uganda.

Accepted 26 October, 2014

Infestation and destruction of rangeland vegetation by subterranean termites is a major constraint to livestock production in the rangelands of Uganda, particularly, in semi-arid Nakasongola. Ethno-ecological studies on termite dynamics are central to formulation of sustainable termite management strategies in such ecosystems. This study was thus conducted to investigate farmers' traditional ecological knowledge of the termite problem with the intent to build more coherent principles required in the development of appropriate termite management strategies. Focus group discussions and individual interviews were conducted to capture information on farmers' ethno-ecological knowledge of the factors enhancing termite damage on vegetation, temporal and spatial variability of damage and diversity of termite species in the Nakasongola ecosystem. Kruskal–Wallis test showed that there was a significant difference (X^2=451.5, P>0.0001) among farmers' ranking of factors responsible for the destructive behavior of termites on rangeland vegetation. Overgrazing and deforestation ware ranked significantly higher (X^2=156, P>0.0001) than other factors. Eight species were identified and the species belonged to one family (Termitidae) and two sub-families (Macrotermitinae and Termitinae). The study provided basic information about farmers' knowledge of the biology and ecology that could aid the development of sustainable and socially acceptable termite control strategies.

Key words: Grazing-lands, diversity, termite-damage.

INTRODUCTION

Devastation of rangeland vegetation by subterranean termites is a major constraint to animal production in the rangelands of Uganda, particularly, in semi-arid Nakasongola (Tenywa, 2008; NEMA, 2007; Sekamatte and Okwakol, 2007). Although termites attack and severely damage all components of rangeland vegetation, grasses are more susceptible to termite damage. Consequently, there is a remarkable decline in the grass component of the ecosystem, which translates into reduced feed availability, poor animal performance and increased susceptibility of livestock to feed scarcity induced mortalities. Termites have not only denuded the grass vegetation but have also frustrated several attempts to restore pasture vegetation on degraded bare surfaces by destroying reseeded pasture (Mugerwa et al., 2008; Mpairwe et al., 2008). Studies have noted that termites of the sub-family Macrotermitinae, the most dominant species in Nakasongola, collect up to 60% of the grass, woody material and annual leaf fall to construct fungus gardens in their nests (Lepage et al., 1993). Mitchell (2000) noted that populations of destructive termite species build up during dry seasons and increase over successive dry years to a level where they remove

*Corresponding author. E-mail:john.milton22@yahoo.com

substantial amounts of the standing grass biomass and all the litter, posing severe competition to livestock for feeds. During such times, the combined grazing effect of livestock and termites is to virtually denude considerable tracts of grassland, exposing soils to erosion by both wind and water.

Termites have also constructed numerous mounds (ranging between 80 to 350 mounds ha-1) on the grasslands which has considerably reduced the size of land available for livestock grazing. This has resulted in restriction of livestock in smaller areas leading to overgrazing and further driving the ecosystem to extreme deterioration (Nakasongola District State of Environment Report, 2004). The escalating number of mounds over time is also associated with proliferation of termite resistant shrubs which gradually become the major component of the woody vegetation. In relation to grazing management, termites have equally constrained interventions aimed at sustainable utilization of pasture through enormous destruction of wooden fencing poles that are normally utilized to partition ranches into grazing paddocks. Increased costs of livestock production due to frequent replacement of damaged poles and continuous purchase of expensive chemicals to treat fence poles are other associated termite-induced constraints to animal production.

The need to mitigate termite damage as well as termite-induced rangeland degradation cannot be overemphasized. This calls for dedicated efforts to develop ecologically sustainable as well as socially acceptable termite management strategies. However, development of such strategies requires an explicit understanding of the genesis of the termite problem in the area, temporal and spatial variability of termite damage and the various types of termites damaging the ecosystem (Cowie et al., 1989; Okwakol and Sekamatte, 2007). Such useful information could be constructively obtained from farmers faced with the problem. Sileshi et al. (2009) noted that communities have a clear understanding of termite associated problems and practice mitigation measures based on indigenous knowledge of termite ecology and taxonomy. Involving communities in the research cycle would enhance proper understanding of the problem situation as well as focusing research to the actual issues of interest to the concerned communities (Norton et al., 1999). Further, this would result in generation of interventions that are responsive to peoples' challenges which is critical to adoption of generated interventions (Chitere and Omolo, 1993). Berkes (2008) also noted that resource-poor farmers look for practices that best fit their biophysical, economic, and socio-cultural conditions. Ethno-ecological knowledge or traditional ecological knowledge (Okwakol and Sekamatte, 2007) is particularly important for formulation of sustainable termite management in Africa. Ethno-ecological knowledge is defined as " a cumulative body of knowledge, practices and beliefs evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings with one another and with their environment" (Berkes, 2008). Despite its importance in sustainable termite management, there continues to be little information on farmers' traditional ecological knowledge about termite ecology and management. This study was thus conceived to investigate farmers' traditional ecological knowledge of the termite problem with the intent to build more coherent principles required in the development of appropriate termite management strategies on grazing lands in semi-arid Nakasongola, Uganda.

MATERIALS AND METHODS

Description of the study area

Location, climate, soil and vegetation

The study was conducted in Nakasongola District (55°140 N, 32° 50 E) which forms part of Uganda's cattle corridor that stretches diagonally from the Uganda-Tanzania border in the South through the plains of Lake Kyoga Region, to Karamoja in the North Eastern part of the Country. Nakasongola District is located in the central region of Uganda on Bombo–Gulu Road, 114 Km north of capital Kampala.

The annual mean daily maximum temperature is 30°C. Rainfall ranges between 500 to 1000 mm per annum and there are two rain seasons (Nakasongola District State of Environment Report, 2004). The main rain season follows from March-April to June-July while the second rain season follows from August to October-November. A long dry season occurs from December to February while a short spell comes around July-August. The soils of Nakasongola are relatively homogeneous and strongly weathered with high sesquioxide content (Haplic Ferralsols) (FAO, 1998). The natural vegetation in Nakasongola is dominantly open savannah woodland with tall grasses. Major woody species in the area include:

Combretum terminalis, *Acacia brevispica*, *Canthium lactescens*, *Grevia mollis*, *Teclea nobilis* and *Vernonia brachycalyx*. The dominant grass species is *Hyparrhenia rufa* (Mugerwa, 2009).

Sampling procedure, sample size, data collection analysis

The study was conducted in three sub-counties (Nabiswera, Nakitoma and Wabinyonyi) which were purposively selected based on the severity of the termite problem on grazing lands. The District Livestock Production Department provided a sampling frame which contained all livestock keeping households from the selected sub-counties. After consultations with the district extension staff, forty households were then selected from each sub-county using the sampling frame following systematic random sampling procedures. Qualitative and quantitative data was obtained using semi-structured pre-tested questionnaires administered by way of one-on-one direct interviews. Focus group discussions (one per sub-county) were also held to corroborate the information gathered in direct interviews. The questionnaires and focus group discussions were intended to capture information such as:

(i) Genesis of the termite problem on grazing lands;
(ii) Severity of termite damage on grazing lands;
(iii) Factors favoring the destructive behavior of termites on rangeland vegetation;
(iv) Diversity of termite species on grazing lands;
(v) Spatial and temporal variability in termite damage levels.

Samples of all termite species identified by farmers were collected, preserved in 80% alcohol and transported to the laboratory for identification. In the laboratory, the specimens were identified to genus or species level following the standard determination keys by Webb (1961). The termite record developed by Sekamatte (2001) was also utilized to aid in identification of specimens. Samples of various grasses species reported by farmers were also collected and transferred to the laboratory for identification according to Skerman and Riveros (1990).

In characterizing farmers' perceptions of severity of termite damage on vegetation, a general linear model (GLM) assuming binomial error distribution of farmer responses was used. We hypothesized that a farmer's perception of severity of termite damage on vegetation is a function of farmer specific explanatory variables such as dominant termite species, dominant pasture species and level of termite infestation on grazing lands. Farmers' responses on the severity of termite damage on vegetation were used as dependent variables and the dominant termite species, dominant pasture species and level of termite infestation on farmers' grazing lands as explanatory variables. The data was then subjected to logistic regression following the requirements of probit model in XLSTAT (2011). Farmers' responses on factors favoring the destructive behavior of termites on vegetation was subjected to nonparametric statistics (Kruskal–Wallis one-way analysis of variance) to determine if differences existed between the different factors. Five factors were ranked by farmers using a scale of 1 to 5, with 5 being the most important factor enhancing termite damage and 1 the least important factor. The computed sums of ranks were compared using multiple pair wise comparisons to establish the significance differences among different factors (Dunn, 1964). XLSTAT (2011) was used to generate summary statistics (frequencies, percentages and means) for most variables and later tabulated. Also the information charactering the different termite species identified by farmers was summarized and tabulated.

RESULTS

Genesis of the termite problem

Majority of the farmers (60% of respondents) rated severity of termite damage on vegetation as high (Table 1). Farmers' perception of severity of termite damage was found to be a function of only one operator-specific variable (dominant termite species). The probability of a farmer perceiving severity of termite damage as high or low (only two responses for logistic) differed significantly (X2=57, DF=3, P<0.001; X2=52, DF=3, P<0.001; X2=56, DF=1, P<0.001) with the dominant termite species on farmers' grazing lands in Nakitoma, Nabiswera and Wabinyonyi sub-counties, respectively. Farmers perceived severity of termite damage as low on grazing lands where the dominant termite species were *Cubitermes* spp. (Termitidae: Termitinae). Most of the farmers (45%) indicated that the problem was first recognized as far as ten to twenty years back. It was also reported that severe termite damage on rangeland vegetation among sites was noticed at different times depending on the management techniques undertaken on various management units (ranches) but generally, the problem seem to have intensified 20 years ago.

Kruskal–Wallis test showed that there was a significant difference (X2=451.5, P>0.0001) among farmers' ranking of factors responsible for the destructive behavior of termites on rangeland vegetation. The significant differences in farmers' ranking of the factors were maintained among the various sub-counties (Table 2). Farmers' ranking of overgrazing and deforestation was significantly higher (X2=156, P>0.0001) than for the other factors. However, deforestation was ranked highest of the two factors in Wabinyonyi and Nabiswera sub-counties. The farmers reported that overstocking is a common phenomenon on most grazing lands due to the strong social attachment to large numbers of cattle. This has resulted into overgrazing followed by emergence of large bare surfaces that enhance extra-ordinarily high rates of erosion (NEMA, 2007). It was further observed that charcoal making is increasingly becoming the major source of livelihood to people whose grazing lands can no longer sustain livestock production or where climatic variations have made animal production a non-sustainable source of livelihood. The combined effect of the two (overstocking and charcoal making) has resulted in severe denudation of the herbaceous and woody components of the ecosystem, consequently driving the system to extreme degradation. The farmers' rating of overgrazing and deforestation as the major factor enhancing termite damage on rangeland vegetation was seen to be consistent with their rating of termite damage levels in sites with varying levels of primary production. Damage levels of pestiferous termite species on rangeland vegetation varied with primary productivity attributed to extent of anthropogenic disturbance among different sites. Majority of farmers (98%) rated termite damage levels as low in sites with high primary productivity (areas with dense herbaceous cover) while 99% of the respondents rated damage levels to range between high and very high in sites with low primary productivity (areas with sparse herbaceous cover). Reduced number of termite predators from the ecosystem and reduced use of fire as a rangeland management tool were ranked as the least important factors enhancing termite damage on vegetation in Wabinyonyi and Nabiswera sub-counties, while increased

Table 1. Damage levels and year of recognition of the termite problem.

Variable	Frequency	Percentage of respondents
Sex of respondents (N=120)		
Male	116	96.7
Female	4	3.3
Age group (N=120)		
20-29	2	1.7
30-39	14	11.7
40-49	65	54.2
50-59	17	14.2
>60	22	18.3
Main occupation (N=120)		
Livestock production	91	75.8
Crop production	27	22.5
Charcoal making	2	1.7
Major animal enterprise (N=120)		
Cattle	107	89.2
Goats	9	7.5
Pigs	2	1.7
Chicken	2	1.7
Severity of damage on vegetation (N=120)		
Low	40	33
Moderate	8	7
High	72	60
Year of recognition (N=118)		
1-10 years ago	34	28.8
11-20 years ago	53	44.9
21-30 years ago	24	20.3
31-40 years ago	7	5.9

occurrence of drought was ranked lowest in Nakitoma sub-county.

Diversity of termite species

Over 57% of farmers were aware of at least one termite species encountered on their grazing lands (Table 3). Farmers' identification of termites was based on a number of characteristics. These included: (i) presence of mounds, (ii) shape of mound, (iii) size of mound, (iv) presence or absence of vents on mounds, (v) size and color of alates, (vi) size, color and shape of soldiers and workers, (vii) flight period of alates, (viii) feed source and (ix) spatial distribution. A total of eight species were identified in the local language and some of these were markedly consistent with farmers' identification of termite types reported by Nyeko and Olubayo (2005). The findings reviled that Nsejere (*Macrotermes bellicosus*), Mpawu (*Macrotermes herus*) and Nkurukuku (*Cubitermes* spp. Termitidae: Termitinae) were the most common termite species and were reported by 97, 95 and 95% of the respondents respectively. Bulala (*Odontotermes* spp. 3) and Ntaike (*Odontotermes* spp. 2) were also noted as the least known termite species to farmers.

Spatial and temporal variability in termite damage

Generally, farmers considered damage levels to be

Table 2. Farmers' rankings of factors enhancing termite damage on rangeland vegetation.

Sub-county	Causes	Sum of ranks	(Chi-square, DF, p-value)
Wabinyonyi	Deforestation	6580[c]	X^2=156, 4, P>0.0001
	Overgrazing	6260[c]	
	Droughts	3060[b]	
	Reduced use of fire	2420[ab]	
	Reduced no. of predators	1780[a]	
Nakitoma	Deforestation	6260[c]	X^2=156, 4, P>0.0001
	Overgrazing	6580[c]	
	Droughts	1780[a]	
	Reduced use of fire	2420[ab]	
	Reduced no. of predators	3060[b]	
Nabiswera	Deforestation	6580[c]	X^2=156, 4, P>0.0001
	Overgrazing	6260[c]	
	Droughts	3060[b]	
	Reduced use of fire	2420[ab]	
	Reduced no. of predators	1780[a]	

Numbers followed by different letters indicate significant differences (Kruskal–Wallis multiple pair wise comparison test, $P < 0.05$).

Table 3. Farmers' identification of termite species.

Termite species	Main characteristics
"Mpawu" (*Macrotermes herus*), N=114, 95%	Builds big-sized mounds with no basal ventilation holes. The mounds are more rounded than those of *Macrotermes bellicosus*. The outer wall of the mounds is usually massive and is made of solid, highly compacted soils. In very hot areas, the mound bears a chimney of up to 5m. Mounds located in valleys are massive and are also covered with vegetation. Some mounds bear an overhung. Alates swarm between March and April usually before or after a rainfall. Alates are dark brown in color and medium-sized. The soldiers have yellowish heads and dark brown abdomens. The termite feeds on both fresh and dry materials, relatively tolerant to poorly drained soil and hence can be found in both lowlands and upper slopes.
"Ntunda" (*Macrotermes* spp. 1), N=68, 65%	Builds small mounds with vents. The mounds are usually constructed on the sides of the bigger mounds constructed by Mpawu and Nsejere termites. The soldiers have big yellowish heads similar to soldiers of "Mpawu". Alates have black abdomens with pale white wings and usually swarm in September during evening hours. The termite feeds on small quantities of soft dry materials. The termites can be evenly distributed as long as there are big mounds where they construct their small mounds.
Ntaike (*Odontotermes* spp. 2), N=62, 59%	Does not construct mounds. Alates swarm from bare ground in September usually around midday, especially during bright sunshine. Alates are easy to lure out when some noise is made around the exit points. The soldiers have white abdomens and workers have pale red heads. The termite consumes minute amounts of soft dry materials. Mostly abundant on up slopes.
"Nsejere" *Macrotermes bellicosus* (Smeathman) N=116, 97%	Builds the big mounds with/without basal ventilation holes. The shape of mounds ranges from roughly cone-like to irregular shapes. Some mounds bear tall, thin walled hollow structures (turrets) for ventilation. The turrets disappear on mounds located in relatively cooler areas. The occurrence basal shaft for ventilation is only common on mounds of this species. The size of mounds varies from place to place but mounds located in valleys are usually massive and are covered by vegetation. The mounds are usually leveled on top with no finger-like structures. Alates are dark brown in color and are largest of all types of alate. Alates swarm in May, especially on a rainy day. The soldiers have big dark brown heads with dark abdomens. The soldiers are very active, so defensive and take longer to desiccate and/or die when exposed to heavy direct sunshine as compared to other types. The termite feeds on both fresh and dry materials, tolerant to poorly drained soil and hence can be found in both lowlands and upper slopes.

Table 3. Contd.

"Bulala" (*Odontotermes* spp. 3) (N=60, 57%)	Does not build mounds but forms circular patches on ground with small vents in the middle of the patch. Alates are medium-sized and brown. Alates swarm in April at any time of the day. Workers are small with darker brown heads. Soldiers are medium-sized with brown heads and white abdomen.
"Kaseregeti" *Pseudacanthotermes militaris* (Hagen)N=113, 94%	Does not construct mounds. Workers are small in size, yellow in color and pointed. Alates medium sized and dark. Alates swarm from 1 to 4 pm between late October and December, depending on availability of rainfall. Two type of soldiers: medium sized with red heads and small dark ones. Feed on all sorts of dry and fresh organic materials. The species are common up-slope.
"Naakka" (*Odontotermes* spp. 1), N=100, 83%	Does not build mounds. The soldiers have big yellowish heads similar to soldiers of "Mpawu". In case of any danger to the colony, the soldiers produce a characteristic sound by rubbing their mandibles on dry materials to alert the rest of the colony. Alates are small in size, have black abdomens and white wings. Alates swarm in October and usually respond to rains of the previous night. The termite usually feeds on soft dry materials such as litter from forage leaves and stems. The alates are so delicious and highly cherished in Central Uganda (Buganda). Mostly abundant on up slopes.
"Nkulukuku" (*Cubitermes* spp.), N=114, 95%	Builds small mounds. The mounds are usually constructed using highly compacted soil making them very strong. Workers have swollen abdomens which are usually black in color. The abdomen of workers is usually full of soil. The soldiers have yellowish cylindrical heads. The termite usually feeds on soil. Alates are black in color. The workers are mostly cherished by predator insects and easily desiccate under direct sunshine. Mainly located in waterlogged areas in lowlands.

Table 4. Termite damage levels in different seasons.

Damage level	Frequency	Percentage of respondents
Damage level in first rainy season (March-May)		
Low	102	87.9
Moderate	14	12.1
Damage level in second rainy season (Sep-Nov)		
Low	97	83.6
Moderate	18	16.4
Damage level in first dry season (Jun-Aug)		
Low	29	25
Moderate	22	19
High	55	45.8
Very high	10	8.6
Damage level in second dry season (Dec-March)		
High	39	33.6
Very high	77	66.4

Level of termite damage was rated as low, moderate, high and very high.

higher in the dry months than in the wet ones (Table 4). The farmers also illustrated variations in damage levels among the different dry seasons and rated damage levels as very high and high for the second and first dry seasons respectively. No variations in damage levels were reported among the different rainy/wet seasons. However, farmers noted that once denuded patches are reseeded with pasture, termites can cause very high damage levels on pasture seedlings even in the wet seasons. This is in line with Mugerwa et al. (2008) who

Table 5. Damage levels on varying topography.

Topography	Frequency	Percentage of respondents
Lowland (N=108)		
Low	87	80.6
Moderate	21	19.4
Mid slope (N=108)		
Low	8	7.4
Moderate	79	73.1
High	21	19.4
Upper slope (N=108)		
High	36	33.3
Very high	72	66.7

Level of termite damage was rated as low, moderate, high and very high.

observed that termites damaged all pasture seedlings a few days post emergence in the wet season. Variations in levels of termite damage to rangeland vegetation among various topographic classifications were reported by majority of respondents (Table 5). Farmers reported the level of termite damage to rangeland vegetation as very high and low on upland and lowland respectively.

DISCUSSION

Genesis and prevalence of the termite problem

Restructuring of ranches in the early 1990's is blamed as the initial cause of severe deterioration of grazing lands in semi-arid Nakasongola (Nakasongola District State of Environment Report, 2004). The restructuring partitioned formally big ranches into smaller ones and subjected them to a constant stocking rate of one livestock unit per acre. This was followed by fencing off most of the established ranches in an attempt to control grazing and spread of livestock disease amongst animals on different ranches. Most semi-arid ecosystems are largely non-equilibrium systems, characterized by extreme change-ability and unpredictability of ecosystem dynamics, and require flexible land use strategies. The changes brought by the restructuring were inconformity to system behavior. Restrictions on livestock mobility due to fencing and subsequent subjection of the system to constant stocking rates lead to severe overgrazing and eventually degradation of the ecosystem. It is therefore not surprising that the farmers reported the termite problem to have intensified about ten to twenty years back shortly after the ranching restructuring exercise.

Increase in termite damage due to overgrazing and deforestation in rangeland ecosystems has also been reported by NEMA (2007), Mugerwa et al. (2008) and Wood (1991). Mugerwa et al. (2011, unpublished) also noted that the rate of consumption of herbaceous vegetation by termites was higher in highly disturbed than in less disturbed or intact systems. Overgrazing and deforestation are associated with a reduction in availability of feed resources to termites. Termites of the genus *Macrotermes*, the dominant species on the grazing lands in Nakasongola (Sekamatte, 2001) are predominantly litter feeders but can also forage on dung, wood and grass (Wood, 1991). Reduction in the availability of litter deprives the species of their major source of food and in turn the species resort to standing grass for nourishment. Mitchell (2000) also reported that when litter production is reduced due to a combination of droughts and overgrazing, generalist feeders (*Macrotermes* and *Odontotermes* species) resort to standing grass as the main source of nutrition. Further, denudation of rangeland vegetation attributable to overgrazing and deforestation is associated with destruction of nesting sites for termite predators. Sekamatte et al. (2003) also noted that denudation of basal vegetation resulted into loss of nests for termite predators particularly predator ants that nest in litter. Farmers also reported that predator mammals (such as Orycteropus afer) that tunnel into mounds to prey on all casts of termites have been lost from the ecosystem due to hunting. Consequently, the prey-predator relationship between termites and their predators has been disturbed leading to increased population of termites which is associated with severe damage to vegetation. The results of the study supports the general notion that as termite-infested grazing lands become degraded due to overgrazing and indiscriminant tree cutting, termites become more destructive to the ecosystem.

Diversity of termite species

The findings are also consistent with Sekamatte (2001) who noted that termites from two sub-families (Macrotermitinae and Termitinae) were common species on grazing lands of Nakasongola. Sekamatte (2001) further reported that members of the genera *Cubitermes* and *Macrotermes* were the most abundant termite species in Nakasongola rangelands while Nyeko and Olubayo (2005) observed that *Macrotermes bellicosus* and *Macrotermes hyalinus* dominated the termite assemblage structure in the rangelands of Tororo District in Uganda. Farmers demonstrated that use of simple features such as mound structure, mound building character, flight period of alates and size, shape and color of soldiers, workers and alates are effective simple means of identifying termites. Based on feed sources, farmers demonstrated ability to identify pestiferous termite species responsible for denudation of pasture. However, as earlier noted by Nyeko and Olubayo (2005), such community based taxonomic skills seemed limited to few farmers. Mechanisms are necessary to promote farmer-to-farmer dissemination of such important information. Further, local names of species need to be compiled so that researchers and extension workers can communicate effectively with farmers on particular species rather than using general names of pest groups such as termites, which comprise of over 2,600 described species (Kambhampati and Eggleton, 2000). The absence of some genera (such as Ancistrotermes and Microtermes) earlier reported by Sekamatte (2001) implied that the farmers' list of species was not exhaustive and necessitates more scientific investigations on termite assemblage structure in the area.

Spatial and temporal variability in termite damage

Farmers reported the level of termite damage on rangeland vegetation as most severe in the dry periods. A similar negative relationship between termite damage and rainfall was reported by farmers in Tororo District and Darfur Region of Uganda and Sudan, respectively (Nyeko and Olubayo, 2005; Pearce et al., 1995), and is consistent with the general notion that peak termite attack on biomass occurs during dry periods (Logan et al., 1990). Lepage (1982) noted that periods of intense foraging of Macrotermes species reflect the dynamics of colony energy requirements. In tropical environments where swarming occurs early in the rainy season, the highest food demand for nymphal maturation occurs during the subsequent dry season, and this suggests an adjustment in foraging to the needs of the colony (Lepage and Darlington, 2000). These findings suggest that grazing management techniques that enhance production of enormous amounts of biomass during wet periods and subsequent accumulation of litter during dry periods would help to meet the high food demands in dry periods. This would in turn reduce termite damage to pasture. Resting termite infested areas in the wet season would allow accumulation of litter which will nourish the termites to deter them from pasture. No wonder, termite damage is less severe in areas rested from grazing for about one year (Mugerwa, 2009).

The variability in levels of termite damage among various topographic classifications was attributed to the differing ecological conditions (such as vegetation and soil characteristics, fauna and flora biodiversity) that resulted into varying distributions and abundance of termite species (Holt and Greenslade, 1979). Holt and Greenslade (1979) further noted that differences in distribution and abundance of mound building fauna from site to site were related to differences in the drainage capacity of the soil. In this regard, farmers noted that the abundance of pestiferous species was remarkably higher on the uplands than lowlands. Lowlands were mainly associated with *Cubitermes* spp. (Termitidae: Termitinae), which are largely soil feeders and cause insignificant damage to pasture. Malaret and Ngoru (1989) also noted that farmers in Machakos District of Kenya associated

Macrotermes and *Odontotermes* spp. (Termitidae: Macrotermitinae) with sparse vegetation more than dense vegetation while Nyeko and Olubayo (2005) noted that M. bellicosus was rated as most abundant in the upland. The findings imply that uplands need to be grazed lightly or rested from grazing for some time to allow sufficient production of biomass and accumulation of litter. This will provide sufficient food resources to termites and consequently deter them from damaging pasture. During such periods of rest or light grazing on uplands, heavy grazing may be done down slope.

Conclusion

It was evident in the study that farmers are aware of the genesis of the termite problem. Although a number of factors were fronted to explain surges in termite damage on vegetation, majority of farmers largely attributed the termite problem to ecosystem deterioration associated with overgrazing and deforestation. Termite damage was particularly high during dry periods when ecosystems are low in vegetation cover and litter. Sustainable termite management strategies on grazing lands should not only target termites, but also focus on ensuring ecological integrity as well as proper functioning of the ecosystem. Grazing management strategies that enhance surface cover and litter accumulation into the dry period will help meet termite food demands and thus mitigate ecosystem damage. It is also necessary to conduct scientific experimental investigations to establish degradation thresholds beyond which termites become destructive to rangeland vegetation. Such information would assist to guide management decisions in an attempt to maintain an ecologically favorable equilibrium between termites and other ecosystem components. The study has also provided some basic information about farmers' knowledge of the biology and ecology of termites that could aid the development and promotion of sustainable and socially acceptable termite control measures on grazing lands. Farmers demonstrated a deep knowledge of the diversity, pest status and the spatial and temporal distribution of termites. Based on community-based taxonomic skills, farmers identified eight termite species in their local names, which were remarkably consistent with scientific identifications. Such indigenous scientific taxonomic knowledge need to be documented, promoted and where possible improved to facilitate communication between farmers, extension staff and scientists on specific termite species.

ACKNOWLEDGEMENTS

The study was funded by the National Livestock Resources Research Institute (NaLIRRI) in Uganda.

REFERENCES

Berkes F (2008). Sacred ecology: traditional ecological knowledge and resources management. Second edition. Routledge, New York, New York, USA.

Chitere PO, Omolo AB (1993). Farmers' indigenous knowledge of crop pests and their damage in western Kenya. Inter. J. Pest Manage., 39: 126-132.

Cowie RH, Logan JWM, Wood TG (1989). Termite (Isoptera) damage and control in tropical forestry with special reference to Africa and Indo- Malaysia: A review, Bull. Entomol. Res., 79: 173-184.

Dunn OJ (1964). Multiple comparisons using rank sums. Technometrics, 6(3): 241-252.

FAO (1998). The digital soil and terrain database of north eastern Africa. FAO, Rome.

Holt JA, Greenslade PJM (1979). Ants (Hymenoptera: Formicidae) in mounds of Armitermes laurensis. J. Austr. Entomol. Soc., 18: 349-361.

Kambhampati S, Eggleton P (2000). Taxonomy and phylogeny of termites, in Abe T, Bignell DE, Higashi M (eds) Population dynamics of termites. Termites: Evolution, Sociality, Symbiosis, Ecology. Dordrecht, The Netherlands: Kluwer Academic Publishers, pp. 1-22.

Lepage M, Darlington JPEC (2000). In Abe T, Bignell DE, Higashi M (eds) 'Population dynamics of termites', Termites: Evolution, Sociality, Symbiosis, Ecology. Dordrecht, The Netherlands: Kluwer Academic Publishers, pp. 333-361.

Lepage M, Abbadie L, Mariotti A (1993). Food habits of sympatric termite species (Isoptera, Macrotermitinae) as determined by stable carbon isotope analysis in a Guinean savanna (Lamto, Cote d'Ivoire). J. Trop. Ecol., 9: 303-311.

Lepage M (1982). 'Foraging of Macrotermes species (Isoptera: Macrotermitinae) in the tropics', in Jaisson P (ed.) Social Insects in the Tropics. Paris: Université de Paris-Nord, 2: 206-218

Logan JWM, Cowie RH, Wood TG (1990). Termites (Isoptera) control in agriculture and forestry by non-chemical methods: A review. Bull. Entomol. Res., 80(3): 309-330.

Malaret L, Ngoru FN (1989). Ethnoecology: A tool for community based pest management farmer knowledge of termites in Machakos district, Kenya. Sociobiology, 15: 197-211.

Mitchell JD (2002). Termites as pests of crops, forestry, rangeland and structures in southern Africa and their control. Sociobiology, 40: 47-69.

Mpairwe D, Mugerwa S, Mutetikka D, Kiwuwa G, Zziwa E, Owoyesigire B, Peden D (2008). Options to improve livestock-water productivity (LWP) in the cattle corridor within the White Nile sub-basin in Uganda. Paper presented in the "Challenge Programme on Water and Food" workshop held between 10th- 15th November 2008, Addis Ababa, Ethiopia.

Mugerwa S (2009). Effect of reseeding and cattle manure application on pasture and livestock water productivity on degraded rangelands of Nakasongola. MSc thesis. Kampala: Makerere University.

Mugerwa S, Mpairwe D, Mutetikka D, Kiwuwa G, Zziwa E, Owoyesigire B, Peden D (2008). Effect of cattle manure and reseeding on pasture productivity. Paper presented in the Challenge Programme on Water and Food" workshop held between 10th- 15th November 2008, Addis Ababa, Ethiopia.

Nakasongola District State of Environment Report (2004). Nakasongola District Council,http://www.nemaug.org.

National Environment Management Authority (2007). State of the Environment Report for Uganda. NEMA, Kampala, p. 357.

Norton GW, Rajotte EG, Gapud V (1999). Participatory research in integrated pest management: Lessons from the IPM CRSP. Agriculture and Human Values, 16(4): 431-439.

Nyeko P, Olubayo FM (2005). Participatory assessment of farmers' experiences of termite problems in agroforestry in Tororo district, Uganda. Agricultural Research and Extension Network Paper, Overseas Development Institute, London, UK, p. 143.

Okwakol MJN, Sekamatte MB (2007). Soil macrofauna research in ecosystems in Uganda. Afr. J. Ecol., 45(Suppl. 2): 2-8.

Pearce MJ, Logan JWM, Tiben A (1995). Termites (Isoptera) from the Darfur region of the Sudan with comments on their pest status. J. Arid Environ., 30: 197-206.

Sekamatte MB, Okwakol MJN (2007). The present knowledge on soil pests and pathogens in Uganda. Afric. J. Ecol., (Supplement) 45: 9-19.

Sekamatte MB, Ogenga-Latigo M, Russell-Smith A (2003). Effect of maize–legume intercrops on termite damage to maize, activity of predatory ants and maize yield in Uganda. Crop Prot., 22: 87-93.

Sekamatte MB (2001). Termite situation on crops and rangelands in Nakasongola District. A report submitted to the Environmental Protection and Economic Development (EPED) project, Kampala, Uganda.

Sileshi GW, Nyeko P, Nkunika POY, Sekematte BM, Akinnifesi FK, Ajayi OC (2009). Integrating ethno-ecological and scientific knowledge of termites for sustainable termite management and human welfare in Africa. Ecol. Soc., 1: 41-48.

Tenywa G (2008). Thousands homeless as termites turn Nakasongola into a desert. The New Vision, 24 June 2008. [online] URL: http://www.newvision.co.ug/D/9/36/635585?highlight&q=termite.

Webb GC (1961). Keys to the Genera of the African Termites. Ibadan University Press, Ibadan, Nigeria.

Wood GT (1991). Termites in Ethiopia: The Environmental Impact of Their Damage and Resultant Control Measures. Ambio., 20: 3-4.

XLSTAT (2011): http://www.addinsoft.com.