Improving agricultural water productivity through integrated termite management


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Abstract: Termite infestation is symptomatic of severe land degradation in many semi-arid regions of the Nile Basin. One characteristic of land degradation is low organic matter (OM) reserves in vegetative biomass and soil. One consequence is excessive rainwater depletion through non-productive evaporation and runoff leading to low agricultural water productivity and diminished livelihoods. CPWF research demonstrated that rapid restoration of pasture production is possible by providing manure through night corolling of cattle prior to re-seeding termite affected rangeland in Uganda. In degraded Ethiopian and Ugandan croplands, preliminary results also suggest that application of maize or sorghum stover to growing maize crops reduces termite damage and associate yield losses. Termites appear to prefer feeding on litter, manure and stover rather than on living plant material. We hypothesize that sustainable crop and livestock production requires a minimum threshold of available dry-season ‘litter’ to avoid termite-driven destruction. We propose an integrated termite management (ITM) approach that involves establishment of sufficient OM reserves to sustain termites and other ecosystems services. One anticipated consequence is enabling termites to resume their beneficial roles in promoting nutrient recycling, infiltration and aeration of soil. In this context, ITM requires an appropriate mix of relevant bio-physical and socio-economic interventions. Besides providing water for animal and crop production, the process of rebuilding OM reserves on degraded termite affected rainfed agricultural land requires additional water. We anticipate that the long-term results of increasing OM reserves will be higher agricultural water productivity, increased crop and animal production and improved livelihoods.

Media grab: Integrated termite management, an ecosystem approach to termite control, helps increase agricultural water productivity, rehabilitate degraded rangelands and enhance agricultural production in East Africa.

Introduction

Better management of African rainfed agriculture affords numerous approaches and opportunities to improve food security and livelihoods while promoting healthy and sustainable agro-ecosystems. Changes for the better require increased water and land productivity and an enabling socio-economic environment for affected people. One widely perceived constraint to rehabilitating degraded land and improving livelihoods is the widespread destructive behaviour of termites. Termites’ destructive behaviour is most evident in degraded semi-arid grazing, cropping and forestry
systems, owing to the disruption of the ecological prey-predator relationship between termites and their predators, shifts in termite species composition and depletion of termites’ preferred feed resources Mugerwa (2013). The economic and social costs attributed to termites are high, but not well documented. UNEP (2003) and Mugerwa (2013) state that 20–50 out of about 1000 African termite species damage hundreds of thousands structures such as fence posts and houses and generate major losses of agricultural output including 10 to 30% and 30 to 60% for groundnuts and maize, respectively. Termites also account for widespread destruction of grazing land and negate efforts to implement forestry and agroforestry (Nyeko and Olubayo 2005; Mugerwa 2013; Peden 2013). The Macrotermesinae is the family accountable for most agricultural damage in Africa (Abdulahi et al. 2010; Mugerwa et al. 2013). Although distribution of Macrotermes species is not well understood, Diga woreda, Ethiopia and Nakasongola, Uganda, represent two locations in the Nile River Basin where accelerating agricultural losses associated with termites constrain efforts to improve rainwater management, agricultural production and sustainable land management. This paper summarizes emerging concepts, results and recommendations from CGIAR Challenge Program on Water and Food (CPWF) research on integrated termite management undertaken through the lens of agricultural water productivity.

Termites, organic matter and water productivity

Agricultural water productivity (WP) is the ratio of the set of net benefits from agricultural goods and services to the volume of water depleted in the processes of producing these benefits (Molden and Sakthivadivel 1999). WP includes the crop and livestock water productivity (CWP and LWP). CPWF research concluded that the greatest opportunities for increasing food production arise in rainfed agriculture where current WP is very low (Molden et al. 2007). One key principle underlying this finding is recognition that in degraded agricultural land much water is lost through evaporation and excessive down-slope runoff (Peden et al. 2012). Interventions that divert otherwise depleted water to transpiration promise opportunities to increase agricultural production and enhance the organic matter storage and carbon flow in degraded agro-ecosystems on which production depends. A key requisite step is increasing vegetative cover of trees, pasture, crops and soil organic matter (SOM). However, production of this organic matter capital also requires water. Past research has not adequately addressed the provision of water to replenish OM that is lost from the ecosystem, or what we might call OM water productivity (OMWP). We hypothesize that successful rainwater management must take into account not only water requirements for production of crops, pasture and trees, but also for all OM such as litter and soil OM that sustains ecosystem functioning. This implies allocating water to satisfy production for people and additional water to drive carbon accumulation and turnover in agro-ecosystems.

In healthy tropical ecosystems, organic matter (OM) production and imports must equal or exceed OM losses. Human activity including overgrazing, charcoal production, inappropriate fire regimes and cultivation and export of agricultural and wood products along with in-situ respiration leads to long-term loss of the OM capital in supporting agro-ecosystems. In some cases, OM may also be lost when carried away by flood water. In degraded areas of the Nile Basin such as Nakasongola and Diga, Macrotermes undermine efforts to replenish depleted OM and thus to rehabilitate the productive capacity of the land.

Donovan et al. (2001) classified Macrotermes as generalist feeders, consuming many types of biomass, including detritus or litter derived from vegetative biomass. Litter is their preferred food resource but when detrital production declines, these species switch to foraging on herbaceous producer biomass, causing significant denudation of grassland vegetation (Mitchell 2002). Although behavioural ecologists generally apply the concept of ‘switching’ to the ingestion of food items by consumers, detritivores (particularly termites) may also show behaviour akin to switching. Switching is characterized by the forager concentrating on more abundant food species, paying little attention to rarer species (Begon et al. 2006). Findings by Mugerwa et al. (2011) support the expansion of the concept of switching to termites. These authors demonstrated that, in litter-deficient grazing lands, subterranean termites resorted to producer biomass, consuming up to 90% of the available biomass. According to this theory of optimal foraging, a forager will tend to maximize the net gain of energy from food above that expended in searching for and ingesting it (Smith and Smith
To achieve this, a forager will: 1) prefer the most profitable food items that yield the greatest net energy gain; 2) feed more selectively when profitable food items are abundant; 3) include less profitable items in the diet when the most profitable food are scarce; and 4) ignore unprofitable items, however common, when profitable food items are abundant.

To rehabilitate termite affected degraded land, rainwater management must ensure increased OM storage. In particular, timely production of litter must exceed this threshold to prevent their damaging behaviour. This OM can be produced within the systems or imported in forms such as manure and crop residues from elsewhere. The management objectives are to rebuild ecosystem capacity to satisfy termites’ dietary needs such that subsequent termite activity enhances soil fertility, infiltration and aeration that benefit crop production and natural vegetative growth and to eliminate the need for chronic application of chemical pesticides.

CPWF research demonstrated that termite induced damage can be reduced in rangelands and croplands by importing organic matter (Mugerwa 2007; Peden et al. 2012). In highly degraded grazing areas, night corralling of cattle prior to reseeding former pasture deposits manure that attracts termites and enables rapid recovery of graminaceous ground cover. Mugerwa (2007) realized an increase in forage production from nil to about 3000 kg/ha in only one season. Preliminary evidence suggests that this outcome is sustainable with appropriate grazing practices (Peden et al. 2012). We hypothesize that sustainability is achieved in rehabilitated pasture when annual shedding of root biomass before the dry season becomes sufficient to satisfy termites’ appetite. In both Nakasongola and Diga, application of maize and sorghum stover, respectively, led to increased maize production that was at least partly due to a shift in termite feeding practices. Clearly, importing organic matter enabled increased production of food and feed for people and animals. However, a broader ecosystems approach that considers a wider range of biophysical and socio-economic factors is needed, a process we call integrated termite management (ITM).

Potential opportunities and constraints for integrated termite management

Traditional approaches to termite control commonly involve interventions such as manual removal of queens and nests, application of chemical termicides, baiting and use of repellent plant, urine and animal excreta (UNEP 2003; Abdulahi et al. 2010; Mugerwa 2013). Furthermore, chemicals potentially harm non-pest species and interfere with the positive roles termites play in healthy ecosystems. In general, these approaches are costly. Although affected farmers seem knowledgeable about termites and their damaging behaviour, these interventions are frequently ineffective or only helpful for a short time only. Longer-term solutions are needed. Triggering the threshold dependent response of termites to available litter (Figure 1) provides an alternative intervention tied to the complex structure and function of termite affected ecosystems. ITM links this termite feeding behaviour to larger agro-ecosystem process along with associated livelihood strategies.

Figure 1. Hypothesized litter biomass threshold below which Macrotermes shift feeding from litter to live plant materials and wooden infrastructure such as fence posts.
Figure 2 proposes a framework that links termite feeding to available litter biomass (Figure 1) and the ecosystem functions that promote increases and decreases thereof. This simplistic model suggests that carbon storage (OM) increases due to photosynthesis and biomass imports and decreases through respiratory loss of carbon dioxide and methane and export of plant and animal material including food, feed and wood products. Selection of appropriate plant species along with good soil, water and vegetation management are the key factors that affect above ground and concomitant below ground biomass production. In turn, accumulated soil OM increases soil water holding capacity and nutrient levels that promote additional primary production. For example, Bationo et al. (2006) call for interventions to increase crop biomass production that can in turn be transformed into soil OM that further sustains and enhances nutrient recycling and productivity.

Figure 2. Termite interaction with litter production is one of many important socio-economic and biophysical component processes inherent in degraded agro-ecosystems implying the need for complementary interventions that draw on appropriate natural, physical, financial, human and social livelihood assets.

Termite affected agro-ecosystems are part of the natural capital that sustains human livelihoods. Science-based biophysical interventions are essential for rainwater and land management that promotes increased biomass production and soil OM accumulation. At least for rehabilitation of degraded agro-ecosystems, biomass accumulation must exceed biomass depletion. Key interventions that have been shown to help achieve this include:

- Biomass transfer such as night corralling and import of stover
- Exclosures that prevent overgrazing
- Conservation agriculture that minimizes loss of soil carbon
- Enhancing proliferation of termite predators
- Water harvesting that enables increased CWP
- Use of inorganic fertilizer especially combined with manure to increase crop and forage production
- Selection of appropriate types and varieties of crops and livestock that maximize WP
- Restrictions on grazing pressure, harvesting of wood products and utilization of crop residues to ensure that litter biomass exceeds the required threshold
- Adoption of agroforestry that provides long-term production of litter biomass and
• Demand management of competing uses of biomass to help ensure that in-situ biomass levels maintain levels that promote sustainable ecosystem functioning.

Biotechnical solutions are not sufficient. As depicted in Figure 2, the contextual environment involving people’s access to livelihood assets determines farmers’ capacity to rehabilitate degraded land. Although context specific, adoption of effective ITM requires farmers’ access to appropriate levels of physical, financial, human and social capital and the tradeoffs they make in their attempts to overcome numerous livelihood challenges.

Future research in the Nile Basin and indeed elsewhere in Africa warrants mapping the distribution of termite species that threaten sustainable agricultural production. Wherever they are found in association with severe land degradation, ITM involving allocation of litter biomass along with other proven agronomic practices can help farmers restore agricultural productivity and the sustainability of their natural capital. In this context, ITM can make a meaningful contribution to increasing WP in rainfed agricultural systems. Moreover, we suggest that the process of rehabilitating degraded grazing and crop lands demands investments in water that help rebuild agro-ecosystem structure and function and increase agricultural production.

Conclusions

Farmers perceive termites as a major constraint to livelihoods in semiarid rainfed agricultural areas of the Nile Basin. In reality these insects are symptomatic of degraded pasture and cropland in which termites consume crops and feed because litter, their preferred source of food, is insufficient. Rehabilitating termite affected agricultural land requires production and imports of organic matter at levels that exceed losses. Research results indicate that import of manure and stover can quickly increase pasture and crop production. Once ecosystems structure and functioning has been reestablished, agricultural production must be undertaken in a manner that does not diminish organic matter reserves. While biophysical interventions underpin efforts to increase agro-ecosystems’ natural capital, investments of physical, financial, human and social capital remain vital. Taking an ITM approach where relevant requires an investment in water to produce increased biomass and OM in degraded agro-ecosystems, but will likely result in long-term increases in agricultural WP.

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