Effectiveness of Eco-Friendly Management Practices in the Management of Termite Infestation in Semi-Arid Areas of Uganda: A Case Study of Nakasongola District

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ABSTRACT

The problem of termite infestations is an alarming issue that negatively impacts agriculture and rural livelihoods in semi-arid areas of Uganda, with Nakasongola District among the areas severely affected within the cattle corridor. Although considerable damage, accounting for about 30% crop destruction worth UGX 200 million per year, has been reported in terms of termite infestation, the current measures used for the prevention and control of termites have been largely chemically-based approaches that have proven to be ineffective. In this research paper, we examine the effectiveness of five eco-friendly practices: cultural, physical, biological, botanical, and integrated pest management in the management of termite infestation in semi-arid areas of Nakasongola District, Uganda. A cross-sectional survey design combining both quantitative and qualitative methods was used. The data were collected from 264 respondents using structured questionnaires and from 16 key informant interviews. The analysis used descriptive statistics, Pearson correlation, and multiple regression in SPSS version 23. Results revealed that cultural control practices have the strongest and most significant influence on reducing termite infestations ($\beta = 0.356$, $p < 0.01$), followed by the botanical control practices ($\beta = -0.220$, $p < 0.01$) when practiced. Biological control practices have a significant positive relationship ($\beta = 0.245$, $p < 0.01$), despite the difficulties faced during implementation under semi-arid conditions, followed by integrated pest management with a weak positive effect ($\beta = 0.124$, $p < 0.05$). The physical control practices had no significant influence ($\beta = -0.015$, $p = 0.832$). The five control practices, taken together, accounted for 32.4% of termite infestation management ($R^2 = 0.324$). The study concludes that cultural and botanical methods are the most viable eco-friendly approaches for managing termite infestation in semi-arid areas, while physical controls are ineffective as standalone interventions. Biological and integrated pest management methods require improved training, timing, and monitoring to deliver intended outcomes.

Keywords: cultural control practices; biological control practices; botanical control practices; integrated pest management; termite infestation

INTRODUCTION

Termite infestation is one of the worst yet least dealt with ecological and economic threats in semi-arid agricultural areas around the world. Termite insects, mainly subterranean and mound-building (Macrotermes spp., Odontotermes spp. and Microtermes spp.), play important ecological roles in soil ventilation and nutrient recycling in their natural habitat; however, in numbers beyond ecological balance, these pests have proven to cause immense harm to crops, woodwork, and rural infrastructure (Loko, 2017). Worldwide, termite infestation is said to be costing over USD 40 billion each year, mostly for the agricultural, forestry, and rural infrastructural industries of developing nations (Rust & Su, 2012). The issue has been further made worse by global warming, desertification, deforestation, and an increase in termite populations in Arid and Semi-Arid Lands (ASALs), which make up over 40% of Africa's land mass. This climate-driven expansion is not merely speculative: a recent global biogeochemical analysis estimated that termite activity, and the associated methane emissions and decomposition rates, has been increasing steadily since the early 1900s and is projected to keep rising through 2100 under all modelled climate and land-use scenarios, with the largest gains expected precisely in the hot, increasingly arid tropical and subtropical zones where Nakasongola is located (Ito, 2023).

Termites account for 25–30% damage in crops such as millet and sorghum in East and West African countries (Logan, 1990). In Kenya, the Baringo and Makueni Counties experience up to 50% yield reduction annually due to termite attacks (Mulatya, 2021), whereas in Ethiopia, 67% of small-scale farmers were found to have suffered from termite damage in their crops and fences (Yonas, 2015). More recent Ugandan evidence confirms that termite pressure on farm-level assets has not eased: Mwanja et al. (2024), testing preservative treatments for bamboo, a crop increasingly promoted for agroforestry and erosion control in Uganda, found that untreated bamboo suffered severe termite attack within months, underscoring the continuing vulnerability of farm woodwork and tree-based livelihoods to termites even as new crops and agroforestry interventions are introduced. In spite of all these problems, pest control practices in sub-Saharan Africa largely rely on chemical pesticides, such as chlorpyrifos, cypermethrin, and fipronil, whose negative effects on the environment and human beings are numerous (Verma et al., 2009). They degrade the soil, affect non-target species, and create an unstable ecosystem. Resistance of termites to chemical insecticides adds to the problem.

In Uganda, termites tend to cause serious problems in the cattle corridor between the southwestern and northeastern parts of Uganda. According to Sekamatte et al. (2003), there was notable reduction in maize yields in Luweero District resulting from termite attacks on crop stalks and roots in the dry season, whereas Mugerwa et al. (2011) showed that more than 60 percent of farmers in Soroti and Tororo districts have encountered yearly termite attacks on their crops and tree seedlings, an act that has served to discourage the practice of agroforestry among farmers living in such areas that require vegetation rehabilitation efforts. In the cattle corridor, Nakasongola District is among the most seriously affected districts. It receives annual rainfall of 500–1000 mm, sandy-loam soils that are conducive to termites, and dry periods coupled with termite mounds. According to local government reports in Nakasongola District (2021) and NARO's community survey (2022), termite attacks constitute one of the top three factors causing low agricultural productivity within the district, where there are yearly losses of up to UGX 200 million and more than 30% destruction of new tree plantations in areas like Wabinyonyi and Lwampanga Sub-counties. Management efforts against termites in the district are mainly focused on digging termite mounds, kerosene treatment, and outdated insecticide formulations that are detrimental to soil fertility.

Globally, sustainable practices provide effective and affordable solutions. Bioformulations like neem (Azadirachta indica), Tephrosia vogelii, and chilli have been found to effectively curb termite infestations without adversely impacting other forms of life (Akhtar & Isman, 2018). Neem bioformulations were found to effectively reduce termite activity in the absence of any harm to the soil microbial communities by Khan and Ahmad (2020). Similarly, Abdou et al. (2017) were successful in implementing chilli and cow urine formulations in community forestry programs in Niger. This evidence base has continued to grow regionally: in a 2024 study from Burundi, a country sharing Uganda's cattle-corridor agro-ecology, Kwizera and Gençer found that water-soaked Euphorbia tirucalli and Tephrosia vogelii extracts repelled subterranean termites for up to 31 days, while also documenting how expanding settlements and croplands are steadily encroaching on the pastures that once served as stable termite habitats, a land-use pressure with direct relevance to Nakasongola's own overgrazed and deforested landscape. The National Environment Management Authority of Uganda (NEMA, 2022) has called for the adoption of climate-smart and ecological pest management strategies. However, the lack of locally verified scientific evidence about eco-friendly pest control methods is a major impediment to this process.

This study addresses this critical evidence gap by evaluating the effectiveness of five eco-friendly management practices: cultural control practices, physical control practices, biological control practices, botanical control practices, and integrated pest management, in the management of termite infestation in semi-arid areas of Nakasongola District, Uganda. Specifically, the study sought to: (1) examine the role of cultural controls; (2) establish the effect of physical controls; (3) assess the effect of biological controls; (4) determine the effect of botanical controls; and (5) evaluate the effect of integrated pest management on termite infestation management in semi-arid areas of Uganda.

LITERATURE REVIEW

Theoretical Framework

The study is hinged on two complementary theories. The Integrated Pest Management (IPM) Theory, which was first developed by Smith and Van den Bosch in 1967 and later expanded by Kogan in 1998, provides the scientific basis for assessing eco-friendly approaches to termite control. IPM emphasizes the importance of decision-making that integrates biological, cultural, mechanical and least harmful methods, emphasizing the need for preventive actions instead of the use of chemical methods. The focus of IPM theory is on safety, economic considerations, and relevance to specific environments, making it especially appropriate in semi-arid farming environments. In addition to this, Rogers' (2003) Diffusion of Innovations Theory is another framework for analyzing the reasons behind the adoption of some eco-friendly practices while ignoring other practices. According to Rogers, there are five factors affecting the adoption of innovation: relative advantage, compatibility, complexity, trialability, and observability, which influence how farmers in Nakasongola adopt termite management techniques.

Cultural Control Practices

Cultural control practices such as crop rotation, intercropping, field sanitation, soil management, and timing of planting form the oldest and most extensively studied type of environmentally friendly termite management. Sekamatte et al. (2003) reported an enhancement in predatory ant nests by maize-soybean intercropping in Uganda that led to a reduction in termite foraging by employing two strategies: an increase in ground moisture, making favorable habitats for ants and provision of alternative sources of prey from fallen leaves of legumes, diverting termites' attention away from crops. An increase in mulch is positively correlated with predator abundance but negatively correlated with termite damage (Sekamatte, 2001b; Girma et al., 2009). Cultural perturbations like deforestation, overgrazing, and burning affect termite microhabitats, leading to changes in community composition towards destructive species (Mugerwa et al., 2011; Dawes-Gromadzki, 2007). The degraded habitats in Nakasongola due to grazing and logging activities make cultural restoration measures significant not only as a pest management technique but also as an ecosystem recovery measure.

Physical Control Practices

Physical control methods like mound excavation, heat treatment, water flooding, physical barriers, and termite baiting systems are used. Mound excavation, common in sub-Saharan Africa, just offers brief relief because certain termite genera can replace their queens (Cubitermes, Macrotermes, and Nasutitermes) (Harris, 1971; Logan, 1990). Heat treatment isn't much help either since it doesn't reach deep royal cells, leaving reproduction abilities undamaged (Mugerwa, 2011; Nyeko & Olubayo, 2005). In addition, Acda (2018) notes that Nakasongola's soil allows termites to easily dig new tunnels around barriers. Bait systems do work to suppress colonies through their sharing behaviour (trophallaxis), yet the pricey setups aren't practical for cash-strapped smallholders (Su, 1994). Overall, the literature shows that physical controls alone barely make a dent, especially against non-mound-forming species like Odontotermes and Microtermes (Sileshi et al., 2009).

Biological Control Practices

Biological control uses natural enemies like entomopathogenic fungi, nematodes, and predatory ants to curb termite populations. The fungus Metarhizium anisopliae has worked best in East Africa. In 2001, Maniania and crew found that applying M. anisopliae when planting lowered termite damage on maize. Sekamatte checked this in Uganda with similar success—one isolate cut termite damage and raised maize yield by 70%, matching chemical lindane but without the downsides (Sekamatte, 2000). This fungus kills termites on contact or repels them, protecting whole colonies (Milner & Staples, 1996). Scientists can also attract predator ants using fish meal and molasses, which cuts termite damage by boosting Pheidole and Lepisiota ant numbers (Sekamatte, 2001a). Yet, issues arise in semi-arid zones because of overgrazing. With fewer plants, there's less food for the good bugs that eat termites (Raiesi & Asadi, 2006). Also, what works in labs with nematodes and bacteria often fails outside since it's tough to infect entire termite colonies in the real world (Chouvenc, 2008). More recently, attention has shifted toward the termite gut microbiome itself as a biocontrol resource: Enagbonma et al. (2025)

showed that gut-associated Streptomyces and other symbiotic bacteria isolated from termites possess antifungal and antimicrobial compounds with biotechnological potential, opening a parallel avenue in which termite-derived microorganisms, rather than only external entomopathogens, could eventually be harnessed for sustainable pest and pathogen management. Similarly, emerging RNA interference (RNAi)-based biopesticides, which silence essential termite genes through sequence-specific double-stranded RNA, have advanced rapidly since the first regulatory approval of a sprayable RNAi product in 2023 and are increasingly discussed as a next-generation, target-specific alternative to broad-spectrum chemical termiticides (Zhao et al., 2026).

Botanical Control Practices

Botanical pesticides from plants that naturally fight bugs provide eco-friendly options compared to synthetic chemicals. Neem, or Azadirachta indica, gets the most attention because of its key ingredient, azadirachtin. This compound messes up the insects' moulting hormone production, leaving young termites unable to fully shed their skins and making adult female termites sterile. It also stops the bugs from wanting to eat (Isman, 2006). People in sub-Saharan Africa use other plant-based bug fighters too, such as euphorbia, tephrosia, and tithonia, along with tobacco, red pepper, and wood ash (Kiwuso, 2004; Nyeko & Olubayo, 2005; Mugerwa, 2011; Namutebi, 2015). Yet, these botanical pest controls come with issues. For one, they break down fast when exposed to UV light, which means they don't last long outdoors. Plus, the useful compounds in plants aren't always at strong enough levels to actually work against the pests (Isman, 2006; Logan, 1990). Termite reactions vary, too; something that works on one might not affect another. All this shows that we need better standardization in how we apply and distribute these natural pesticides, but that information rarely reaches the farmers in Nakasongola.

Integrated Pest Management

Integrated Pest Management combines two or more control methods within an ecological framework to protect farmlands and keep farmers productive (FAO, 2017). Su and Scheffrahn (1998) say IPM requires knowledge of pest biology, their environment, and when action is needed based on economic factors. In a 2011 study in Uganda, just one-third of farmers had received pesticide training before the program started (Oesterlund, 2014). After the intervention, the use of harmful pesticides dropped, along with health risks. The FAO promotes IPM for smallholder farmers in sub-Saharan Africa, but there are challenges. In Uganda, implementing IPM at a community level is tough because of low awareness and weak support systems. Many farmers still react without prevention plans, which this study aims to change. Elsewhere in West Africa, Adomako et al. (2024) demonstrated that climate-smart IPM (CS-IPM) hubs combining biofertilizers, biopesticides, and farmer-to-farmer knowledge platforms improved smallholder resilience to climate-induced pests in Ghana's yam and sweetpotato value chains, illustrating a structured model of community-level IPM delivery that the more reactive, monitoring-poor system observed in Nakasongola has yet to adopt. On the technological side, advances in unmanned aerial vehicle (UAV) and remote-sensing-based mound detection (Sandino et al., 2017) point toward an emerging capability for low-cost, large-area infestation monitoring that could eventually support the kind of systematic record-keeping and data-driven strategy review that IPM frameworks require but that farmers in this study reported as largely absent.

METHODOLOGY

Study Area

The study was conducted in Nakasongola District, central Uganda's semi-arid cattle corridor region. Spanning 3,424 km², it has two rainy seasons: March to July and August to November, with temperatures between 25–35°C. Rain totals 500–1000 mm yearly, and the area is covered in open deciduous woodland. But sandy-loam soil, long dry spells, and overgrazing, coupled with making lots of charcoal, sped up land degradation. This created perfect spots for termites. Researchers gathered data from Nabiswera, Lwabiyata, and Kalungi, three sub-counties in the district.

Research Design

A cross-sectional survey design was employed, combining quantitative and qualitative methods. The quantitative component used structured, closed-ended questionnaires to generate descriptive and inferential statistics, while the qualitative component used key informant interviews to provide contextual depth and corroborate quantitative findings. This mixed-methods approach permitted both statistical generalizability across the farmer population and a nuanced understanding of local termite management realities.

Population, Sample Size, and Sampling

The study population consisted of 10,000 residents in Nakasongola District. Using Krejcie and Morgan's (1970) table, they picked a sample of 373 people. Simple random sampling got 357 farmers from household registers in the three sub-counties. Additionally, 16 key informants were chosen through purposive sampling. These included five District Agriculture staff, three local leaders (LC I and LC II), and eight opinion leaders. They were picked based on their know-how and influence in the community when it came to termite management, as summarised in Table 1.

Table 1: Study Population, Sample Size, and Sampling Techniques

Study Population	Population	Sample Size	Sampling Technique
District Agriculture Staff	5	5	Purposive
Political Leaders (LC I & II)	3	3	Purposive
Opinion Leaders	8	8	Purposive
Households/Farmers	5,000	357	Simple Random
Total	5,016	373	—

Source: Primary Data (2026)

Data Collection Instruments

Two instruments were used in the study. Firstly, there was a structured questionnaire given to farmer respondents. It had 10 five-point Likert-scale items per independent variable, totaling 50 items, and 15 items for the dependent variable. Respondents rated the items from 1 (Strongly Disagree) to 5 (Strongly Agree), and mean scores ≥ 3.0 showed agreement. Secondly, a semi-structured interview guide was used with 16 key informants. This collected in-depth qualitative data about local termite management, indigenous knowledge, and institutional challenges.

Validity and Reliability

The Content Validity Index (CVI), which is calculated by dividing items rated as relevant by the total number of items, was used for content validity assessment. Every variable hit CVI values above 0.714, the required threshold. Botanical control practices had the lowest at 0.714, while physical controls topped out at 0.909, showing good instrument coverage, as shown in Table 2. To check internal consistency reliability, we ran a pilot test on 30 randomly picked folks and used SPSS version 23 to get Cronbach's alpha coefficients. All variables surpassed the necessary minimum of 0.7, based on Mugenda and Mugenda (2003), with scores from 0.840 to 0.935, confirming strong reliability, as shown in Table 3.

Table 2: Content Validity Index (CVI) Results

Variable	Total Items	Valid Items	CVI
Cultural Control Practices	12	10	0.833
Physical Control Practices	11	10	0.909

Biological Control Practices	13	10	0.769
Botanical Control Practices	14	10	0.714
Integrated Pest Management	12	10	0.833
Termite Infestation	17	15	0.882

Source: Primary Data (2026)

Table 3: Cronbach's Alpha Reliability Coefficients

Variable	No. of Items	Cronbach's Alpha
Cultural Control Practices	10	0.873
Physical Control Practices	10	0.922
Biological Control Practices	10	0.891
Botanical Control Practices	10	0.935
Integrated Pest Management	10	0.871
Termite Infestation	15	0.840

Source: Primary Data (2026)

Data Analysis

Quantitative data were entered and analyzed in SPSS version 23 using both descriptive statistics (mean and standard deviations) to characterize farmer awareness and adoption levels; Pearson correlation coefficients to determine the direction and strength of bivariate relationships; and multiple linear regression analysis to establish the independent predictive contribution of each practice while controlling for the simultaneous effects of the remaining four. Qualitative data from key informant interviews were analyzed thematically, with representative quotations used to contextualize and corroborate quantitative findings.

RESULTS

Respondent Profile

Out of 373 questionnaires handed out, 264 were returned and analyzed, representing a 70.8% response rate. More males responded than females—53.4% and 46.6%, respectively. The biggest age group was 18–30 years old at 35.2%, then came 41–50 years old with 22.7%, and 31–40 years old with 22.3%. Most respondents had a certificate-level education (58.7%). Crucially, over half (52.7%) had farmed for more than 10 years, showing that the sample had extensive practical experience and contextual knowledge of termite infestation dynamics in Nakasongola District.

Cultural Control Practices

Respondents mostly agreed with the cultural control practices listed, with scores from 3.17 to 4.01, as shown in Table 4. Crop rotation for pest control (M = 4.01, SD = 1.028) and managing soil well to cut down on chemicals (M = 3.91, SD = 1.060) got the highest ratings. Adding legumes to rotations did well too (M = 3.89, SD = 1.048), matching Girma et al.'s (2009) findings. That study showed fewer pests when legumes were integrated into crops. The lowest score went to mulching and cover cropping (M = 3.17, SD = 1.482). This implies that while crop rotation is commonly done, soil covering methods aren't used as much. Overall, though, high scores show that Nakasongola farmers have a strong grasp of and commitment to these farming techniques.

Pearson correlation showed a moderate, statistically significant positive link between cultural control practices and managing termite infestations ($r = 0.467$, $p < 0.01$). Also, multiple regression highlighted that among the five variables, cultural practices were the top predictor for reducing termite infestations ($B = -0.254$, $\beta = 0.356$,

$p < 0.01$). This, combined with the highest descriptive scores and the strongest Beta coefficient, proves that cultural practices are both the most effective and the most widely used eco-friendly approach in Nakasongola.

Table 4: Descriptive Statistics of Cultural Control Practices (n = 264)

Statement	Mean	SD
Crop rotation is a reliable cultural method for managing crop pests	4.01	1.028
Practicing good soil management reduces the need for chemical termiticides	3.91	1.060
Including legumes in crop rotation improves soil health and manages termites	3.89	1.048
I practice crop rotation regularly to reduce termite infestation	3.98	1.020
I apply organic manure or compost to suppress termite outbreaks	3.61	1.098
Healthy soil contributes to my crop's resistance against termites	3.51	1.457
Rotating crops between different plant families reduces termite populations	3.52	1.419
I observe fewer termite problems when avoiding consecutive same-crop planting	3.45	1.443
Reduced or minimum tillage has lowered soil-borne termites on my farm	3.22	1.408
I use mulching or cover cropping to control termites	3.17	1.482

Source: Primary Data (2026). All means ≥ 3.0 indicate agreement.

Physical Control Practices

The physical control practices showed prevalent disagreement across all items, with mean scores between 1.88 and 2.20, the second lowest among the five categories, as shown in Table 5. Respondents were least familiar with how termite traps work ($M = 1.88$, $SD = 1.167$) and their access to building materials for the traps ($M = 1.88$, $SD = 1.232$). During a qualitative interview, a political leader in Nabiswera Sub-County said these methods aren't sustainable because termites just move somewhere else when disturbed. To top it off, Pearson correlation showed a small and statistically insignificant relationship ($r = -0.006$, $p = 0.928$), and regression backed up that finding ($B = -0.010$, $\beta = -0.015$, $p = 0.832$). So, we can say that physical controls are the least effective on their own in our study.

Table 5: Descriptive Statistics of Physical Control Practices (n = 264)

Statement	Mean	SD
The use of heat treatment does not negatively affect the soil or environment	2.20	1.194
Heat treatment is a sustainable and accessible method for controlling termites	2.18	1.118
Termite traps are effective in reducing termite populations on my farm	2.19	1.176
I am aware of heat treatment methods used for termite control in my area	2.00	1.262
Deploying and maintaining termite traps is a major challenge in my area	1.95	1.231
I am familiar with the different types of termite traps for termite control	1.94	1.251
Heat treatment is more effective than other methods I have used	1.93	1.094
I have the technical knowledge and safety skills to apply heat treatment	1.89	1.133
I have access to locally available materials for constructing termite traps	1.88	1.232
I understand how termite traps function to control termite infestations	1.88	1.167

Source: Primary Data (2026). All means < 3.0 indicate disagreement.

Biological Control Practices

The study on biological control practices found an interesting pattern (M = 3.05–3.89), as shown in Table 6. Naturally occurring predators got high scores; farmers see lots of them around. For example, there are the helpful hornbills and starlings (M = 3.81), plus some useful ground-dwelling predators locally (M = 3.75). But when it came to tech-savvy biocontrol agents like Metarhizium anisopliae (M = 3.09), parasitic nematodes (M = 3.11), and microbial biopesticides (M = 3.05), awareness levels hovered right at the agreement threshold. Importantly, people thought the semi-arid climate made it tough to use biocontrol parasites (M = 3.13). Data from Pearson correlation showed a moderate, positive link ($r = 0.449$, $p < 0.01$), yet regression analysis yielded a significant positive coefficient ($B = 0.172$, $\beta = 0.245$, $p < 0.01$) that was kind of surprising. This discrepancy could be explained by the two-tier pattern: while farmers get that natural predators are great, they aren't well versed in formal biocontrol methods. The harsh climate means these methods don't work as planned anyway, leading to more reactive rather than preventive actions.

Table 6: Descriptive Statistics of Biological Control Practices (n = 264)

Statement	Mean	SD
Natural predators of termites are commonly present in semi-arid areas	3.89	1.058
Birds such as hornbills and starlings help control termite populations	3.81	1.040
Ground-dwelling predators like ants and beetles reduce termite infestations	3.75	1.042
There is indigenous knowledge supporting the conservation of termite predators	3.70	1.223
Natural predators are frequently observed attacking termite colonies	3.34	1.437
The semi-arid climate poses challenges to applying biological parasites	3.13	1.240
Community members are aware of microbial agents that suppress termite colonies	3.12	1.342
Parasitic nematodes are considered effective in managing termite populations	3.11	1.287
Biological agents like Metarhizium anisopliae are known and used in this area	3.09	1.289
Biopesticides are being promoted or practiced in termite-prone areas	3.05	1.349

Source: Primary Data (2026). Means ≥ 3.0 indicate agreement.

Botanical Control Practices

Respondents didn't agree with any of the botanical control practice statements, giving the lowest scores out of all five categories, as detailed in Table 7. They liked knowing how to use toxic plants the least (M = 1.83), followed closely by how often they used plant-based repellents (M = 1.94). Still, even with those low numbers, the results showed something interesting. Through multiple regression, researchers found a significant negative coefficient ($B = -0.143$, $\beta = -0.220$, $p < 0.01$), meaning that using botanical practices actually reduced termite infestations. This is contrary to what a basic bivariate correlation would show ($r = -0.064$, $p = 0.299$), highlighting the adoption-gap paradox. Basically, not enough people use botanical practices for a straightforward test to pick this up, but when researchers controlled for other variables, the effectiveness came through clearly. So, in Nakasongola, the issue isn't that botanical controls don't work. It's that farmers just aren't using them because of a lack of information and resources. This is exactly the kind of thing that could be fixed with some help from extension programs.

Table 7: Descriptive Statistics of Botanical Control Practices (n = 264)

Statement	Mean	SD
Toxic plant application does not negatively affect soil quality or beneficial insects	2.22	1.195
I am aware of plant-based repellents that can deter termites	2.20	1.236

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It is easy to access and use plant-based repellents for termite control	2.20	1.276
Plant-based repellents are more effective than synthetic repellents in my experience	2.16	1.202
Using toxic plants is safer and more beneficial compared to chemical termiticides	2.08	1.143
Toxic plants are effective in significantly reducing termite populations	2.05	1.151
Locally available toxic plants are commonly used in my area to manage termites	2.04	1.187
Most farmers in my area have adequate knowledge of using plant-based repellents	2.01	1.233
I frequently use plant-based repellents to manage termite infestations	1.94	1.243
I know how to prepare and apply toxic plants for controlling termites	1.83	1.104

Source: Primary Data (2026). All means < 3.0 indicate disagreement.

Integrated Pest Management

IPM practices mostly got low scores, with only one item barely passing the agreement mark, as shown in Table 8. Local leaders and extension workers regularly arrange awareness meetings, which scored the highest (M = 3.30, SD = 1.358). An extension officer backed this up, saying that training sessions boosted farmer-to-farmer learning. Yet, systemic infrastructure items lagged behind the 3.0 threshold. Community cooperation was strong but not great (M = 2.43); regular termite area checks were somewhat common (M = 2.55), but reliable record-keeping (M = 2.02) and using data to shape strategies (M = 2.24) fell short. A district leader pointed out there's no ongoing monitoring system. They noted that NGOs like Kulika Uganda and World Vision occasionally helped but didn't stay involved long-term. Pearson correlation showed a weak yet significant positive link ($r = 0.245$, $p < 0.01$), while regression produced a small positive coefficient ($B = 0.085$, $\beta = 0.124$, $p < 0.05$). Just like with biological control results, the positive direction suggests IPM is used reactively, not preventively. This means farmers tend to use IPM after pest problems get bigger rather than stopping issues early on. These methods correlate more with handling high-infestation situations.

Table 8: Descriptive Statistics of Integrated Pest Management (n = 264)

Statement	Mean	SD
Local leaders and extension workers frequently organize awareness meetings	3.30	1.358
Community members are actively involved in identifying termite infestation problems	2.99	1.430
Cultural beliefs positively influence adoption of IPM techniques	2.69	1.460
Information on eco-friendly termite control is easily accessible in my community	2.55	1.378
Termite-infested areas are regularly monitored by local authorities	2.55	1.207
Effective monitoring methods are in place to assess termite control interventions	2.52	1.205
There is strong community cooperation in implementing collective termite management	2.43	1.349
Termite control methods are frequently reviewed based on monitoring and feedback	2.38	1.328
Local termite infestation data is regularly used to guide control strategies	2.24	1.236
There is a reliable system for keeping records and reporting termite infestation	2.02	1.127

Source: Primary Data (2026). Only items ≥ 3.0 indicate agreement.

Comparative Model Summary and Regression Coefficients

The overall regression model was statistically significant, with R = 0.569, $R^2 = 0.324$, and Adjusted $R^2 = 0.311$, as shown in Table 9. This means the five eco-friendly practices explain 32.4% of the variance in termite management in Nakasongola District. Table 10 gives the full regression coefficients, letting us compare all the practices directly.

Table 9: Model Summary of Eco-Friendly Management Practices on Termite Infestation

Model	R	R Square	Adjusted R Square
1	0.569	0.324	0.311

Predictors: (Constant), IPM, Botanical, Biological, Physical, Cultural. Source: Primary Data (2026)

Table 10: Regression Coefficients — Eco-Friendly Management Practices (Ranked by |Beta|)

Practice	B	Std. Error	Beta (β)	t	Sig.
Cultural Control Practices	−0.254	0.046	0.356	5.509	0.000**
Biological Control Practices	0.172	0.043	0.245	4.024	0.000**
Botanical Control Practices	−0.143	0.048	−0.220	−3.001	0.003**
Integrated Pest Management	0.085	0.042	0.124	2.034	0.043*
Physical Control Practices	−0.010	0.048	−0.015	−0.213	0.832

** $p < 0.01$; * $p < 0.05$. Dependent Variable: Termite Infestation. Source: Primary Data (2026)

DISCUSSION

Cultural Control as the Most Effective Eco-Friendly Intervention

Cultural control practices came out as the best and most accessible eco-friendly methods in Nakasongola District. They got the highest scores both descriptively (M = 3.17–4.01) and in regression ($\beta = 0.356$, $p < 0.01$). So, this approach really shone in terms of effectiveness. This fits with what Sekamatte et al. (2003) found: maize and legume intercropping boosted predatory ant nests and limited termite activity in Uganda. Plus, Girma et al. (2009) noted less termite damage when legumes were added to sorghum fields. Cultural practices in Nakasongola work well for three main reasons. First, they deal with big issues like bare soil and single-crop problems. Second, these practices don't require extra resources, making them perfect for farmers who barely make enough. Lastly, they fit with what farmers already know, which fits Rogers' (2003) ideas on what gets widely used—things that seem better, fit in, and stand out. To improve termite management there, we should focus on spreading knowledge about practices like mulching and minimum tillage, both rated at M = 3.17 and M = 3.22, respectively. These seem to be the easiest ways forward.

Botanical Control: Proven Effectiveness, Critical Adoption Gap

Botanical control practices came in second for effectiveness ($\beta = -0.220$, $p < 0.01$), showing they reduce termite problems where used. Yet, this is seen against very low scores for knowledge, usage, and accessibility by Nakasongola farmers (M = 1.83–2.22). It's notable that the bivariate correlation wasn't significant ($r = -0.064$, $p = 0.299$), but the regression Beta was. This highlights the adoption-gap paradox: these practices actually work, yet almost no one uses them correctly. Isman (2006) found that while azadirachtin truly deters termites, its quick breakdown from sunlight and low concentration makes it ineffective in fields. This isn't due to the product itself, but due to a lack of proper knowledge and dosage information. Namutebi (2015) showed that Ugandan farmers getting organized support saw results that matched chemical treatments. So, there's a great chance for extension services to step in; botanical controls can be effective, are locally available, and are inexpensive. Closing this information gap could really help farmers.

Biological Control: Strong Predictor, Wrong Direction Under Current Conditions

Biological control methods showed the second strongest impact, but in the opposite direction than intended ($\beta = 0.245$, $p < 0.01$). Increased use was linked to more, not less, infestation. Three key issues led to this unexpected outcome, not because the approach itself is ineffective, but due to implementation snags. Firstly, semi-arid conditions aren't ideal. Metarhizium anisopliae, the biocontrol agent in question, needs certain temperatures and humidity levels for successful infection, levels often absent during the dry seasons in Nakasongola (Rouland-Lefèvre, 2011). Secondly, farmers know more about predator benefits (average score M = 3.89), but their grasp of formal biological controls is just surface-deep (average score M = 3.05–3.12), which barely registers as knowledge. Lastly, there's the timing issue. Since biological control takes time to work, farmers tend to use it too late, only after serious infestations occur. Thus, it looks like it's used in response to, not prevention of, big problems. These findings echo Chouvenc (2008), who noted that hitting those infection levels needs the right timing, ecology match, and high enough starting numbers, which current support in Nakasongola doesn't offer. While biological control still has big long-term promise, it needs climate-adjusted approaches, proper timing for pre-planting, and well-structured farmer training, too. This unexpected positive relationship also points to a broader evidence gap: emerging biocontrol pathways such as termite gut microbiome-derived antimicrobials (Enagbonma et al., 2025) and RNAi-based biopesticides (Zhao et al., 2026) have not yet been tested under semi-arid smallholder conditions comparable to Nakasongola, and future trials of these newer tools alongside Metarhizium-based approaches may help clarify whether the climate mismatch identified here is specific to fungal agents or a more general constraint on biological control in arid and semi-arid lands.

Physical Control: Least Effective, Impractical as a Standalone Intervention

Physical control practices didn't show significant results in either bivariate correlation ($r = -0.006$, $p = 0.928$) or multiple regression ($\beta = -0.015$, $p = 0.832$). In fact, they were the only practice category that didn't contribute anything meaningful to termite management. The descriptive stats back this up too—mean scores for all ten physical control methods ranged from M = 1.88 to 2.20, showing that farmers found these methods ineffective, inaccessible, and unsustainable. This aligns with what we know about physical controls in semi-arid areas. For example, excavating termite mounds isn't effective since replacement queens and young colonies still thrive (Harris, 1971; Nyeko & Olubayo, 2005). Heat treatments fail to reach deep royal cells (Mugerwa, 2011), and physical barriers are easily bypassed in the region's sandy-loam soil (Acda, 2018). Still, physical controls might have some benefit when paired with other methods. For instance, destroying mounds right before using botanical or biological agents could help those approaches work better. But, on their own, physical controls can't reliably manage termites in Nakasongola's conditions.

IPM: Comprehensive Framework, Constrained by Reactive Implementation

Integrated Pest Management had a weak but still significant positive link ($\beta = 0.124$, $p < 0.05$). Just like biological control, this finding shows more about how IPM is actually put into practice in Nakasongola rather than what it could potentially do. The numbers back this up—things like awareness meetings organized by extension workers did surpass the expected agreement threshold (M = 3.30). However, systemic infrastructure items, community teamwork (M = 2.43), solid record-keeping (M = 2.02), and adjusting strategies based on data (M = 2.24) all came in below 3.0. When farmers only turn to IPM after termite troubles get really bad, it makes sense that the approach is connected with serious infestations, not prevention. This supports Oesterlund (2014), who showed that proper training for IPM in Uganda led to better results only when farmers got complete, organized guidance, not just bits and pieces of information. IPM could handle termites far better than any one method by tackling them biologically, culturally, and ecologically at the same time. But in Nakasongola, this doesn't happen because there's no real preventive planning, joined-up community effort, or dependable monitoring happening. The structured CS-IPM hub model documented by Adomako et al. (2024) in Ghana, in which farmer platforms, extension officers, and validated bio-based technologies were deliberately organized around shared community infrastructure, offers one plausible template for closing this gap; similarly, low-cost

UAV and remote-sensing tools for mound detection (Sandino et al., 2017) could eventually substitute for the manual record-keeping and monitoring systems that respondents in this study identified as weakest.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study assessed the effectiveness of five eco-friendly methods to control termite infestations in Nakasongola District, Uganda. Researchers gathered data from 264 farmers and 16 key people in three sub-counties. They used descriptive statistics, Pearson correlation, and multiple regression to analyze everything. Their findings directly match the study's objectives, resulting in five main conclusions.

Cultural control practices are the most effective and accessible eco-friendly methods for Nakasongola farmers, with a regression coefficient of $\beta = 0.356$, $p < 0.01$. They show the highest adoption rates, too. These practices, including crop rotation, legume intercropping, organic manure application, and soil health management, strongly reduce termite infestations, especially in semi-arid areas. So, not only are they reliable, but they're also measurable.

Botanical control practices could be really effective, though their use barely scratches the surface ($\beta = -0.220$, $p < 0.01$). The issue isn't their weakness but their obscurity. There's a big information and access gap, yet structured extension programs could fix this quickly and cheaply.

Biological control practices have real long-term potential, but right now, they're causing problems ($\beta = 0.245$, $p < 0.01$). This is because of three implementation issues: the agents don't match the semi-arid climate, farmers don't know how to use them properly, and efforts are reactive instead of preventive deployment.

Physical control practices don't work on their own, though ($\beta = -0.015$, $p = 0.832$). So, we should only use them as extra help alongside botanical or biological agents.

For integrated pest management, while it sounds great in theory, it's actually used more reactively in practice. Also, there isn't enough support for it to really make a difference. Thus, it ends up having a weak positive link to infestations instead ($\beta = 0.124$, $p < 0.05$).

Together, the five practices explain 32.4% of the variance in how well we manage termite infestations ($R^2 = 0.324$). The rest, 67.6%, is due to other factors, like different termite species, soil types, seasonal changes, and household resource constraints. These elements give researchers plenty to look into for future studies.

Recommendations for Farmers in Nakasongola District

Cultural control: Farmers should prioritize expanding maize-legume intercropping and create formal crop rotation plans by swapping cereals with legumes each season. They also need to boost organic manure use and widely take up lesser-used methods like mulching and minimum tillage, all spread through direct farmer demonstrations.

Botanical control: Agricultural extension services should create easy-to-use, illustrated field guides in local languages. These guides should cover how to prepare neem, Tephrosia vogelii, tobacco extract, and Euphorbia tirucalli, along with the right dosages and safety steps. Plus, community demo plots should show sustainable botanical harvesting. Because these compounds break down fast in sunlight, farmers need training on reapplication for continued effectiveness.

Biological control: The District Agricultural Officers and NARO should make a seasonal biocontrol calendar for Nakasongola's two rainy seasons. This means applying Metarhizium anisopliae granules during pre-planting soil preparation when conditions are wettest. They should also protect termite-eating ants, birds, and beetles by restoring plants that help these creatures thrive. Local wisdom on keeping these natural predators around should be recorded officially and added to the lessons in extension programs.

Physical control: Extension materials should make it clear that physical methods are just supportive, not main interventions. When mounds are being destroyed, farmers should right away apply botanical or biological agents to the exposed colony. Also, farmers should be advised against putting a lot of resources into physical controls alone; these shouldn't stand alone as strategies.

Integrated pest management: To tackle termites district-wide, the District Agricultural Office, NARO, NEMA, World Vision, and Kulika Uganda need to join forces. They should make a seasonal monitoring calendar, put simple record-keeping tools into play, set up an alert system, and meet every quarter to review strategies using collected data. Also, expanding Farmer Field Schools is key. These should follow a planned curriculum that introduces farmers to cultural, botanical, and biological methods at appropriate times throughout the seasons.

Policy Implications

MAAIF needs to add eco-friendly termite management, focusing on cultural and botanical practices, to the national agricultural extension courses for semi-arid regions in Uganda's cattle corridor. According to NEMA's (2022) climate-smart pest management guidelines, there's already a basis for doing this, which can be put into action at the district level in places like Nakasongola. NARO should concentrate on studying how to make climate-adapted biological control solutions and standardized botanical termiticides that can be sold through current dealer networks.

Study Limitations

This study achieved a response rate of 70.8% (264 of 373 distributed questionnaires), which exceeds the 70% threshold conventionally regarded as adequate for descriptive and inferential survey research (Mugenda & Mugenda, 2003), and is therefore reported here as a feature of the study's data quality rather than as a constraint on its findings. Several other methodological boundaries, however, merit acknowledgement. First, the cross-sectional design captures farmer perceptions and practices at a single point in time, which limits the extent to which causal relationships between eco-friendly practices and termite infestation outcomes can be established; the positive regression coefficients for biological control and integrated pest management, in particular, may partly reflect reverse causation (farmers responding to existing infestations) rather than a causal effect of the practices themselves. Second, termite infestation was measured through farmer-reported perceptions rather than direct field counts, mound surveys, or crop-damage assessments, introducing the possibility of recall bias and subjective variation in how respondents judged infestation severity. Third, while Nakasongola District is broadly representative of Uganda's semi-arid cattle corridor, the single-district focus constrains the generalizability of findings to other semi-arid agro-ecological zones with different soil types, rainfall patterns, or termite species compositions. Finally, the study's cross-sectional survey, although strengthened by key informant interviews, was not designed to capture seasonal variation in termite activity or practice effectiveness across full agricultural cycles.

Suggestions for Future Research

Building on the limitations above, six directions for future research are recommended. First, future studies should adopt longitudinal or experimental research designs to establish stronger causal relationships between eco-friendly practices and termite control outcomes, for example, by tracking the same farms across multiple seasons or by randomizing the introduction of specific practices across comparable plots. Second, researchers should incorporate direct field observations and infestation measurements, such as mound counts, bait-station uptake, or standardized crop-damage assessments, alongside farmer perceptions to improve data accuracy and reduce reliance on subjective recall. Third, expanding the study to other semi-arid districts within and beyond Uganda's cattle corridor would enhance the generalizability of findings across different soil types, rainfall regimes, and termite assemblages. Fourth, more investigation is needed to explain the unexpected positive relationships observed for biological control and integrated pest management; controlled trials that separate the timing of application (preventive versus reactive) from the choice of agent would help clarify whether the direction of these effects reflects implementation timing rather than the inherent value of the practices. Fifth, the inclusion of recent literature and emerging technologies in sustainable termite management, including RNA interference (RNAi)-based biopesticides (Zhao et al., 2026), termite gut microbiome-derived biocontrol agents (Enagbonma et al., 2025), climate-smart integrated pest management frameworks for smallholder farming systems (Adomako et al., 2024), and unmanned aerial vehicle (UAV)-based mound detection and infestation mapping (Sandino et al., 2017), would strengthen the theoretical foundation of subsequent studies and help identify which emerging tools are best suited to semi-arid smallholder contexts. Sixth, policymakers should support farmer training, demonstration plots, and extension services to improve the adoption of effective botanical and biological methods, particularly given this study's finding that several practices are effective in principle but under-adopted in practice because of information and resource gaps.

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