

Review

Economic importance of termites and integrated soil and water conservation for the rehabilitation of termite-degraded lands and termite management in Ethiopia

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In Ethiopia, termites pose serious threat to a variety of agricultural crops, forestry, rangelands, houses and other wooden structures. Termite problem is particularly prevalent in the western part of the country, where it has persisted for many years and has received wide publicity. Termites appeared in the region for the first time in 1904 at a specific place called Bafano Koreche around Kiltu Kara town in West Wallaga zone. From there, they spread in different directions to other areas and termite problem has increased from time to time. The severity of termite destruction has become worse than ever in all the four zones western Oromia National Regional State (ONRS). Termites are also causing serious damages to pastureland in the semi-arid areas of Borna and Guji zones of southern ONRS threatening livestock production. By damaging crops, termites cause food insecurity and by damaging natural vegetation they cause denudation, accelerated erosion, and loss of biodiversity. Therefore, the purpose of this paper is to examine the economic and environmental destruction termites pose in the rural areas of ONRS. Finally, the paper made concrete recommendations to government policy makers and land use professionals in their effort to mitigate the challenges.

Key words: Integrated management, soil erosion, termite pest, western Ethiopia.

INTRODUCTION

Termites are essential members of the soil ecosystem and are found throughout the world (Abdel and Skai, 2011). They are the most important fauna in nutrient recycling, improving soil fertility and serving as food sources for other animals. On the other hand, termites are highly destructive and polyphagous pests of crop plants, which damage green foliage, seedlings, forests, pasture, wooden structures, fibers including household cellulose-based materials, and postharvest stored products (Pearce, 1997; Upadhyay 2013). Damage inflicted by termites impedes food security and threatens livelihoods of smallholder farmers (Demissie et al.,

2019). Termites cause significant yield losses and are often a major constraint in reforestation, especially in the semi-arid and sub-humid tropics (Logan et al., 1990). As they are polyphagous pests and have wider host range, they may cause more damage to crops and other plants when compared with other insect pests with narrow host range. Termites cause significant yield losses to crops and are often a major constraint in reforestation, especially in the semi-arid and sub-humid tropics (Logan et al., 1990). In Ethiopia, termites pose serious threats to a variety of agricultural crops, forestry, rangelands, houses and other wooden structures. Termite problem is

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particularly prevalent in the western part of the country, where it has been well known for many years and has received wide publicity (Abdurahman et al., 2010). It has been long time since termite problem in western Oromia National Regional State (ONRS) was reported. According to Gauchan et al. (1998), a termite mound was for the first time observed in 1904 inside a thatched house of Abba Shebir at BafanoKoreche in a place specifically called TulinGibole in the current district of Kiltu Kara town and then they were not a problem. Most of the local farmers believed that termite threats to crops and houses have spread from this place as a center of origin and spread in different directions using different mechanisms, such as underground movements, transportation of infested wood and by swarming of winged adults (Gauchan et al., 1998). Wood (1991) stated that the first termite damage report came in 1938 around Kiltu Kara town and it is believed that termites had spread from this area. However, according to Gauchan et al. (1998) termite damage was noted and reported in the area for the first time on different crops in 1953 and human migration from the affected areas started in the same year. A report by Sana (1973) shows that termite problem had increased from time to time and it was particularly serious in ManaSibu district where farmers were abandoning desert without vegetation and moving to the lowland areas, searching for new land where termite problem was less severe. The denuded hillsides were subjected to heavy erosion. Abdurahman (1990) stated that Agricultural Office of ManaSibu district reported that 9,155 farmers (about 6%) of the total farming population migrated to lowland areas since the problem has become worse. This migration has exposed the farmers to deadly diseases such as malaria and their livestock to wild animal attack both of which were prevalent in lowland areas.

In response to farmers' complaints about the termite problem, chemical control campaigns against termites was started in western Wallaga in the late 1960s using Aldrin by Ministry of Agriculture (MoA) and the then Ministry of Coffee and Tea Development. Subsequent chemical control campaigns targeting mound poisoning were undertaken in 1983 and 1988 (Abdurahman, 1995; EECMY-WS, 1997; Gauchan et al., 1998). In the 1983 extensive mound poisoning campaign conducted in ManaSibu and Jarso districts 635,098 mounds were treated with 12,078 Kg of Aldrin 40%wp (208,638 man-days). The 1988 campaign was conducted in ManaSibu, Gimbi, Ayira, Guliso, Najo, Jarso and Yubdo districts in which 557,563 mounds were treated with 13,077 Kg of Heptachlor 40%wp (79,197 man-days). EECMY-WS (1997) branch based at Chalia town in the current Guliso district also participated in termite control programme by offering financial incentive for farmers who brought termite queen. Between September 1987 and September 1988 over 23,000 *Macrotermes* queens were handed in and US \$19,592.27 was paid (Abdurahman, 1990). The

effects of campaigns were evaluated in 1984, 1989 and 1997. According to the 1984 evaluation by MoA up to 60% improvement was reported based only on the number of perished mounds. No yield increment was reported. Wood (1986a) made the 1989 evaluation and realized that the campaign towards termite control through mound destruction did not show any significant effect as the destructive species are several and the campaign was mainly targeted towards mound forming species (EECMY-WS, 1997), while the damaging species were the non-mound forming species such as *Microtermes* species (Abdurahman, 1990; Wood, 1991).

In interviews held with farmers in a baseline study conducted in Diga district of East Wallaga Zone, Taye et al. (2013) reported that farmers most frequently mentioned deforestation, soil degradation and overgrazing as factors for increased termite infestation in the district. According to the authors, farmers mentioned that termite infestation has increased with deforestation because some termite eating rodents have migrated to other areas. Similarly, ants living under the grasses that eat termites have decreased due to overgrazing. Soil degradation does not only affect the crop cover, but it also leads to less decaying materials on which termites can feed. This implies that termites can be managed by rehabilitation of degraded lands through soil and water conservation, afforestation, conservation of natural enemies, and limiting the number of livestock below the carrying capacity of the environment to avoid overgrazing.

Physical, biological and chemical controls of termites have been practiced for decades in western ONRS; unfortunately, none of these practices have been successful in reducing crop damage by termites (Negassa and Sileshi, 2018). Mound digging and/queen removal and mound poisoning which have been used mainly for termite management in the region targeting only mound forming termites, could not solve the problem much. Currently, termite pest severity to crops, young tree plantations, pasturelands and environmental degradation has become worse than ever in all the four zones of Wallaga, Jima zone, BunoBedelle zone, Ilu Abba Bor zone and West Shawa Zone in western ONRS. Therefore, the purpose of this paper is to indicate economic importance of termites in terms of damage they cause to crops, tree seedlings, rangelands and soil in ONRS; it focuses on viable termite management options as an integrated approach with water and soil conservation and recommends these management options as a strategy to the government to enhance growth of agricultural productivity, poverty reduction and livelihood improvement of the community.

ECONOMIC IMPORTANCE OF TERMITES

Termites are pests of crops, forests, wooden portions of

buildings and pastureland as well as non-cellulose materials such as dam linings, bridges and electrical cables (Pearce, 1997). They cause significant yield losses in crops and are often a major constraint in reforestation, especially in the semi-arid and sub-humid tropics (Logan et al., 1990).

Termite damage to crops

In Ethiopia termite problem is more severe in western part of the country and is a predominant problem in the termite infested areas of western Wallaga followed by land degradation and overgrazing (EECMY-WS, 1997; Gauchan et al., 1998). A report by Gauchan et al. (1998) stated that both researchers and agricultural extension agents ranked termites first of all the agricultural problems in West Wallaga, while other crop pests and diseases ranked fourth and livestock diseases ranked sixth and this shows the severity of termites in the area. Termites can cause widespread damage to all crops from seedling to harvest stage (Wood, 1991). Both agricultural experts of ONRS and farmers in all the four zones of Wallaga (East Wallaga, HoroGuduruWallaga, Kelem Wallaga and West Wallaga), Jima-, BunoBedelle-, Ilu Abba Bor- and East Shawa- Zone claim that the severity of termite destruction has become worse than ever.

Maize, teff, finger millet, pepper and sugarcane are among the most severely attacked crops while eucalyptus is the most susceptible among trees. Sorghum is widely grown in the area but it is least susceptible to termite damage (Abdurahman, 1995). FAO (1984) reported that 50% damage by *Macrotermes* species in maize and hot pepper in Wallaga while a report by Girma et al. (2009) shows that termites attack these crops from the seedling to maturity stage causing up to 100% yield loss, especially in ManaSibu and LaloKile districts of western Wallaga. *Macrotermes subhyalinus* is considered an important pest species in several parts of Wallaga and Asossa zones. *M. subhyalinus* causes damage on maize, teff, eucalyptus, grasses, wheat, barley, pepper, tomato and other vegetable crops. *Macrotermes herus* has been reported causing 50% pre- and post- harvest damage on maize and pepper and serious damage on young eucalyptus trees (Abdurahman et al., 2010). Complete loss may occur on crop stacks left in the field for days without constructing above ground drying structures. Ofgaa et al. (2007) reported higher damage on teff (28.89 ± 1.16) and maize (16.62 ± 0.67) and low damage in sorghum (1.52 ± 0.05) occurring from seedling to maturity stage. Yield loss assessment studies in teff using aldrin treated and untreated plots in Wallaga showed yield increase in treated plots from 0 to 85% and it is claimed up to be 100% on farmers' farms, although losses due to termites are exaggerated by farmers in some localities (Abdurahman et al., 2010). Among cereal crops, maize

is the most often damaged by termites (UNEP, 2000) and its susceptibility is attributed to its recent introduction into Africa by the Portuguese explorers in 1502 and has not been exposed to the range of termite life-history strategies of those species occurring in Africa (Ayuke, 2010). In parts of Africa, indigenous crops such as sorghum and pear millet, cowpea, Arabica coffee and teff are more resistant to termite damage because of co-evolution and selection by farmers over many centuries (Pearce, 1997; Ayuke, 2010). Teff, wheat, maize, sorghum and barley are the five major cereals occupying almost three-quarters of total area cultivated, and represent almost 70 percent of total value added in recent years in Ethiopia (Alemayehu et al., 2011).

However, unlike in western Ethiopia, termite damage to crops is less severe in the central part of the country, Central Rift Valley. Abdurahman (1990) stated that in contrast to the western area an economic damage has ever been reported on agricultural crops even on highly susceptible crops such as maize and hot peppers in Meki-Ziway area of central Ethiopia, even though the density of *Macrotermes* mounds is considerably higher and the rainfall is much lower, an ideal condition for termite damage. The only incidence of damage reported was on crops which were left in the field for drying. Daniel and Eman (2015) reported that in the Central Rift Valley of Ethiopia farmers rated maize and haricot beans as the major crops grown in their area and also the most susceptible crops to termite damage. Accordingly, farmers' estimation of percentage yield loss due to damage to standing maize plants and haricot bean is 10.58 ± 1.91 and 18.02 ± 0.27 (mean \pm standard deviation). In an interview held with farmers in the area, all of them mentioned that complete loss of haricot bean can occur if there is an incidence of cloud and/or rain at harvest stage.

Termite damage to standing crops is generally expressed as percentage of plants attacked or plant mortality. However, standing crop damage may not necessarily lead to significant yield loss as there is a possibility of compensatory growth and yield response from unattacked plants (Abdurahman et al., 2010). In maize, compensatory growth by surviving plants following early season attack, harvest of cobs on the ground from plants lodged late in the season, and damage to vegetative parts occurring after cob formation will result collectively in over-estimates of yield loss if they are based only on attack or damage scores (Logan et al., 1990).

Termites that frequently cause damage belong to the genera *Macrotermes* and *Microtermes*, and to a lesser extent *Odontotermes* and *Ancistrotermes* in Africa. These genera differ characteristically in their biology and mode of attack. *Macrotermes* build large epigeal nests (mounds) from which they forage outwards for distances of up to 50 m in galleries/runways either just below or on the soil surface (Darlington, 1982; Logan et al., 1990;

UNEP, 2000). They attack plants at the base of the stem, ring-barking or cutting them through completely. *Odontotermes* species build both subterranean and epigeal nests. Damage is due to either foraging under soil sheeting on the outer surface of the plants, sometimes leading to severance of the stem (Cowie and Wood, 1989) or attack on the roots (Logan et al., 1990). *Microtermes* and *Ancistrotermes* species have diffuse subterranean nests and attack plants from below ground by entering the root system and tunneling up into the system, hollowing it out and frequently filling it with soil (Cowie and Wood, 1989; Logan et al., 1990; UNEP, 2000).

Ofgaa et al. (2007) reported that termite species belonging to the genera *Ancistrotermes*, *Macrotermes*, *Microtermes*, *Odontotermes* and *Pseudacanthotermes* attack maize, teff and sorghum, while *Macrotermes*, *Odontotermes*, *Pseudacanthotermes* and *Trinervitermes* were recorded from rangeland in ManaSibu district of West Wallaga. *Ancistrotermes* and *Trinervitermes* were less common. Daniel and Eman (2014) reported that *Angulitermes* and *Trinervitermes* were very rare in the Central Rift Valley of Ethiopia and collected by maize stalk baiting only from protected grassland.

The effects of termites on crops are both direct and indirect. Termites decompose organic material and transport it into deeper soil layers that are not accessible by a crop, which leads to poor crop growth. Farmers relate the high yield reduction of millet especially to this indirect effect that termites pose it by affecting soil fertility. The consequence of termite damage is not only yield reduction, but also the direct and indirect effects of termites interrupt planting of important crops like barley, wheat, field pea, faba bean, and chickpeas some of which have now been abandoned. These crops play vital roles in human diet and their absence in the diet of the study area may have contributed to malnutrition. Low crop yields due to termites have negative consequence, such as low income, shortage of food and migration of the community to the lowland areas. The consequences of termite infestation as described above result in further reduction in overall agricultural productivity (Gauchan et al., 1998).

Termite damage to rangelands

Throughout tropical Africa, several species of Macrotermitinae consume grass litter as a significant part of their diet and the most common of these species belong to the genera *Macrotermes*, *Odontotermes* and *Pseudacanthotermes* (Wood, 1991). Typical foraging is characterized by subterranean galleries leading to surface foraging holes from which termites emerge to remove dead grass and grass litter under cover of constructed soil sheeting. Termite foraging is particularly obvious during the dry season when bare rangeland can

have up to 55 foraging holes per m² (Cowie and Wood, 1989).

Termites are occasionally associated with severe damage to rangeland vegetation, particularly, in degraded arid and semi-arid ecosystems (Pearce, 1997). Grass eating termites are often many in tropical and subtropical grass lands where livestock also graze and compete with grazing animals for forage, to actually damage forage resources, and to interrupt soil nutrient cycles (Gauchan et al., 1998). Termites enhance soil degradation and erosion by reducing the vegetation cover (Demissie et al., 2019) and occasionally, spectacular effects of termite activity resulting in almost complete denudation and leading to accelerated erosion have been reported (Gauchan et al., 1998). A soil infested with termite mostly resulted in distortion of soil structures and compactions. Hence soil becomes difficult to plough; this in turn results in a reduction of productivity of crops (Gebreslasie and Meressa, 2018). The author of this paper knew some areas in western Wallaga for the past 50 years. In the 1960s and 1970s the areas were covered with dense tall and short grasses and used as grazing lands. The virgin land that was covered with dense grass in the past four decades currently has been degraded drastically with the combined effects of termites, land cultivation and overgrazing.

Abdurahman (1995) reported that as a result of their feeding activities termites also contribute to severe soil degradation problems by reducing vegetation and leaving the soil surface barren and exposed to the elements of erosion. Large areas of rangeland in Ethiopia, particularly in western Ethiopia (Mandi, Jarso, Najo and other districts in western Wallaga) have been denuded and are subject to serious erosion. In these areas *Macrotermes subhylianus* termite is present almost everywhere, as are several *Odontotermes* spp. *Pseudacanthotermes militaris* is more locally distributed but where it occurs, it is often the dominant grass feeder, usually at higher altitudes. In western Wallaga, overgrazing by domestic stock is probably the primary cause of denudation, with termites contributing by removing the small remaining quantities of grass litter (Cowie and Wood, 1989). However, Abdurahman (1990) reported that farmers and extension agents believe that termites are the cause of the widespread denudation of grazing lands in ManaSibu, Nedjo-Jarso, Ghimbi and Ayra-Guliso districts. Mugerwa et al. (2011) also reported that termites are regarded as the primary cause of vegetation denudation and partly contributing to formation and expansion of bare surfaces on grazing lands of semi-arid district of Nakasongola, Uganda.

Overgrazing is a major problem in ManaSibu district (EECMY-WS, 1997). Termites primarily feed on dead grass (grass litter) during the dry season. In the overgrazed rangelands they remove all grass litter and much of the small amounts of dry grass biomass consumed by termites results in the denudation of the

area. The massive termite damage in the infested districts leads to degradation of the pastureland, lack of fodder and soil erosion (EECMY-WS, 1997). Lack of fodder leads to weak animals that are susceptible to diseases, give low milk and beef yield, and that are weak in traction affecting the socio-economy of the community. Lack of fodder also leads to overgrazing. Animals trampling on overgrazed land leads to soil compaction. Infiltration on compacted soil is low and results in high runoff, and subsequent erosion (EECMY-WS, 1997; Gauchan et al., 1998). Similarly, Mugerwa et al. (2011) reported as a consequence of termite damage to vegetation on grazing lands of semi-arid district of Nakasongola, Uganda, the herders are faced with reduced feed availability, poor animal performance, high livestock mortalities and eventually high levels of poverty among pastoral communities. Through removal of the sparse herbaceous vegetation, termites have also contributed to distortion of the complex ecological interactions between grasses and woody species leading to encroachment of grazing lands with shrubs. Termites are the major barrier to pasture restoration on degraded bare patches in the district due to severe destruction of reseeded seedlings. In a participatory systems analysis of the termite situation in west Wallaga, Gauchan et al. (1998) stated that as the grasses in the rangeland are almost lost because of overgrazing by livestock and grass feeding termites, the pressure on trees for foliage as alternative fodder source is growing.

In Borana zone of southern ONRS, high densities of *Macrotermes* termite mounds are common and the land is devoid of grasses and thus exposed to forces of erosion (pers. obser.). Daniel (2018) recorded higher number of species and density of *Macrotermes* termites in the zone than in western and central Ethiopia. A large termite colony, e.g. of *Macrotermes*, in a savannah habitat can remove more than one tone of vegetation per year (Pearce, 1997). In a study conducted by Kejela et al. (2007) in Dire District of Borana zone, 98% of the respondents recognize that rangeland productivity is poor. The major reasons for poor productivity of rangeland raised by the community and researchers are mainly bush encroachment, increased livestock population, bad climatic factors including soil erosion and expansion of termites as critical challenge on rangeland productivity. Agricultural experts of the Bureau of ONRS claim that there is severe termite problem on pastureland in the semiarid southern zones of Borana and Guji, and that attention is given only to the western parts of the regional state where termites are serious pests of crops.

Termite damage to forestry trees and plantations

Termites by no means confine their attentions to dead plant tissues such as wood. Certain species of termites are serious pests of growing crops including living trees

(Hickin, 1971) and they are one of the major agroforestry pests in the tropics (Nyeko and Olubayo, 2005). In western Ethiopia, termites cause severe devastations on the forest, and thus soil remains bare and exposed to elements of soil erosion (Gebreslasie and Meressa, 2018). Trees support the survival of living organisms through soil and water conservation, carbon sequestration, nutrient recycling, ameliorating environmental pollution and by supporting the life of wildlife which form part of the ecological functions of an environment (USDA, 2016). Construction materials, household furniture, etc. can also be obtained from trees.

In the tropical and sub-tropical regions of the world where rainfall is low and a dry savannah-type of situation has developed, termite attacks appear most acute and this has caused serious problems in the development of nurseries and young tree plantations (Hickin, 1971). Termites have serious impacts on tropical forestry and major obstacles to afforestation in the dry areas of Africa. They destroy seedlings and saplings required for afforestation, cause yield reduction of timber from forests where they are active in mature trees, and affect natural regeneration of woodlands (Harris, 1971). Another phase of the problem is the susceptibility to termite of a popular group of tree species for the tropical planting, the eucalyptus (Hickin, 1971).

Eucalyptus tree can produce large volumes of poles for construction and wood products for fuelwood and construction in a short time without requiring much attention for management. Eucalyptus is an important tree in various socioeconomic dimensions of many Ethiopians. For many years, Ethiopians have been attached to it as it served by being the prime source of construction material for houses. This fast growing tree has provided goods and services that enabled livelihoods development in one way or another to different localities by providing income generation opportunities and wood products for household consumption (Molla, 2016). Pearce (1997) noted that a high demand for timber in Africa has led to fast-growing trees such as eucalyptus, being planted in poor soil areas where they are under stress and are therefore more susceptible to termites. Though, eucalyptus is the most important tree, particularly for construction material in western Wallaga, yet it is the most susceptible to termite attack and this is a big challenge for growing it in the area.

As elsewhere in Africa, termite damage in Ethiopia is generally greater in rain-fed than irrigated crops, during dry periods or drought than periods of regular rainfall, in plants under stress (e.g. newly transplanted forest tree seedlings) than healthy or vigorous plants and exotic (e.g. eucalyptus, maize) than indigenous plants (Wood, 1986a, 1991). Serious damage is very common on exotic forestry trees, especially on eucalyptus, 1-3 years after transplanting, although most losses occur in the first year and in some localities up to 100% of eucalyptus seedling loss is common (Abdurahman, 1995). In many parts of

western Ethiopia, like Asosa Zone, ManaSibu- and Ayira-districts, Plant Health Clinic personnel and Agricultural experts rank termites as number one of pest of crops and the trees. They claim that there would be total losses in eucalyptus unless chemical termiticides are used (Daniel and Eman, 2017). Cowie and Wood (1989) reported that in some areas in southern, western and eastern Ethiopia some forest trees, usually newly-transplanted seedlings are seriously damaged, particularly eucalyptus, and losses could exceed 90%.

In Zimbabwe on average between 30 and 70% of planted eucalyptus trees are killed by termites in most areas of the country (Mazodze, 1995). In Cameroon 100% losses were recorded with *Eucalyptus saligna*, and 60-80% with other species; in the drier areas of Uganda between 50 and 70% of transplants were regularly lost; in Northern Nigeria *E. camaldulensis* had a failure rate of between 68 and 74% in the first eighteen months and 86% after thirty months (Harris, 1971).

The damaging genera are *Macrotermes*, *Odontotermes*, *Pseudacanthotermes*, *Ancistotermes* and *Microtermes* which attack either nursery seedlings or seedling trees up to 3 years after transplanting in all areas below 1800 to 2000 m.a.s.l. *Macrotermes*, *Odontotermes* and *Pseudacanthotermes* have large nests with long galleries running just below the surface distances of up to 50 m. They cause damage to plants just below or at the soil surface level (Wood, 1986b).

The critical period to prevent termite attack in young plantations of tree seedlings is during the first year in the nursery and a few months after transplanting. Later on, as the trees get older, termite infestation may increase, but once a good canopy is formed attack is often greatly reduced (Pearce, 1997). However, in western Wallaga, Gauchan et al. (1998) stated that the damage is more severe during the first 2-4 years after transplanting. Soon after transplanting seedlings suffer severely from moisture stress, because of soil compaction and low water holding capacity resulting from poor infiltration rates. The roots of such plants begin to dry out. This creates a favorable situation for termite infestation. Damage to forestry trees can be increased due to incorrect transplanting of tree of seedlings and lack of treating soil during raising seedlings.

TERMITE MANAGEMENT OPTIONS

The complexity of the termite problem justifies the use of various management options in an integrated manner, as no single control method is sufficiently effective against this pest. In the past, termite control campaigns including mound destruction and killing of termite queens were practiced in western Ethiopia. However, these control measures did not effectively reduce the damage due to lack of a holistic approach. Moreover, emphasis was

given to the use of chemical insecticides, mainly of chlorinated hydrocarbons, which have detrimental environmental impacts and have since been banned due to their persistent toxicity and effects on non-target beneficial organisms and the environment (Demissie et al., 2019). Because of increased environmental awareness, demanding reduction in the use of commercial pesticides, and increasing cost of synthetic chemical pesticides, there is renewed interest in non-chemical control of termites (Logan et al., 1990; Khader et al., 1993). The current termite control emphasizes on integrated pest management (IPM) which involves looking at the ecology and behavior of the insect and using safer biological and cultural, as well as chemical, methods to alter the pest potential of the total colony (Pearce, 1997). Logan et al. (1990) briefly summarized non-chemical techniques which include a range of cultural procedures, biological control, queen removal, use of resistant crops/trees and a number of other measures.

Cultural control includes those procedures which help to maintain or enhance plant vigour and which generally are good agricultural/silvicultural practices, aim to reduce termite numbers or modify their behavior (Logan et al., 1990). Logan et al. (1990) and Stoll (2000) have reviewed the different cultural control methods of termites such as maintenance of plant vigour (use of good quality seed, healthy seedlings, appropriate planting procedure, avoiding water stress, crop rotation, weeding, use of inorganic fertilizer), manipulating termite numbers and behaviour (inter-cropping, use of crop residues and other organic matter, weeding, breaking up termite galleries), high density sowing, spacing and prompt harvesting.

Abdurahman et al. (2010) have reviewed a wide range of termite management options practiced in Ethiopia. Accordingly, termite control measures practiced by farmers in western Ethiopia include traditional methods such as flooding mounds, digging mounds and removal of the queen or excavating the top parts of the mounds and burning straw to suffocate and kill the colony, placing the produce of different crops on wooden beds (protects harvested crops raised few centimeters above the ground from termite damage), mound poisoning and seed treatment. Gebreslasie and Meressa, (2018) reported that the application of crop residue and cattle manure reduced the number of termites on crop fields by 21.6 and 29.7% compared to non-treated fields. Demissie et al. (2019) also reported that the application of maize stover as mulch combined with animal manure, maize-soybean intercrops and wood ash, maize-desmodium intercrops, and mulching combined with maize-soybean intercrops consistently reduced termite damage to maize in in field experiments conducted in Sibu Sire and GudayaBilla districts of East Wollega Zone of Oromia National Regional State. The authors claimed that the results were comparable to the standard check, Diazinon 60% EC. In addition, intercropping maize with desmodium, mulching

+ intercropping maize with soybean, and Diazinon 60% EC reduced the number of lodged plants per plot compared to control.

Planting resistant plants

This section focuses on the use of growing resistant grasses and trees and terracing which are viable and integrated approach in soil, water, and biodiversity conservation, rehabilitation of termite degraded lands, and termite management.

Chomo grass

Chomo grass, *Brachiaria humidicola* (Rendle) Schweick, is native to Africa, from South Sudan and Ethiopia in the north to South Africa and Namibia in the south. It is strongly stoloniferous and rhizomatous perennial grass, forming a dense ground cover. It grows on a very wide range of soil types from very acid-infertile (pH 3.5), to heavy cracking clays, to high pH coralline sands. It can be sown for permanent pasture for grazing and as ground cover for control of erosion and weeds and good nematode control. Chomo grass is a termite-resistant fodder grass and potential grass species to rehabilitate degraded land. It can also be used for rehabilitation of degraded land in humid, acidic soil and termite infested fields. It can maintain good ground cover under heavy grazing and thus can support high stocking rates (Adie and Duncan, 2013). Chomo grass is one such grass species expected to reclaim the degraded land because of its creeping nature that anchors its lower nodes to the ground and its resistance to intermittent attack by termites (Dereje et al., 2014).

According to a report by Dereje et al. (2014) some volunteer farmers in some villages of Diga district (East Wallaga zone), were increasingly engaged in producing fodder crops such as Rhodes grass (*Chloris gayana*), Napier grass (*Pennisetum purpureum*) and Chomo grass (*Brachiaria humidicola*) on their fields. In addition to their major significance as animal feed, these perennial grasses serve to rehabilitate the degraded soil which has developed as a result of improper land management and termite infestation. The grass is thought to compete well with the other two species in terms of tolerance to termites and for simplicity of its multiplication through its tillering habit.

In Ethiopia, this grass does well on degraded and termite infested fields in ManaSibu district. The Ethiopian Evangelical Church MekanaYesus-Development and Social Services Commission (EECMY-DASSC) plants *Chomo* grass as a project in closing areas as one of its strategies to promote environmental rehabilitation of degraded termite lands in ManaSibu district. The project considers the grass as an excellent innovation that

enables the rehabilitation of closed areas as it grows easily on degraded lands and is highly resistant to termites. The grass also harbors big ants locally known as 'Ganduleessa' which are natural enemies of termites.

Vetiver grass

Vetiver grass, *Vetiveria zizanioides* (L.) Nash, is a densely tufted bunch perennial plant native to India which can be easily established in both tropics and temperate regions of the world. The grass plays a vital role in watershed protection by slowing down and spreading runoff harmlessly on the farmland, recharging ground water, reducing siltation of drainage systems and water bodies, reducing agro-chemicals loading into water bodies and for rehabilitation of degraded soils. Vetiver grass could tolerate extremely high levels of heavy metals (Oshunsanya and Aliku, 2017).

Vetiver seems to tolerate a remarkable array of soil types and there are well-documented examples where vetiver is growing in very adverse soils, like on coastal sand dunes in South Africa, extremely acid soils (with pH as low as 4.0) in Louisiana, highly alkaline soils (pH up to 11) at Lucknow in India, black cotton clays (which heave and split and eject most plants) in Central India, barren soils with little fertility or organic matter in South China and other places, waterlogged soils in the black cotton clays, and even swamps, of India, parched land, in the arid state of Rajasthan of India, and Saline soils in Australia (National Research Council, 1993). Thus, vetiver can be easily grown in the acid soil of Wallaga zones.

The accumulation of experiences worldwide is convincing that vetiver hedges can indeed block the passage of soil, can keep topsoil on site and, over time, retard most surface erosion. In many cases they can also help fill up gullies. Contour hedges of vetiver can slow down and hold back moisture that would otherwise rush off and be lost to the slopes and this ability to hold moisture on the slopes, and thus increase infiltration (National Research Council, 1993). The improvement of agricultural crop yield is one of the resultant benefits of the effects of vetiver grass technology on soil and water conservation. This could be beneficial to farmers, especially those farming on sloppy lands that are usually prone to erosion. Vetiver grass improves crop harvest by reducing crop failure against the dry spell (Oshunsanya and Aliku, 2017). The very long extensive root system of vetiver grass holds soil particles together in place and the aerial part which grows in profuse reduces runoff water and control erosion increasing water infiltration.

Besides its other uses and rehabilitation of termite degraded lands, vetiver grass can be used as biological pest control (Oshunsanya and Aliku, 2017). Vetiver roots contain repellent compounds to insects including termites. Repellent compounds present in vetiver oil

extracted from roots of vetiver grass consists of several hundreds of compounds (Zhu et al., 2001) of which six are reported to possess insect repellent properties (Jain et al., 1982) including termites. There are experimental evidences that vetiver grass prevents plant damage by termites when applied mulches. Results of the research carried out in Guangxi University, China, after subjecting vetiver grass to insect attack, showed that of the 79 species of insect found on vetiver rows, only four attacked young vetiver leaves (Chen, 1999).

Vetiver grass can be used as one of the components of IPM systems. In these systems it could have a role as trap crop for specific pests and as refuge for natural enemies of many different pest species. A good agricultural management practice that ensures good crop health forms the basis of crop protection. Selection of suitable crop varieties, correct soil cultivation methods, the encouragement of natural enemies and even the judicious use of insecticides all have a role in integrated pest management. A trap crop such as vetiver together with good management practices could contribute significantly towards sustainable pest management. An increased understanding of the influence of plant- and associated arthropod-species diversity on pest populations will lead to the development of recommendations for utilizing vetiver grass and its associated arthropod-diversity as resources for pest management (National Research Council, 1993).

Vetiver Grass Technology (VGT) involves the correct application of this unique grass in erosion and sediment control in agricultural lands, land stabilization in civil construction, mining rehabilitation and flood mitigation (Truong, 1999). Vetiver grass technology has been applied globally for controlling soil erosion, stabilizing land and water resources and remediating contaminated lands in order to improve crop growth and yields.

Vetiver grass is also used as fodder for animal feed, mulch for improving soil moisture and fertility, and fibrous root system for holding soils in place could guarantee food production on a sustainable basis owing to the fact that this grass can withstand adverse environmental and climatic conditions, coupled with quick regeneration after pruning. Thus, when vetiver grass is applied appropriately, it could be a low-cost, simple and easily applicable multi-purpose soil and water conservation tool for sustainable agriculture. It is also a grass of great utility that could provide other means of revenue for local farmers (Oshunsanya and Aliku, 2017).

The use of vetiver grass has been regarded as a low-cost technology for soil and water conservation; on- and off-farm land and water sources stabilization and remediation of polluted soils; enhancement of water quality for irrigation purposes when compared with other soil conservation technologies. It could be a dynamic tool for mitigating environmental and agricultural problems, thereby enhancing crop yield and supporting all year round agricultural cultivation (Oshunsanya and Aliku,

2017).

Planting termite resistant trees

Not all trees are equally susceptible to termites and thus some are more resistant to termite attack. A German citizen named Cruze residing in Chalia town in Guliso district, planted termite resistant coniferous trees on completely termite degraded lands at different sites in Ayira district; the trees are now well established and converted to forest which is used in checking water erosion and important in soil conservation. Besides, the forest has become a habitat for different animals and thus it is important for their conservation; when harvested the termite and decay resistant trees are sold at high price and thus are used as source of income for the community as well as for the project which runs it.

Terracing

As per a discussion made in February 2015 with the agricultural development agents of the termite hot spot districts in western Wallaga, such as ManaSibu, Qiltu Kara and Ayira, mound destruction and queen removal were used mainly to control mound forming termites, *Macrotermes* termites. Terracing was widely used to control the non-mound forming termites such as *Microtermes* termites which have underground diffused nests. Because of difficulty in locating their nests and due to their cryptic nature, it is very difficult to control these termites.

Constructing physical soil and water conservation measures, such as terraces, trenches, and soil and stone bunds, can support the regeneration of native plant species. These can improve the quality and quantity of livestock feed that can be harvested from the enclosure. This, in turn, improves livestock production and increases the benefits obtained by local communities (Truong, 1999).

Terraces are constructed for soil and water conservation purposes on sloppy areas in Ethiopia. Besides soil and water conservation, terraces are also used for the control of termites in western Wallaga. Nowadays, farmers in western Wallaga highly appreciate the role of terraces in controlling termites and agricultural and rural development offices also encourage farmers to practice the method. The water stored in the terraces during rainy seasons enters termite tunnels and reaches the nests, suffocates and kills termites found in the nests and in the tunnels. The effect of terracing on termites can be evidenced as a large number of dead termites are seen floating on the surface of water in the terraces.

Mulatu and Eman (2016) reported that 15 m long and above open and closed level terraces protected *Eucalyptus* spp. wood baits from termite attack than the

control treatment in Gimbi district where *Eucalyptus* spp. are one of the most affected construction materials in the western Wallaga. In line with this, wide use of watershed-based approach is also crucial in the integrated approach. Watersheds are areas where rainfall surface run-off drains into one common stream, river or other water body. Area enclosure management is also another part of the integrated approach in which degraded lands are kept free from anthropogenic activities. Enclosures are areas closed off or otherwise protected from interference from people and domestic animals, with the goal of promoting natural regeneration of plants and reducing land degradation in formerly degraded communal grazing lands. In a cut-and-carry fodder system, local communities harvest grass within the enclosure and carry it to their homestead areas where livestock is kept. A cut-and-carry fodder system increases the quantity and quality of fodder, limits livestock movements and reduces grazing pressure (Mekuria et al., 2017). The combination of the different methods in an integrated approach leads to a synergistic effects and increased efficiency. One of the primary advantages of a watershed-based approach is the combined effect of conservation and development efforts on land management, as well as soil, water retention, and termite management.

CONCLUSION AND RECOMMENDATIONS

- (i) Termite problem is more serious in ONRS than it was in the past and it will continue to be a problem in the future unless more effective, economical, safe and easily applicable integrated methods of control are worked out.
- (ii) Currently the extent of yield loss of different crops due to termite damage is not available in the area. Thus, yield loss assessment of major and susceptible crops has to be conducted using chemically treated and untreated control replicated at different sites in termite hot spot districts.
- (iii) Abandoning of cultivating termite susceptible crops such as maize and teff and encouraging of growing other termite resistant crops such as sorghum and other root crops and vegetables.
- (iv) Planting of chomo grass and vetiver grass and terracing should be encouraged in the area because of their multipurpose especially in the integrated management of soil, water and termite management. Chomo and vetiver grasses can also be used as animal fodder, whereas farmers can sell resistant trees they plant at high price. The use of these methods have multipurpose, can be easily adopted by farmers, and they are farmer-friendly.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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