PREVALENCE OF TERMITES AND LEVEL OF THEIR DAMAGE ON MAJOR FIELD CROPS AND RANGELAND IN MANASIBU DISTRICT, WESTERN ETHIOPIA

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Dedication

To my father, the late Mr. Djirata Dako, and my wife Mrs. Mestawot Hailegeorgis, who understands.

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List of Abbreviations

ANOVA	Analysis of variance
df	Degree of freedom
DG	Dandi Gudi (kebele administration)
EARO	
FAO	Food and Agricultural Organization of the United Nations
HSD	Honestly Significant Difference
L K	Lelisa Komis (kebele administration)
LS	Lelisa Soyema (kebele administration)
m.a.s.l.	Meters above sea level
MDDAD	Manasibu District Department of Agricultural Development
OKa	Oddo Kabba (rangeland)
OKe	Oddo Kello (rangeland)
SE	Standard Error
SPSS	Statistical Product and Service Solutions
SR	Serbi (kebele administrayion)
UG	Ula Ganti (kebele administration)
USAID	United States Agency for International Development
WP	Wettable Powder

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Abstract

Current status of termite damage on maize (*Zea mays*), teff (*Eragrostis tef*), sorghum (*Sorghum vulgare*), and rangelands was studied in Manasibu District, western Ethiopia. Investigation was made in five Kebele administrations, within three farmers' fields in each Kebele administration, for each study crop.

Questionnaires were used to get baseline information from knowledgeable elders of farming community of the study sites. Percentages of responses to the questionnaires were considered as supplementary ideas in discussing the results obtained from field investigation.

Termite samples were collected from infested study crops and rangelands, and identified to genus level by the use of key to the Ethiopian termites. Six genera of termites: *Ancistrotermes, Macrotermes, Microtermes, Odontotermes, Pseudacanthotermes* and *Trinervitermes* were identified. The first five genera belonged to subfamily Macrotermitinae whereas *Trinervitermes* belonged to Nasutitermitinae. All of the genera were identified to belong to the family Termitidae. The number of samples of every genus identified was divided by total number of identified samples, and the percentage was taken as percentage occurrence for each respective genus. It was found that subterranean termites in general and *Microtermes* in particular, were the most prevalent termites in the study area.

The damages that termites caused to maize and sorghum were assessed by using quadrates, and by laying wooden frames in the quadrates for teff. For all the three crops, damages were assessed at vegetative, flowering, and maturity stages.

It was found that, the levels at which the three field crops were damaged by termites were significantly different from each other. Teff was the most seriously damaged crop in the study area. Damages at vegetative, flowering and maturity stages, within each crop, were also found to be significantly different from each other. On the other hand, when the levels of termite damages to the crops were compared between the five Kebeles, it was found that the differences were not significant.

To evaluate impact of termites on rangelands, in the absence and presence of grazing effects by livestock, three plots of rangelands were fenced and protected for six months. It was found that percent of cover vegetation and number of termite foraging holes per m^2 in the protected and unprotected plots of rangelands were significantly different.

Key words /phrases: Field crops, Prevalence, Rangeland, Termite.

1. INTRODUCTION

Termites are serious pests in tropical and subtropical Africa. They attack various field and plantation crops. Termites damage pasturelands, which are primarily used for livestock production. Ethiopia is among the tropical countries where crops and pasturelands are severely damaged by these pests. Increasing reports (Abdurahman Abdulahi, 1990; B & M Development Consultants, 1997; Gauchan *et al.*, 1998) indicated that the problem is more severe in western Ethiopia. There is, as a result, growing interest in evaluating the level of damages that termites cause to *Zea mays, Eragrostis tef* and *Sorghum vulgare* and also in assessing the possible interactions between grazing and termite impacts on rangelands. There is also a need to determine as to which type of termite group is more prevalent in fields of the crops and also in the rangelands.

In Ethiopia, there are 61 species of termites in 25 genera and four families, of which very few are regarded as pests (Abdurahman Abdulahi, 1990). According to Oromiya Agricultural Development Bureau (1996) and B&M Development Consultants (1997), in the last 40-50 years, the damages caused by termites in western Ethiopia became more and more acute. West Wollega zone has been known to suffer from increasing termite problems for the last 20 years, and now spreading rapidly in easterly direction from the affected districts of the west (Gauchan *et al.*, 1998). These reports underlined that the problem has become so complex that the farmers around Mendi, the major town of Manasibu District in western Ethiopia, have been forced to abandon their lands and move to less affected lowland areas. It is possible to note from this that termite problem in Manasibu District has serious socioecological implications. Cowie and Wood (1989) reported that termites in western Ethiopia damaged maize and teff. They reported that, up to 6%

of grass was covered by termite soil sheeting and an average of 15 foraging holes per Meter Square were observed in rangelands. They mentioned that this was from a quick estimation and not based on systematic investigation.

Most data available on the level of damages caused by termites on the major crops of Manasibu District are either obtained from farmers' complaints (B&M Development Consultants, 1997) or taken at most from field observations done at only one stage of development of the crops, and there is totally no data on teff (Cowie and Wood, 1989). Wood (1986a) recommended that fencing a small area of denuded rangeland would help to compare the impact of termites on rangeland in the presence and absence of grazing by livestock. The present study was, therefore, intended to evaluate the level of damages that termites caused on *Zea mays, Eragrostis tef,* and *Sorghum vulgare,* by consistent follow up in the three stages of development of the crops, on the same plots for each crop in the study sites. It was also aimed to assess the relation between overgrazing and termite impacts on rangelands.

Objectives of the study

General objective:

To investigate the current status of termite problems in Manasibu District

Specific objectives:

1. To study types and prevalence of termites in overgrazed and protected rangelands and on major crops of the study area
2. To investigate level of damages that the termites cause to some major crops
3. To investigate impact of termites on overgrazed (denuded) rangeland as compared to protected area.

2. LITERATURE REVIEW

2.1.Characteristic features of termite

Termites are social insects, which live as organized colonies in nests. Each colony is composed of morphologically differing castes. The head of termites is hypognathous or prognatous, and their mouthparts are typically blattoid and mandibulated, but varying in different castes (Gullan and Cranston, 2000). In soldiers, the mouthpart is highly modified into well-developed mandibles or into prolonged snout-like nasus, where as in the numerous workers it is specialized for gnawing all sorts of cellulosic materials. Glandular secretions are also commonly used for defense by various termite soldiers (Pearce, 1997). Compound eyes are reduced in most cases and antennae are long and moniliform with varying numbers of segments among species. Termites possess a sub-cylindrical and soft body, whose abdomen is broadly joined to thorax. A pair of segmented cerci is found on terminal segment of termite abdomen. Because of their poor abdominal sclerotization, mainly in worker casts, termites appear white and as a result, they are often erroneously referred to as 'white ants', in some parts of the world. However, they show many morphological and behavioral differences from ants. For example, termites are very soft-bodied and usually dark-colored; their front and hind wings are similar in shape and size, when present, but in ants the hind wings are smaller than the front ones (Matheson, 1961; Borror *et al.*, 1981; Potter,2002).

Termites have an incomplete metamorphosis whereas ants have complete metamorphosis. The most important behavioral feature that distinguishes termites from ants is that the male ant dies after its first nuptial flight and mating with the queen, but in termites the king lives as long as the queen does and mating occurs periodically in them (Wilson, 1971; Watson and Gay, 1991).

Richards and Davies (1978) and Pearce (1997) reported that termites are related more to cockroaches than to ants. Because of the presence of an anal lobe on the hind wing, and the presence of egg mass which is similar to the ootheca of cockroaches in it, an Australian species of termite, *Mastotermes darwiniensis* Froggatt, is looked upon as a sort of connecting link between the termites and cockroaches (Borror *et al.*, 1981).

Reproduction in termites is through laying fertilized eggs by the queen. Since there is usually only one reproductively active couple in a colony at a particular time, the individuals in that colony are derived from one pair of parents (Howse, 1970; Gullan and Cranston, 2000). In some specialized termites, the abdomens of queens gradually become swollen because of enlargement of ovarioles and fat bodies. Mature queens with such physogastric abdomens are highly fecund and the sizes of their colonies are large (Wilson, 1971; Richards and Davies, 1978). The egg laying capacity per day by a matured queen is 2000 to 3000 eggs in *Nasutitermes exitiosus* and *Coptotermes lacteus* (Watson and Gay, 1991), 4000 to 36,000 eggs in *Odontotermes badius* and *Macrotermes natalensis* (Howse, 1970). Development in termites shows three phases, as it is not complete metamorphosis. The nymph increases in size as different nymphal instars in a series of molts towards its adult form without a quiescent pupal stage, and internal developments also keep in steps with the external one (Harris, 1961).

Studies on food preference of termites indicate that the main nutritional ingredient in their food being cellulose, nearly all sources of this structural component, including wood, roots, twigs, mulch, paper, cardboard and fabrics made of cotton and other plant-based materials are consumed by them (Wood and Lee, 1972; Baklenov and Guseve, 1973; Cheok and Wong, 2001; Pesticide

Educational Resources, 2002). Some termites harvest fungi, and some other termites feed on humus and organic matter from the soil (Richards and Davies, 1978).

2.2. Termite classification

Termites can be separated taxonomically using many different features. According to Krishna (1970) and Pearce (1997), external morphology, internal features, feeding type, chemical and behavioral features can be used for this purpose. The shape and size of head and mandible, the presence or absence of teeth and their arrangements, shape of pronotum, etc are among external morphologies, which are used to distinguish different genera (Abdurahman Abdulahi, 1991). Shape of colon and cuticular structures in the esophagus and crop, as well as size, shape, number and arrangement of spines in the gut vary in different termites, in relation to their main diets (Watson and Gay, 1991; Pearce, 1997). Termites can also be divided as wood feeding, litter feeding, humus and soil feeding and fungus growing types. However, overlaps often occur in feeding habits of different termites. Some termites build epigeal mounds whereas others are subterranean and still other termites survive in dry or dump woods. There are also termites, which live in nests attached to the outer side of trees.

Different species of termites often exhibit differences in times of nuptial flights. Such behavioral variations help in distinguishing different groups of termites (Abdurahman Abdulahi, 1990). The classification of the order of termites, Isoptera, has changed many times. For example, Krishna (1970) classified it into six families as Mastotermitidae, Kalotermitidae, Hodotermitidae, Serritermitidae, Rhinotermitidae and Termitidae. On the other hand, Hickin (1971) recognized Termopsidae as a family among the above, but not Serritermitidae. Later, the known termite species were grouped into seven families (Wood *et al.*, 1986 cited in Abdurahman Abdulahi).

These are Mastotermitidae, Hodotermitidae, Rhinotermitidae, Kalotermitidae, Serritemitidae, Termopsidae and Termitidae. The first six families are collectively known as 'lower' termites and Termitidae are referred to as 'higher' termites. The lower termites largely depend on wood for their diet, and their symbiotic intestinal microorganisms are dominated by cellulolytic protozoa (Honigberg, 1970). However, the 'higher' termites lack symbiotic protozoa (Logan *et al.*, 1990). The fungus-grower *Macrotermes subhyalinus* is benefited from cellulolytic enzyme of *Termitomyces* (Abo-khatwa, 1978; Gullan and Cranston, 2000).

From the seven families of termites, Mastotermitidae is the most primitive. It is represented by a single surviving species, *Mastotermes darwiniensis* Froggatt, and is confined to northern Australia and New Guinea (Logan *et al.*, 1990). Wilson (1971) noted that the colonies of this species which nest in soil, are immense; the largest containing over one million individuals. They are thought to be the most destructive termite species in Australia and the most serious insect pest of any kind in the northern part of that country.

Kalotermitidae is commonly known as dry wood termite. The members of this family live in small colonies by excavating in wood, generally with no contact with soil (Harris, 1961; Krishna, 1970). They are also regarded as primitive termites and appear to have evolved from Mastotermitid base (Wilson, 1971). Some species cause damage to building and injury to woody tissues, but they are generally minor pests in agriculture and forestry (Logan *et al.*, 1990; Constantino, 2002).

Termopsidae and Hodotermitidae, which are now independent families, had once been classified as subfamilies Termopsinae and Hodotermitinae under the family Hodotermitidae, by Synder

(1949) and Emerson (1955,1968), as cited in Krishna (1970). Recent studies and classification recognized Termopsidae as a small family of termites living in damp, rotten wood, partly or wholly buried under ground and they are distributed essentially in the north warm zones and are rarely pests (Hickin, 1971; Logan *et al.*, 1990). In this primitive termite family, there are three recognized subfamilies (Harris, 1961).

Hodotermitids are known as harvester termites for that they collect grass and grass litter and take back to their nests. The three living genera of this family are *Hodotermes, Microhodotermes* and *Anacanthotermes. Hodotermes* build subterranean nests and damage pastures more seriously, where there is excessive grazing by livestock and may occasionally damage crop (Cowie, *et al.*, 1990; Logan *et al.*, 1990). Only *Hodotermes* is found in Ethiopia (Abdurahiman Abdulahi, 1990).

The family Rhinotermitidae is composed of wood eating termites. They are widespread groups with underground nests. This family is grouped into six subfamilies (Harris, 1961; Krishna, 1970).

Krishna (1970) reviewed the former classification of Serritermitidae, and stated that, it was placed as a subfamily under Rhinotermitidae in 1911 by Holmgren, but as of 1950 Ahmed placed it under Termitidae where it had remained until it was elevated to full family status in 1965 by Emerson. Serritermitidae is known by only South American species and it is not a pest.

Termitidae is composed of termites referred to as 'higher' termites because of their greater specializations for social life. The four subfamilies of Termitidae are Apicotermitinae, Nasutitermitinae, Macrotermitinae and Termitinae, and they are thought to make up over 75% of the total termite species (Wilson, 1971; Logan *et al.*, 1990). The members of Termitidae show diversity in nest type, pest status, morphology, and defense structures of soldiers. They lack cellulolytic protozoa in their guts. Macrotermitinae, the fungus-growers, are widely distributed throughout the old world except in desert areas and at higher altitudes (Logan *et al.*, 1990).

Classification of termites appears difficult. Different authorities (Hickin, 1971; Wood and Cowie, 1989; Constantino, 2002) similarly stated that identification of termites has remained a difficult task, and particularly Hickin (1971) claimed that termite identification requires extensive taxonomic training. According to Constantino (2002), very few specialists are able to identify Neotropical termite species, and taxonomy of termites in South America has been a major impediment. Big differences are observed among the number of species reported by different authors. For example, the described numbers of species were reported to be 1914 (Wilson, 1971), 1900 (Borror *et al.*, 1989), 2500 (Logan *et al.* 1990; Pearce, 1997), 2300 (Daly *et al.*, 1998) and 3000 (Muntha, 1990, cited in Daniel Getahun, 2003).

2.3. Termites as social insects

All termites are eusocial insects and hence live in organized family groups or colonies. Wilson (1971) noted that, eusociality is defined in terms of three basic qualities that should be fulfilled by members of the colony, for that group to be considered eusocial. These traits are cooperative brood care, reproductive division of labor and overlap between generations. In termites, individuals of the same species in a colony cooperate in caring for the young, sterile individuals work on behalf of the reproductive, and there is some period of time at which the offspring assist their parents. Termites engage in a unique way of anal liquid exchange, trophallaxis. Howse (1970) reported that trophallaxis is of immense importance to the structure and cohesion of insect societies like that of termites. Species of termite live as a coherent family group in which each individual performs a specific biological function, which is essential for survival of the whole group.

Colony foundation begins by the release of large numbers of alates from the parent colonies. They leave the colony in swarming or colonizing flight; shed their wings at the basal suture and tandem pairs of a male and a female are formed, and seek out a nesting site in soil or wood where they excavate and seal themselves into a small nuptial chamber (Borror *et al.*, 1989; Watson and Gay, 1991). They finally mate and establish the colony. The emergence of alates and consequent swarming is considered as the event, which marks the annual reproductive cycle. This flight of alates takes place at a specific season in a year and time of a day, and it varies from one group of termite to the other (Abdurahman Abdulahi, 1990). Sizes of colonies vary from species to species and depend on age of a colony. Bouillon (1970) on the other hand, stated that the optimum numerical level of a colony appears to be limited by combined factors such as nutritive capacity of the worker caste and fecundity of the royal couple. Matured colonies may range in size from a few hundred individuals, as the case of many kalotermitids, to over a million as in the case of *Mastotrmes*, some species of *Coptotermes*, and some Termitidae (Watson and Gay, 1991). Gay and Calaby (1970) reported that a mature mound dwelling colony had been observed to persist with undiminished vigor for 35 years and since the mound was intact at the time of observation, the authors claimed that it could have survived for over 50 years.

Among morphologically differing castes, primary reproductives, the king and the queen, are the most sexually developed members. They have well developed wings and compound eyes. Their bodies are fully sclerotized and heavily pigmented. The females are usually greater than the males, and in some tropical species, a queen can reach a size of 11 cm compared with one to two cm for the king (Borror *et al.*, 1989). Some queens show extra ordinary distended abdomen, the situation known as physogastry, up to about 500% -1000% of their original sizes because of fat in their bodies and proliferation of ovarioles (Watson and Gay, 1991; Daly *et al.,* 1998). The main function of the royal pair is reproduction; the queen is fertilized by the king and lays eggs.

Apart from primary reproductives, a colony may recruit new reproductives (neotenics) to supplement the already existing old reproductives or to replace the lost ones; or new reproductives may be needed in a distant part of a wide or a fragmented colony (Crozier and Pamilo, 1996). According to Pearce (1997) supplementary reproductives, neotenics, in most cases develop from nymphs with wing pads (brachypterous neotenics) already present in the nest or may develop from wingless workers (ergatoid or apterous neotenics). In both cases, supplementary reproductives never reach swarming stage and no nuptial flights in them. The neotenics are less fecund and short-lived compared to primary reproductives (Pearce, 1997). Many neotenics may be required to maintain a colony in which only one imaginal pairs could be sufficient. They are also morphologically different from the first-form reproductives in that they are generally less heavily pigmented and usually possess small eyes (Borror *et al.*, 1981). In termite colonies, non-functional, aged as well as surplus reproductives are eliminated by workers. Pearce (1997) stated that, if replacement reproductives are produced and become disabling, the workers might attack them. Workers maintain characteristic size of a colony by eliminating excess supplementary reproductives. In 'higher' termites, worker caste consists of individuals incapable of further molts. Therefore, they belong to terminal caste and are sterile adults. When there is size variation in worker caste of the same colony, it means both sexes are involved in this caste. For example, in *Macrotermes michaelensis* Sjöstedt, minor workers are females and the major ones are males (Pearce, 1997). In workers of higher termites, no wing buds, and their eyes are reduced or completely absent (Wilson, 1971). Workers are generally soft-bodied and pale-colored. In lower termites such as Mastotermitidae, Rhinotermitidae and Termopsidae the workers are often termed pseudo workers or pseudergates whereas in the Kalotermitidae they are known as nymphs (Pearce, 1997). According to Crozier and Pamilo (1996), and Gullan and Cranston (2000) the working individuals in lower termites are capable of molting into reproductives and hence are developmentally plastic.

Workers perform most of the works in a colony. They collect food and feed individuals of other castes and newly hatched young; build and clean nests, passageways and tunnels. In Macrotermitinae, the responsibility of growing fungus garden is held by the workers (Wood and Johnson, 1986, cited in Haimanot Abebe, 2002). Workers are the most numerous individuals in a colony. For example, Akhtar (1977) noted that worker-soldier ratio in *Odontotermes lokanandi* was 12:1. Added to such big proportion, the feeding habit of worker caste causes widespread destruction in both natural and agroecosystems, for which termites are referred to as notorious insects.

Soldier caste is equipped with morphological features for defense. Soldiers of most termites possess highly sclerotized head with tough and enlarged mandibles, which in some cases bear scissor-like blades. On the other hand, in some termitids, mandibles are vestigial and the heads are drawn into nozzle-shaped projections bearing opening of frontal gland through which repellent or entangling substances are sprayed against invaders (Hickin, 1971; Borror *et al.*, 1981; Pearce, 1997; Daly *et al.*, 1998). In subfamily Nasutitermitinae, the soldiers exclusively use such chemical means for defense of the colony (Borror *et al.*; 1989). Soldiers of different sex and size are found in some species of termites. Some termites have two and still others have three kinds of soldiers, which vary in their body size, shapes of head, and mandibles (Pearce, 1997). For example, *Acanthotermes acanthothorax* (Macrotermitinae) has three kinds of soldiers. Minor soldiers defend the workers foraging outside, whereas the major ones defend the colony in the nest (Wood and Johnson, 1989, cited in Abdurahiman Abdulahi, 1990). Some termite genera, such as *Anoplotermes,* are known to lack soldier caste; as a result, the nymph and worker defend the colony (Borror *et al.*, 1989). It is not unusual to find soldier - reproductive intercaste, where some of the female characteristics such as wing rudiments or ovaries with eggs, may be present in some soldiers (Pearce, 1997). It was stated that, such intercastes were often found in the genus *Zootermopsis,* more commonly, where the original reproductives had been missing. In a termite colony, in addition to the above principal castes, immature forms such as eggs and nymphs are also present.

2.4. Nest system and foraging in termites

New colonies of termites are formed following dispersal flights of the royal pairs, which usually take place synchronously in different colonies of a species over a given area or district (Daly *et al.*, 1998). On landing, the royal pairs look for a crack or gap in wood or moist area of soil in which to burrow (Pearce, 1997) and the female excavates a chamber where eggs are laid (Wood, 1988). The queen and the king usually remain in the royal chamber, sometimes known as royal cell, which becomes the focal point of the nest system. The workers construct and enlarge the nest and foraging galleries that radiate away from the main nest towards the sources of food and water. Construction materials are largely composed of earth and wood mixed with saliva and faecal matter (Richards and Davies, 1978). Pearce (1997) reported that it had been suggested that nest building initially evolved as a defense reaction in which the termite faeces were used to seal off intruders from nest. Living and foraging within a more or less controlled environment minimizes the probability of exposure to their natural enemies. It is also suggested that nests are essential in that they provide the termites with stabilized optimum temperature and humidity (Harris, 1961). Termites construct various nest types. They can be in wood, arboreal (attached to outer part of wood), subterranean, or epigeal mound (Harris, 1961; Noirot, 1970; Pearce, 1997). Watson and Gay (1991) stated that the simplest form of nest is constructed by Kolotermitidae and Termopsidae, in which the whole colony lives in chambers and galleries excavated within wood. In such cases, the termites get their nourishment from within the wood itself. Colonies in such types of nests are characterized by their small sizes.

Arboreal types of nests are attached to outside of trees. In some cases, they are connected to ground by covering galleries, which descend the trunk. They may have regular structure of wood carton of fine texture with fine superficial envelope and are homogenous throughout, except for the harder and massive section that surrounds the royal cell (Noirot, 1970). Arboreal nests are found only in Termitidae.

Subterranean nests can be simple and diffuse structures of galleries with no sharp boundaries and network of chambers or may be complex type with a larger chamber connected by subterranean galleries (Noirot, 1970).*Coptotermes, Microcerotermes, Nasutitermes, Microtermes, Ancistrotermes* are some examples of termite groups known by constructing subterranean nests, at various degrees of complexities. Subterranean termites pose greater pest threats compared to dry wood termites (Pearce, 1997).

Epigeal nests have subterranean bases, because the colony founders begin their new lives by settling down in soil. It is after production of workers that the mound gradually grows by layers of soil and termite faeces (Gullan and Cranston, 2000). Mounds vary in shape, size and structure according to the type of the species, and within the same species in different climatic zones (Watson and Gay, 1991; Pearce, 1997). In some areas, *Cubitermes* construct mounds, which are mushroom-shaped and with drip tips to help remove rain quickly, whereas nests of the same species lack this umbrella cap, in dry areas (Pearce, 1997). Wood (1988) noted that the mounds of *Macrotermes belicosus,* in parts of West Africa, are as tall as nine meters in height. Their aboveground parts have large central air spaces whose walls are perforated by galleries. In Kenya and Uganda, *Macrotermes subhyalinus* built mounds of different shapes and internal architectures, in relation to variations in temperature and soil types. Australian species build termitaria of very distinctive forms, such as low, dome-shaped to upright mounds, as well as tall columnar structures (Watson and Gay, 1991). In line with this, the most complex mounds of *Coptotermes* and *Nasutitermes* species in Australia, consist of densely packed galleries in which the eggs, young and molting individuals shelter, and also contain flat cell (royal cell) in which the reproductives live. Epigeal nest is never found in Mastotermitidae, Kalotermitidae, or Termopsidae and the raised cones of excavated materials above the ground in certain Hodotermitidae are not populated (Noirot, 1970). True epigeal nests are built by some of the Rhinotermitidae, but are more common in Termitidae.

From nests of various types, termites move about for foraging through associated galleries and runways in almost all cases. Foraging can be along haul in some termites or within the nest, as in the dry wood termites. The workers move about away from the main chamber, in most cases through galleries and runways, and in rare cases out of galleries on surface on humid days or at night. The defensive caste is also out with the workers during foraging. Soil galleries are constructed by soil moistened with saliva, molding it into a soft pellet with mouthparts and applying it with rocking movement, but soil runways are usually composed of high proportion of clay and sand particles, which are moistened with saliva (Pearce, 1997). Soil sheeting is relatively thinner and covers large areas of soil under which termites travel, and may cover plants or other wood materials. The large mounds of *Macrotermes* in Africa, or subterranean nests of *Odontotermes* in Africa and India, were associated with galleries radiating outward as long distance as 50m. or even more (Wood, 1988), whereas Daly *et al.*, (1998) stated that passageways radiating from a termitarium of about 50 years or more were found to extend to food sources up to 100m. Wood (1988) reported that, a single mound of *Macrotermes michaelensis* in Kenya was associated with 6 km. of subterranean galleries and 72,000 storage pits in an area of 8000 m^2. It is possible to note how serious the threats that termite pests pose to crops, rangelands and forestry could be, from such intensive nesting and foraging system as well as from enormous number of foragers within each colony.

2.5. Geographical distribution

Termites are mainly tropical and subtropical insects whose distribution extends up to 45^0 N and 50^0 S (Harris, 1970; Kooyman and Onck, 1987; Wood, 1988). According to Pearce (1997), the numbers, species and nest varieties of termites increase towards the equator. The portion of the earth in which they occur extends over two-thirds of the landmass involving some 100 countries with over three billion human population (Wood and Johnson, 1986, cited in Abdurahman Abdulahi, 1990). Therefore, it is evident that termites are more abundant in the resource- rich and economic-poor tropical nations. In the same way as abundance of termites decreases with increased latitude, they are rarely found at altitudes above 3000m (Wood, 1988).

Bouillon (1970) stated that the Ethiopian zoogeographical region appears the richest in genera as well as in species of termites and it is known for its endemic fauna. Of 570 species in the region, 87.5% are considered endemic.

Neotropical and oriental regions are also rich in termite species. Neotropical region is the second to the Ethiopian zoogeographical region in number of described species and abundance of termites, according to Aranjo (1970). Roonwal (1970) reported that one-fourth of the total species number in the world occurs in Oriental Region.

The Australian termites contain representatives of Mastotermitidae, Termopsidae, Kalotermitidae, Rhinotermitidae and Termitidae within 27 genera of which 175 species are described (Gay and Calaby, 1970). Mastotermitidae, with its only one representative species, *Mastotermes darwiniensis* is endemic to Australia whereas the true harvester termites belonging to the Hodotermitidae and the fungus-growing termites belonging to the subfamily Macrotermitinae are absent among termites of this region (Gay and Callaby, 1970; Watson and Gay, 1991).

Unlike the other zoogeographical regions, since most parts of Nearctic and Palearctic regions fall in temperate zones of northern hemisphere, their termite fauna cannot be expected to be so abundant. For example, Palearctic Region, whose species number is only 41 includes Europe, Africa and Arabia north of tropic of cancer (Harris, 1970), and Nearctic is the area of American continent which lies between $31^0 37'$ N and the Arctic circle (Weesner, 1970).

It is evident that geographical distribution of termites is related to temperature and moisture, both of which show variations with changes in altitudes and latitudes.

2.6 Economical significance of termites

From the economic point of view, the activities of termites can be described as destructive or beneficial. However, the dark side of their story appears to be more realized than their important roles, by many people. It is worth mentioning here that not all species of termites are pests. Pearce (1997) described that out of the few thousand known species of termites, only a few hundred cause damages, and serious pests are around 50 species.

2.6.1. Benefits of termites

Termites are eaten by man in many parts of the world. Alates are so rich in protein and fat content that they are consumed by some family members in Africa (Pearce, 1997). According to this author, termites are used as food by some domestic animals, and they were once used as medicine in Australia and South America. Mushrooms that grow out of fungus gardens in mounds of some termites were eaten by Chinese people and sold in markets in Asia and tropical Africa. Bachelier (1971) claimed that the epigeal mound-building termites improve soil texture by bringing up materials from deep in earth, and the concentrated subterranean galleries facilitate passage of air and water, thus checking erosion. The return of organic matter and nutrient to the ecosystem via faeces and salivary secretions and corpses is another important role of termites (Wood, 1976). This is more important in colonies of large sizes within a heavily colonized soil. Wood and Lee (1972) claimed that termite population in subtropical and tropical soils might reach $10,000/m^2$ with a biomass of $50g/m^2$, and a total of termite metabolism of about

100kcal/m^2/year, the same order as the metabolism of the largest known population of herbivorous mammals. Many predators consume termites and hence the termites are integral part of food chain in the ecological system. Mammals such as armadillo and bat, different aves, various reptiles and amphibians, and fish as well as numerous species of insects feed on termites (Aranjo, 1970). Fishes swallow alates that fall on water bodies. The pig-like nocturnal mammal, Aardvark, *Orycteropus capensis* is known to prey on termites in Africa (Hickin-1971). A study on colony foundation and development in a species of Macrotermitinae in the Sudan (El Bakri *et al.*, 1989) showed that most of the alates were lost to the predators, either to bats while swarming, or to lizards, toads or various ants on the ground.

The role of termite nests in harboring and housing some fauna, the termatophiles, is another benefit that termites present to other animals. Some of these termatophies, including other arthropods, feed on eggs and young brood. Some are merely scavengers feeding on nest debris (Watson and Gay, 1991).

2.6.2. Termites as pests

Owing to their feeding behavior, termites are injurious to miscellaneous field and plantation crops, forestry, and rangelands as well as wooden materials. Different reports showed that termites cause serious damages to plantation crops such as cacao, coconut, coffee, oil palm, rubber tree, sugarcane and tea; to field crops such as groundnut, cotton, rice, wheat, maize; to range lands, and trees (Harris, 1961; Hickin, 1971). Hickin (1971) reported that 20% of palm seedling in India, 80% of cotton in the Sudan, 6% of wheat and 22% of maize in India were lost annually due to termite damages. The annual loss in sunflower seeds due to termites reached 66%

in Tanganyika (Harris, 1961). Termites, due to many factors, do not equally damage all crops. Plants such as sugarcane and maize are able to photosynthesize, even at low concentration of carbon, and make higher molecules of glucose per unit leaf area and also grow quickly, compared to many temperate plants, and are attacked more by termites (Pearce, 1997). It was stated that *Zootermopsis* had preferred 1% glucose solution, and this may be an indication that sugar can be stimulatory for termite attack on some plants. Agarwal (1972) stated that emerging roots and shoots of sugarcane being seriously eaten by termites, high mortality up to 40% - 60% had been encountered in them.

Attack by termites on crops has various forms. Cowie and Wood (1989) described more or less three forms, from their observation in Ethiopia. Cutting stems of young plants near the base by *Macrotermes subhyalinus, Odontotermes* spp., or *Pseudacanthotermes militaris* (Hagen); hollowing out of subterranean parts of mature plants by *Micromeres* and *Ancistrotermes*; and covering the outer side of stem and leaves with soil sheeting have been the main forms of termite damages to crops. Crops stored on ground in houses or gardens are also attacked by termites. Termites cause indirect harm to growing crops by depriving them off mulches and vegetation residues before they are broken down far enough to be available to the plants (Harris, 1971).

In Africa, Australia and South America termites consume up to one-third of the total annual production of dead wood, leaves and grass (Blench and Sommer, 1999). They present serious threats to the world pasturelands, which are used primarily for livestock production. Overgrazing was found to increase the population density of grass feeding termites in South Africa, and the range of damage was from 20% to 100% in a dry year (Coaton, 1950 cited in Haimanot Abebe, 2002). Among pasture pests, *Hodotermes mosambicus* causes serious depletion of forage that would otherwise be available for grazing animals, in drier districts of eastern and southern Africa (Hickin, 1971). In some Asian countries, loss of pasture due to termite pests was estimated at 20%. Workers and soldiers of Hodotermitidae possess eyes and, indeed, actively forage and carry back their 'harvesting' of grass to their subterranean nests in day light with no need of covered runways. By cutting young seedlings or hollowing out matured stems of living trees, in many tropical and subtropical countries, termites cause economic losses to commercially important timber species (Gay and Callaby, 1970; Watson and Gay, 1991). Considerable damages are also caused to fences, buildings and other woodwork materials.

Damages caused by termites are not limited to only economic losses. Pearce (1997) explained that much of the history of humankind had been lost due to termites eating books; buildings and even destroying cave paintings and archaeological remains. They had destroyed villages in India and Egypt and the inhabitants were forced to move to other areas, according to the author.

In many nations, where termites are serious pests, various private companies, research institutions and government organizations have attempted to avert the problem. In the meantime much amount of money, labor forces including trained manpower, and materials have been used. Hickin (1971) reported that the cost to control the native subterranean termites in the United States, together with the damages to residential and industrial properties was estimated to be $250 million annually starting from 1961, which had been only $100 million about ten years back from this last report. However, more recent information indicated that there has been sharp increment in the cost to control termite infestation in the same nation. It was estimated at $1.5 billion (Brooks *et al.*, 2003) whereas the amount spent for prevention and treatment in structure has reached approximately $ 2 billion annually (Jones, 2003).

On the other hand, it was stated that control of subterranean termites has been a challenging proposition, given their small size, cryptic habits, and tenacious foraging behavior (Jones, 2003) and they are responsible for 95% of termite damages to wood and wood products in United States of America (Brooks *et al.*, 2003).

2.7. Termite situation in Ethiopia

Ethiopia is among the countries known for their termite fauna in tropical Africa. The Ethiopian zoogeographical region, in general, is the richest in termite fauna and has been center of origin for many species (Bouillon, 1970). Ethiopia is also among the countries in tropical Africa which are known for their termite fauna. Cowie *et al.*; (1990) cited in Abdurahman Abdulahi (1991) reported that the Ethiopian termite fauna consist of 61 species belonging to 25 genera and four families. Only very few of these are regarded as pests of different resources, such as agricultural crops, forestry seedlings and pasture lands (Abdurahman Abdulahi, 1991). The four families composed of pest species in Ethiopia are Kalotermitidae, Hodotermitidae, Rhinotermitidea and Termitidae (Abdurahman Abdulahi, 1991). Species feeding on dead plant materials, soil organic matter, or herbivore dung are found among the termites of Ethiopia.

Cowie and Wood (1989) reported that the Ethiopian fauna consist of species, which are widely distributed in sub-Saharan Africa. Among these, species of *Macrotermes, Microtermes, Synacanthotermes, Microcerotermes, and Trinervitermes* are the main. They noted that majority of Ethiopian termites are found in Macrotermitinae and it is these, which constitute the most serious threat to agriculture, forestry and rural buildings whereas the Nasutitermitinae eat only dead grass and appear harmless in Ethiopia. Wood (1986a) visited some parts of Ethiopia, which had been reported by the Ethiopian Ministry of Agriculture to be infested by termites. These parts were Sidamo, Gamogofa, Wollega, Illubabor, Hararge, Shewa and Keffa areas. His observation showed that maize, teff and sorghum were the major crops, to most of these provinces, of which the first two crops were severely damaged by termites. However, by the time of the visit, it was reported that no damage was observed to standing sorghum, mainly in Wollega and Illubabor (western Ethiopia). Cowie and Wood (1989) stated that the majority of reports on damages caused by termites come from these western provinces of the country.

2.7.1. Problems of termites and their control in western Ethiopia

Almost all major annual crops grown in western Ethiopia are attacked by one or more species of termites, either at one stage of development or throughout growth stages (Abdurahman Abdulahi, 1990). Tree seedlings are also attacked by termites. It is common practice in western Ethiopia to build houses, fences and stores using untreated wood and grasses without proper stone foundation. As a result subterranean termites can easily attack the constructional materials. Bridges crossing streams are also destroyed by termites in the region. Houses survived for only about five to eight years after construction (Abdurahman Abdulahi, 1990). It is evident that frequent cutting of trees, in an attempt to replace miscellaneous constructional materials, which are destroyed by these pests, would unfortunately lead to deforestation and erosion and subsequent ecological disasters.

B&M Development Consultants (1997) stated that massive termite damages were observed in grazing land in Manasibu district, which led to degradation of pastureland and consequent overgrazing on the only available forage, and eventual erosion. Wood (1986a; 1986b) reviewed from his observations and from consistent reports of Ethiopian Ministry of Agriculture that termites pose serious threats to agricultural products, pasturelands and tree seedlings, in the western part of the nation. Some reports (Oromiya Agricultural Development Bureau, 1996; B & M Development Consultants, 1997) claimed that in the last 40-50 years the damages caused by termites in western Ethiopia have become more and more acute.

Damage is generally greater in exotic plants than indigenous plants, rain fed crops than irrigated crops, during dry periods than in regular rainfall, in plants under stress than healthy and vigorous plants, and in low land than highland areas (Gauchan *et al.*, 1998). They reported that the far west Wollega Zone of Oromiya Region has been known to suffer from increasing termite problems for the last 20 years, but it has been intensified in more recent years and was reportedly spreading rapidly in easterly direction, from the more affected districts in the west.

Abdurahman Abdulahi (1990) noted by citing Manasibu district Administrator (personal communication) that the first termite damage report came in 1938 from around Kiltu Kara, a small town in Manasibu district, western Ethiopia. The magnitude of the problem was not similar throughout west Wollega; it appears that Manasibu, Nedjo-Jarso, Ayra-Gulliso and Ghimbi were the most seriously affected districts (Abdurahma Abdulahi, 1990). The problem became so complex that the farmers from around Mendi, the major town of Manasibu district, have abandoned their lands and moved to lowland areas, where termite problem was thought to be less severe (Abdurahman Abdulahi, 1990; B&M Development Consultants, 1997). The farmers that migrated to lowland areas reached 6% of the total farm population (Abdurahman Abdulahi, 1990). On the other hand, these lowland areas were known for their malarial infestations and wild animal attack on livestock.

Termite control methods used by farmers in western Ethiopia include both traditional and chemical approaches. Flooding mounds, queen removal, and burning straws in excavated top part of mounds are among cultural methods. Western Synod branch based at Tchallia, a small town in Ayra-Gulliso District, participated in queen removal method of termite control by offering financial incentives for farmers who could bring termite queens (Abdurahman Abdulahi, 1990). The incentive was payment of US 48 cents for every queen brought. The campaign resulted in capture of over 23,000 *Macrotermes* queens within a period of one year between September 1987 and September 1988. The payment was later on reduced by half, because numerous farmers participated in the program. In July to November 1983, the Ethiopian Ministry of Agriculture conducted mound-poisoning campaign in Manasibu and Nedjo-Jarso districts by mobilizing all members of farming community in the areas (Abdurahman Abdulahi, 1990; B & M Development Consultants, 1997). Attempts were made to destruct and poison all visible mounds in cultivated fields and grazing lands within the two districts. Accordingly 12,078 Kg. Aldrin 40% WP. was applied at the rate of 12.5g or 25g per mound depending on the size of the mounds, 208,638 man-day (labor) involved, and a total of 635,908 mounds were treated. The cost of the project was estimated at US$ 78,954.

Another mound poisoning campaign was also undertaken by Ministry of Coffee and Tea Development, in Manasibu, Ghimbi, Ayra-Gullliso, and partially in Nedjo-Jarso and Yubdo districts during 1988 crop season (Abdurahman Abdulahi, 1990). In the meantime 13,077 Kg Heptachlor was applied, 79,197 man-day (labors) involved, and a total of 557,563 mounds were treated.

For over twenty years (1973-1995) crop protection staff of Ethiopian Ministry of Agriculture based in Wollega used to screen trials of termite control on teff, using aldrin 40% WP as seed treatment (B & M Development Consultant , 1997).The chemical method of termite control in Ethiopia has been based on the use of Organochlorin (Cyclodiene) insecticides, including aldrin, dieldrien, heptachlor, and chlorodane, which were banned in United States of America, western Europe and several other countries, because of their hazardous effects on human being, other terrestrial and aquatic animals including numerous soil fauna (Brown, 1978; USAID, 1985; FAO / WHO, 1994, cited in B & M Development Consultants, 1997).

3. MATERIALS AND METHODS

3.1. Study area

The study was conducted in Manasibu district, which is located in west Wollega Zone of Oromiya Regional State, western Ethiopia (Fig.1.). The district is climatically classified into lowland (68.3%), and middle highland (31.7%), within elevation ranges of 1400 to 1860 m.a.s.l. (Physical Planning Department of Oromiya, 2002). The soil type of the study area was nitosol, which is reddish brown to red in color, and clay in texture. Manasibu District has a rainy season between April and October. However, during the year 2003, the dry season extended up to mid June. The mean monthly rainfall by the year 2003 was 179.3 mm, with a maximum of 676.3 mm in August, and mean maximum and minimum annual temperatures were 30.5°c and 14°c respectively (National Meteorological Services Agency, 2004).

Five Kebele administrations were selected as the study sites from the district. Selection of the sites was made together with the Department of Agricultural Development of the district. Long history of termite infestation and related complaints of highland farming community were among the reasons for selecting the sites. Logistic reasons, such as availability of trails and roads, were also considered in the meantime. Accordingly, the five kebeles, in which the investigation was made, were Lelisa Soyema (N 9^0 43' and E 35^0 19'), Ula Ganti (N 9^0 45' and E 35^0 17'), Dandi Gudi (N 9^0 42' and 35^0 12'), Lelisa Komis (N 9^0 41′and E 35^0 18′) and Serbi (N 9^0 43' and E 35^0 15'). The Kebeles were within elevation ranges of 1568 to 1710 m.a.s.l.

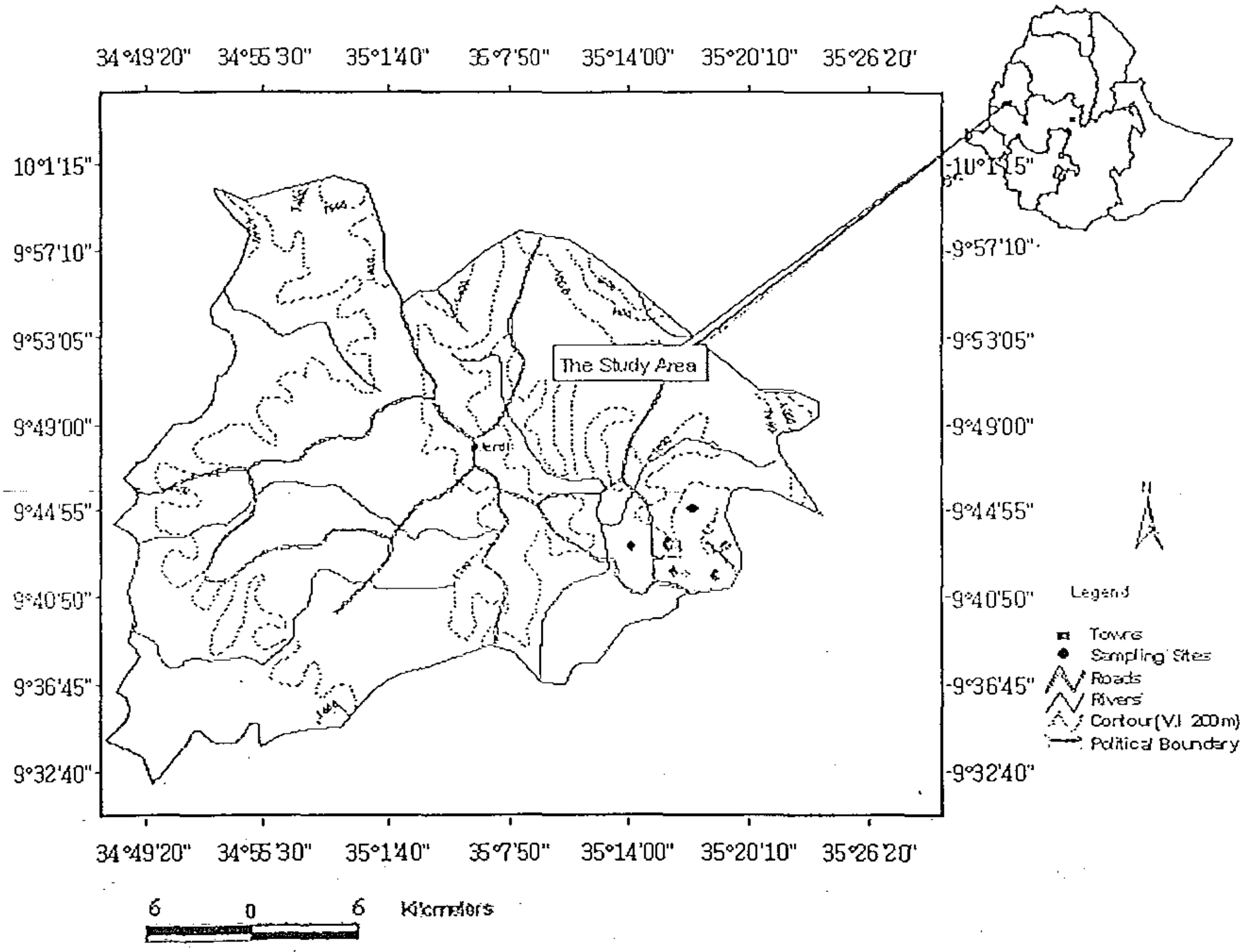

Fig 1.Location of study sites in Manasibu District, western Ethiopia.

Within two of the kebeles, three localities were used for investigation of termite impacts on rangelands. These were Odo Kello (N 9^0 41' and E 35^0 16') at 1614 m. a. s. l, Odo Kabba (N 9^0 41' and E 35^0 15') at 1568 m. a. s. l, and Serbi (N 9^0 43' and E 35^0 15') at 1640 m. a. s. l. Factor considered for selection of these localities was availability of rangelands with appropriate sizes (not less than three hectares) which would remain uncultivated throughout the study period.

These five adjacent Kebeles were known to have human population of 12,584, of which 50.1% were males and 49.9% were females (MDDAD, 2003). Total livestock population of these Kebeles was 9291. The study period was between August 2003 and February 2004, which included both rainy and dry seasons of the study area.

3.2. Collection and identification of termite samples

Termite samples were collected from infested maize (*Zea mays*), teff (*Eragrostis tef*), Sorghum (*Sorghum vulgare*), and rangelands, for identification and subsequent determination of their prevalence on the crops and in rangelands.

3.2.1. Sample collection

In the case of maize and sorghum, infested crops were uprooted and their roots were split, and stems were broken to drop the termites on plastic sheets. Termites in soil sheeting, on outer surfaces of standing crops, were also made to drop on plastic sheet. Shallow galleries at the immediate bases of infested crops, into which termites were observed to disappear through penetrated roots of the crops, were dug and the soil with termites was placed onto plastic sheets. In all cases, separate sheets were used for collection of the termites from different sources (colonies). At least 12 soldiers from each sheet were picked up with plastic forceps and transferred into separate vials containing 80% ethanol.

Termites observed foraging on teff, and grasses in rangelands, within soil sheeting and surface runways, were picked up together with soil by the use of spade and placed onto plastic sheets, from which their soldiers were transferred into vials containing 80% ethanol. All the vials were sealed, labeled and taken to Insect Science Research Laboratory, Science Faculty, for identification.

3.2.2. Identification of samples and determination of prevalence

Termites were investigated in the laboratory under binocular microscope and identified to genus level, by the use of key to the genera of Ethiopian termites (Abdurahman Abdulahi, 1991). Prevalence of each genus was determined as percentage occurrence, by dividing the number of occurrence of that genus (the times that it occurred among the samples) by the total number of the samples. Therefore percentage occurrence of termite genera in each study crop and the rangeland was determined.

3.3. Termite damage level investigation on crops

Questionnaires were used to get baseline information on the problems caused by termites to the crops and related aspects. Based on information obtained from farmers, fifty knowledgeable elders, ten from each Kebele were selected for this purpose (N = 50).

Assessment of damages caused to maize, teff and sorghum was done in farmers' field. The localities in which samplings were done were selected within the five Kebeles by the help of knowledgeable elders of the local people and officials of the Kebeles. For each study crop, three study fields were selected in each Kebele, and thus the investigation was done in 45 fields for all the three crops. Each study field for these crops had an area of 30m X 40m. Damage assessment was done at vegetative, tasseling /flowering/ heading, and maturity stages. All forms of termite attack, such as root penetration, stem cutting, and soil sheeting on parts of the crops were assessed, in the course of investigation. Damage was assessed at center and the four corners of fields of the study crops, within quadrates each with an area of 10m X 10m.

For sorghum and maize, damage was estimated following the method of Abdurahman Abdulahi (1990) with some modifications. He checked plants cut by termites among 20 consecutive plants per sampling site in each randomly selected five sites per field at approximately 10m intervals across the diagonal of the field. However, in this study, total count of damaged crops from each quadrate was divided by the total crop population in that quadrate, and taken as percentage of damaged plant. The mean damage from the five quadrates represented termite damage of that field. To avoid repeated counting, the damaged standing crops, which had already been counted were marked at the most tip parts, by the use of enamel paints.

For teff, percent of stems cut was quantified by laying a wooden frame of $1m^2$ containing 100 cells of each with $100cm^2$ on the crop field within the already defined quadrates. It was made up of wooden frames to which plastic strings were fixed, in such away that it contained hundred cells each with an area of 10cm X 10cm. Each cell represented 1% of $1m^2$. Mean damage from the five quadrates represented mean percent damaged plants in each field of teff.

3.4. Investigation of termite impacts on rangelands.

General surveys were made on and around the rangelands at the beginning of the study period. Questionnaires were used to get baseline information regarding impacts of termites on rangelands from fifty knowledgeable elders of the study area. Fences were constructed on 50m X 50m plots of selected rangelands to exclude grazing by livestock. The fenced areas were guarded from the last week of August 2003 up to the first week of March 2004, while the areas outside of the fences were left free for livestock grazing. At the end of the 6^{th} month, percentage of vegetation cover (grass cover) and number of termite foraging holes per m^2 were recorded in protected and in unprotected plots of rangelands which were located at a close proximity of one hundred meters from the protected ones. For the purpose of determination of foraging holes and vegetation cover, five quadrates each with an area of 10mX10m were formed, in such away that one quadrate was located at the center and the other four were located at the four corners in all the plots. A wooden frame of $1m^2$, which contained hundred cells each with an area of $100cm^2$, was used to quantify percentage of vegetation cover. Mean of the values from the five respective quadrates were considered as mean percentage of vegetation cover, and mean number of termite foraging holes per m^2. Within these quadrates, effect of treatment (fencing and non-fencing) on height of grasses was also observed.

3.5. Data analysis

Data on termite damage to crops were analyzed by SPSS 10.0 (Windows, 2000). One way analysis of variance (ANOVA) was performed to determine the level of variance, and mean comparison was done by the use of Tukey's HSD, (honestly significant difference) at 5% level. Based on nature of the data, arcsine transformation (for maize and teff) and square root transformation (for sorghum) were used to normalize the data, (Gomez and Gomez, 1984). Independent t-test was used to compare numbers of termite foraging holes as well as percentage of vegetation cover, which were obtained from protected and unprotected plots of rangelands in the study area.

4. RESULTS

4.1. Survey

Most parts of the study area were characterized by undulating topography, with riverine forests in the valleys, and highly eroded and denuded hillsides. The forests were occupied by coffee plantations in most cases, but maize was also grown in the valleys, following riverbanks in some localities. No termite infestations were encountered in such wetlands. In hillside rangelands, livestock were frequently observed grazing throughout the study period. The soil looks compacted and dry. Epigeal termite nests were rarely encountered. A total of three mounds were observed in all the three rangelands surveyed. The mounds were dome-shaped, having an average height of 50cm. In those rangelands, they were all confined to under shades of bushes.

Most of the local people believed that there was positive correlation between livestock population and termite damage on rangelands (Table 4.1.).

Table 4.1 Responses of local people on the relationships between livestock population and termite impacts on rangelands.

Responses	% of respondents
No relationship	10
Termites follow trails of livestock	78
Damage caused by termites was more serious in overgrazed rangelands	12

Maize, teff and sorghum were observed to be the major crops of the study area. About 52% of local people said maize, teff, and sorghum were the most seriously damaged crops by termites, among other crops (Table 4.2).

Table 4.2 Responses on the types of crops most seriously damaged by termites.

Crops most seriously damaged by termites	% of respondents
Maize, teff and sorghum	52
Maize, teff and millet	28
Maize, teff and barely	6
Maize, teff, sorghum, barely, sugarcane, and pepper	14

All of the respondents stated that they experienced big differences in annual yield per hectare, when production of these crops before and after occurrences of termites were compared (Table 4.3).

Table 4.3 Yield of maize, teff and sorghum per hectare, before and after occurrences of termites, in quintal.

Responses	% of respondents
I. Maize	
1. Before termite occurrence	
30	36
38	64
2. After termite occurrence	
4	80
6	20
II. Teff	
1. Before termite occurrence	
20	42
26	58
2.After termite occurrence	
½	22
0	78
III. Sorghum	
1. Before termite occurrence	
38	68
44	32
2. After termite occurrence	
10	46
12	54

Even though majority of the respondents (74%) said that the reason for such a reduction in annual yield was termite infestation, the remaining 26% argued that erosion and soil exhaustion also played significant roles in addition to termite infestation in reducing yield in the mentioned crops. It was believed by most of the local people (74%) that, termite problems had been aggravated, year after year, by factors such as deforestation and overgrazing and, the problem would ultimately result in complex sociological and economical difficulties in the future (Tale 4.4).

Table 4.4 Factors which had aggravated termite problems and their future effects.

Responses	% of respondents
Factors:	
Clearing of surface vegetation and opening up of forests for cultivation	22
Overgrazing and depletion of grasses	42
Termites population increased	36
Further effects of termite problems:	
No wooden materials for construction and no straw of teff for plastering of walls of muddy houses for the future	24
No hope for animal production	22
Population migration	54

About 70% of the respondents claimed that serious termite damage to crops was associated with termites which had been observed in fields of crops without any visible mound in their localities, whereas 30% believed that termite damage to crops did not show any difference whether there were mounds or not in the localities. All of the local people who responded to questionnaires informed that some localities were relatively less infested by termites than others, for various reasons (Table 4.5).

Table 4.5 Reasons why some localities were less infested by termites than others

Possible reasons	% of respondents
Their soil had high humus content and were black in color	66
Their soil was with high proportions of gravel	12
The localities had been less frequently grazed and not cultivated	22

Very small proportion of the respondents of the local people (10%) said that they had been using chemical control to minimize or avoid termite damage. However various indigenous methods were being used (Table 4.6).

Table 4.6 Control methods used by the local people to minimize termite damage.

Control methods	% of respondents
1. Modern	
No chemicals were available.	90
Heptachlor (bought from black market) was used to poison mounds	10
2. Indigenous	
Queen removal and flooding	42
Mound opening and smoking	52
Growing 'Bisana', *Croton machrostachyus* in crop fields	6

4.2. Prevalence of termites in crops and rangelands

A total of 150 samples of termites were collected from the study area. 45 samples from each study crop, and 15 samples from rangelands, were included in the samples collected. The termite samples were identified to six genera, namely *Ancistrotermes, Macrotermes, Microtermes, Odontotermes, Pseudacanthotermes* and *Trinervitermes*. The first five belong to subfamily Macrotermitinae but *Trinervitermes* belongs to Nasutitermitinae. They were all classified under the family Termitidae.

Ancistrotermes and *Microtermes* were both small in size compared to the other four genera. *Ancistrotermes* was distinguished by its mandibles, which were strongly curved inward at tip, and its antennae which had 15 segments. Antennae of *Micromeres* possessed 12 to 14 segments, and its mandibles were slightly curved in ward at tip. *Trinervitermes* were unique among the six genera, in that its mandibles were greatly reduced and its head was drawn out into long conical tube, nasus. Two spines located on its pronotum were used to distinguish *Pseudacantotermes*. They were projected from the anterior edge of pronotum. In *Macrotermes,* mandibles were without tooth, and labrum had hyaline tip. *Macroterms* is large in size. In *Odontotermes,* the left mandible was equipped with one robust and forwardly directed tooth, whereas right mandible was with a relatively small tooth.

Relative percentage occurrence of these genera indicated that *Microtermes* and *Pseudacanthotermes* were the most abundant, among the samples collected from target crops in the study area (4.7).

Table 4.7 Percentage occurrence of termite genera in fields of the study crops

Termite genera	% occurrence
Ancistrotermes	4.4
Macrotermes	17.8
Microtermes	37.8
Odontotermes	15.6
Pseudacanthotermes	24.4

Microtermes was encountered frequently in roots and stems of maize and stalks of sorghum, and it was also observed at base of roots of matured teff in one field of Serbi site. *Odontotermes* and *Pseudacanthotermes* were more abundant in teff. *Macrotermes* was found in all the three crops but less frequently and *Ancistrotermes* was the least encountered termite genera (Table 4.8).

Table 4.8 Termite genera on maize, teff and sorghum

Crop	Termite genera	% occurrence
Maize	*Macrotermes*	20
	Microtermes	40
	Odonotermes	13.3
	Pseudacanthotermes	20
	Ancistrotermes	6.7
Teff	*Macrotermes*	21.4
	Odontotermes	35.7
	Pseudacanthotermes	42.9
Sorghum	*Macrotermes*	13.3
	Ancistrotermes	6.7
	Microtermes	66.7
	Psudacanthotermes	13.3

From rangeland of the study area, *Macroterms*, *Pseudacanthoterms, Odontoterms* and *Trinervitermes* were collected, and they were found to occur in varying proportions (Table 4.9).

Table 4.9 Termite genera and their percentage occurrences in rangelands of the study area.

Termite genera	% occurrence
Macrotermes	20
Odontotermes	33.3
Pseudacanthotermes	33.3
Trinervitermes	13.3

4.3. Termite damage to crops

4.3.1. Types of damage

Damage on maize, teff and sorghum generally showed three forms: a) Stems and stalks were cut near the surface b) roots were penetrated, stems excavated, and in some instances filled with moist soil c) external parts were covered by soil sheeting. Stem cutting began at late vegetative stage and stopped before tasseling (heading) in maize and sorghum. However, in teff, stems were cut at all stages of growth, though less seriously at vegetative stage compared to flowering and maturity. It was known from termite samples collected and identified from infested crops that stems were cut by *Macrotermes, Pesudacanthoterms, and Odontotermes*. Root penetration was found to commence at late vegetative stage in sorghum and maize and continued throughout tasseling and maturity stages in maize. In sorghum, stem penetration was not observed after heading. Hollowing out of stems of standing maize up to 50 cm high and filling with soil particles were observed in some fields. *Microtermes,* most frequently, and *Ancistrotermes* to a lesser extent, were encountered in roots and stems.

Covering external parts with soil sheeting was not common in standing maize and sorghum and was limited to the lower parts of their stems when it occurred. But maize, which was lodged following root penetration were observed being totally covered by soil particles and foraged by termites under the cover. It was in teff that the whole part of the plant was covered by soil particles, particularly around maturity.

4.3.2. Levels of damage

Maize, teff and sorghum were not equally damaged by termites (Table 4.10) and the difference in the level of damage was found to be significant ($P < 0.05$) among the crops (Appendix 1).

Comparison of levels of damage among different stages within each crop also showed significant differences ($P < .05$) (Table 4.11, Appendices 2-4), but no damage was observed at maturity in sorghum. Even though there were some differences in levels of crop damage (Table4.12) when compared at Kebele level, there were no significant differences of damage ($P > 0.05$) in all of the crops (Appendices 5-7).

Table 4.10 Mean percent of damaged maize, teff and sorghum, by termites

Crop	Mean % damage ± SE
Maize	16.62 ±. 67b
Teff	29.89± 1.16a
Sorghum	1.52 ± .05c

Means followed by the same letter within a column are not different from each other at 5% level, Tukey (HSD).

Table 4.11 Mean percent of damaged maize, teff, and sorghum at different growth stages

Crop	Mean % damage ±SE		
	Vegetative	Flowering	Maturity
Maize	13.80± 1.25b	28.59±.90a	8.69± .72c
Teff	14.28 ± 2.26c	31.83± 1.35b	43.54 ± 1.08a
Sorghum	2.31± .37a	1.42 ± .26ab	.71± 0.00b

Means followed by the same letter within a row are not different from each other at 5% level, Tukey (HSD).

Table 4.12 Mean percent damaged maize, teff and sorghum in different kebele administrations.

Crop	Mean% damage ±SE				
	LS	LK	DG	UG	SR
Maize	18.55±.33	16.99±.93	14.79±.1.45	15.47±1.75	17.28±.30
Teff	28.82±1.82	32.16±.1.73	28.75±.2.70	32.98±2.90	26.73±.3.04
Sorghu	1.45±.24	1.39±.55	1.67±.51	1.54±.16	1.57±.34

Means in each row are not different from each other at 5% level, Tukey (HSD).

LS= Lelisa Sogema, LK = Lelisa Komis, DG = DandiGudi, UG = UlaGanti, SR = Serbi Kebele administrations in the study area.

4.4. Impacts of termites on rangelands

4.4.1. Proportion of vegetation cover per unit area in protected and unprotected neighboring rangelands.

In all plots of rangelands which were protected from livestock grazing, grasses showed high level of regeneration, as opposed to unprotected neighboring areas (plates 1). Height of most of the grasses in the fenced areas reached above 30 cm. whereas that of the unprotected areas remained under 5 cm. The percentage of vegetation cover per m^2 was by far higher in the protected plots than unprotected plots (Tables 4.13-4.14), and the differences were significant ($P < 0.05$) in all cases (Appendices 8-11).

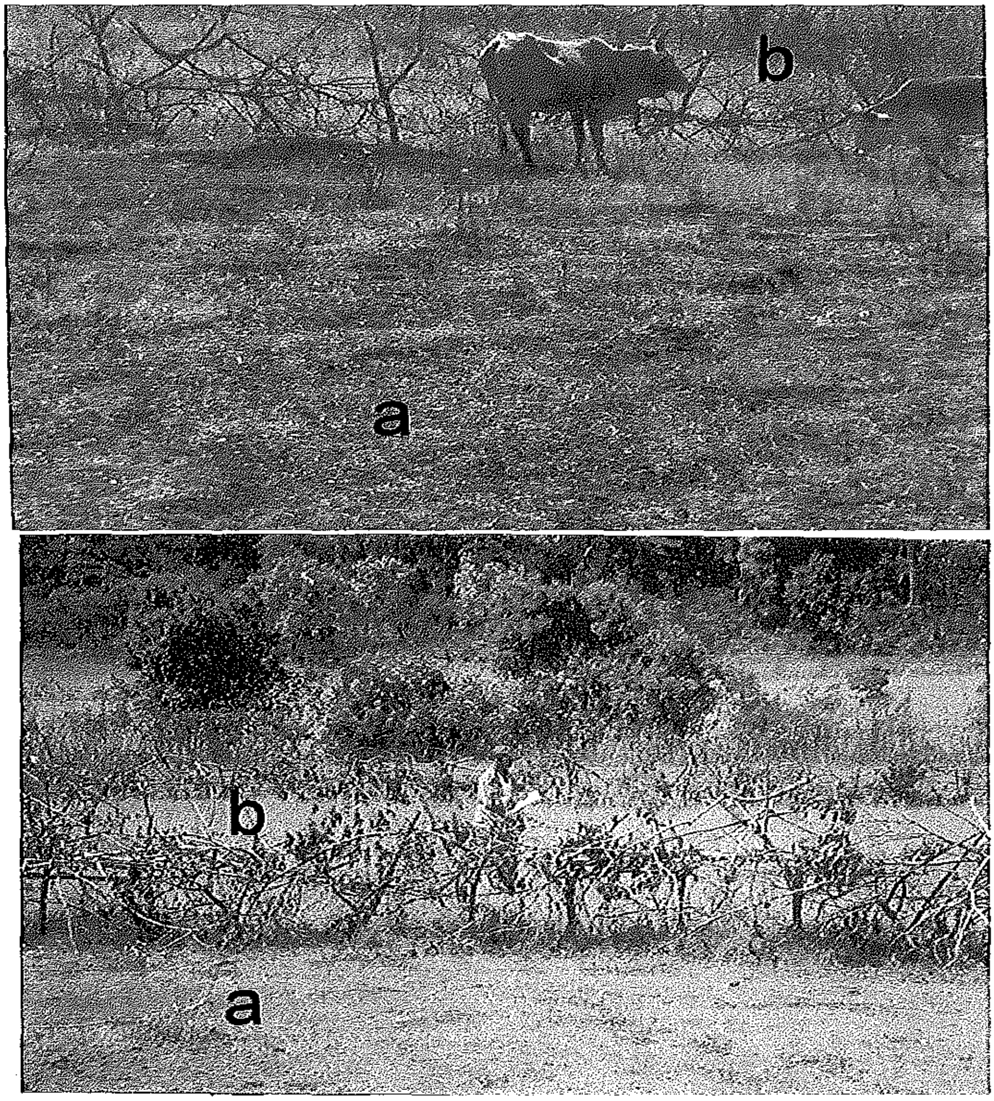

Plate 1.Unprotected (a) and protected (b) plots of rangelands in the study area.

Table 4.13 Mean percentage vegetation cover per m2 in protected and unprotected neighboring plots of rangelands of the study area.

Plot	Mean % Vegetation cover ± SE
Protected	67.67 ± 4.19*
Unprotected	22.60 ± 1.97**

Means followed by the same number of asterisk within a column are not different at 5% level, (T-test).

Table 4.14 Mean percentage vegetation cover per m^2 in protected and unprotected neighboring plots of rangelands in different localities

	Mean % vegetation cover± SE	
Locality	Protected	Unprotected
Oke	70 ± 6.52*	23.00 ± 1.82**
Oka	66.00 ± 5.79*	29.20 ± 2.54**
SR	67.00 ± 10.32*	15.60 ± 2.77**

Means followed by the same number of asterisk within a row are not different from each other at 5% level, (T-test).
Oke = Oddo Kello, Oka = Oddo Kabba, SR = Serbi localities

4.4.2. Density of termite foraging holes per unit area in protected and unprotected neighboring rangelands.

The mean number of termite foraging hole per m^2 was found to be greater in the unprotected plots than that in the protected plots of rangelands in the study sites and the difference was significant ($P < 0.05$) (Table 4.15, Appendix 12). Protected and unprotected plots within each locality were compared for density of termite foraging holes (Table 4.16), and found to be significantly different ($P < 0.05$) except in one locality (Appendices13-15).

Table 4.15 Mean number of termite foraging holes per m^2 in protected and unprotected neighboring plots of rangelands of the study area.

Plot	Mean number of foraging holes ±SE
Protected	10.93 ± 1.99**
Unprotected	23.33 ± 2.32*

Means followed by the same number of asterisk within a column are not different from each other at 5% level, (T-test).

Table 4.16 Mean number of termite foraging holes per m^2 in protected and unprotected neighboring plots of rangelands of different localities

	Mean number of termite foraging holes ±SE	
Locality	Protected	Unprotected
Oke	12.20 ± 4.63*	23.60 ± 3.68*
Oka	9.20 ± 1.96**	18.00 ± 3.11*
SR	11.40 ± 3.91b**	28.40 ± 4.45*

Means followed by the same number of asterisk within a row are not different at 5% level, (T-test).

5. DISCUSSION

The result of the present study indicated that subterranean termites in general and *Microtermes* in particular were the most widespread termite pests in field crops, in Manasibu. This finding is in contrary to that of Cowie and Wood (1989) who reported that very few fields of maize suffered lodging due to *Micotermes* in Wollega, whereas attack by *Macrotermes* was widespread, and sorghum was solely damaged by *Macrotermes* in Manasibu. Forty-five samples of termites were collected from damaged maize in 15 fields and 40% of the samples contained *Microtermes*. They caused root penetration and lodging to maize in the study area. About 6.7% of the samples were *Ancistrotermes*, which was also subterranean, but only 20% of the samples comprised *Macrotermes*. Equal numbers of samples collected from attacked sorghum and identified revealed that 66.7% were *Microtermes,* and only 13.3% were *Macrotermes.* About 70% of respondents said that they observed serious termite damage to crops with no visible mound in their localities. It was known that in the past two decades, governmental and non-governmental organizations made extensive campaigns of termite control (Abdurahman Abdulahi, 1990), through queen removal and mound poisoning in Manasibu district.

The local people developed and used various indigenous practices to control termites, but almost all of them (94%) were targeted at mound-building termites. Only 6% of the respondents said that they grew 'bisana', *Croton machrostachyus* in crop fields as a repellent against subterranean termites. Some or all of these activities probably negatively affected the population of epigeal nest building termites, *Macrotermes,* in the area. On the contrary, subterranean termites, such as *Microtermes*, which were known for their deep and diffuse nest systems, could have probably survived disturbances due to cultivation, and apparently their population increased through time.

Type of termite damage to crops varied from plant to plant and was also found to depend on foraging behavior of termites. Subterranean termites which were small in size, such as *Microtermes* and *Ancistrotermes* were observed foraging frequently in stems. Such damage was limited to maize and sorghum. Only one sample of *Microtermes* was identified from base of root of matured teff in Serbi site. However, no indication of foraging of this termite on teff was observed. This agrees with the report of Abdurahman Abdulahi (1990). The probable explanation for absence of root penetration in teff might be thinness of stem of the crop. Stem/stalk cutting at surface level by *Macrotermes, Pseudacanthotermes* and *Odontotermes* caused severe threat to maize and teff. The later termite was not observed cutting sorghum stalk. Termites also foraged on plants under cover of soil sheeting. These types of damages were also reported by Cowie and Wood (1989). Foraging by termites on outer parts of plants under soil sheeting was observed during rainy season more frequently in sunny days. This mode of foraging increased towards the onset of the dry season. Foraging on crops under soil sheeting generally decreased in continuous heavy rains. Crops in wetlands around riverbanks were not damaged by termites, whereas those on dry hillsides were seriously damaged (personal observation). Peace (1997) stated that constant irrigation of crops prevented termite activities.

Maize, teff and sorghum were all damaged by termites in all of the study sites. The level of termite damage to these crops was significantly different ($P<.05$). Teff was the most seriously damaged crop (29.89 ± 1.16). About 64% of respondents from the local people estimated loss of 100% in teff, and 14% said that they had abandoned teff cultivation due to total loss by termite. The informants disclosed that they used to get about 26 quintals of teff per hectare per annum before occurrence of termites. Cowie and Wood (1989) noted that the most heavily damaged crop in Ethiopia was maize. In this study, the mean percentage damage caused by termite to maize was $16.62 \pm .67$, and that of sorghum was $1.52 \pm .05$. Therefore sorghum was the least damaged of all the study crops.

The extents to which the three crops were damaged by termites in the five Kebeles were not significantly different from each other ($P > 0.05$). But, some differences were observed in the level of these damages, between Kebeles, and from localities to localities and also between fields within the same locality. Less termite attack was observed in crops grown closer to residences and the crops were also very healthy. Crop fields nearer to residences were continuously fed with household leftover (waste) organic materials (personal observation). Respondents from the study area explained that some localities were generally less infested by termites because their soils were black in color (66%), had high proportions of gravels (12%), and were less frequently grazed and not cultivated (22%). In maize, teff and sorghum, the level of termite damages in vegetative, tasseling /flowering/ heading, and maturity stages showed significant differences ($P < .05$). In all the crops, different trends of damage were observed at different growth stages. Less damage was observed in teff at vegetative stage and thereafter it increased sharply through flowering up to maturity stage. Damage to maize began with stem cutting at vegetative stage, and followed by root penetration. At late vegetative stage, there was a brief period at which both root penetration and stem cutting coincided. In sorghum, maximum damage took place at vegetative stage and no new damage was observed after heading.

Abdurahman Abdulahi (1990) reported that a greater amount of damage would be expected to cause higher yield losses, and that the relationship between percentage of plant attack by termite and yield loss was not linear. The present study was not planned to assess yield loss due to termite damage. However, it became possible to observe from this field investigation that some crops which were physically damaged by termites were totally collapsed. All sorts of termite damage to teff, for example, were found to be total loss, and all of maize and sorghum which were cut, mainly at vegetative stage, wilted. Lodging and wilting were common among maize, whose roots were penetrated and stems were hollowed. Cobs of lodged maize were found being foraged by termites under soil sheeting in most sites.

Macrotermes, Odontotermes and *Pseudacanthotermes* were identified from soil sheeting in the rangelands. This is in agreement with Cowie and Wood (1989). In addition, snouted termites belonging to the genus *Trinervitermes* of subfamily Nasutitermitinae were identified from badly denuded and eroded rangelands in the present study. They were observed foraging on lower parts of living grasses, emerging out of their galleries through narrow holes. This finding agrees with that of Hickin (1971). The inner parts of subterranean galleries of these termites were plastered with materials of black color.

Newly cut grasses were observed in soil sheeting of *Odontotermes, Pseudacanthotermes* and *Macrotermes*.

Marked regeneration of grasses was registered on all the three rangelands, which were protected from grazing by livestock, which could be an indication that livestock played a major role in denuding rangelands in the study area. On the other hand, the fact that number of termite foraging holes per m^2 became significantly greater in unprotected rangelands than in the protected ones revealed that foraging activity of termites increased in overgrazed rangelands. This probably indicated the presence of competition between termites and livestock. When the unprotected plots of the three rangelands were observed, the number of termite foraging hole per m^2 was found to be inversely related to the mean percentage of vegetation cover per m^2 of the plots.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

All of the termites collected from maize, teff, sorghum, and rangelands were identified to belong to the family Termitidae. Six genera of termites were identified from these samples and grouped into two, based on their nest system, mound- building and subterranean types. It was revealed by this study that subterranean termites, in general, and *Microtermes* in particular were most prevalent in Manasibu District. However, this study did not represent the whole district.

Termite attack to crops in the area generally showed three forms: a) stem cutting at surface level, b) root penetration and excavation of stems c) foraging on external portion of the plants under soil sheeting

Maize, teff and sorghum were damaged by termites. The level at which these crops were damaged showed significant difference. Teff was the most seriously damaged crop by termites in the study area. The damage caused to teff could be considered as a yield loss. Maize was next to teff in mean percentage of damage, but sorghum was the least damaged crop. In all of the crops, the extent at which vegetative, flowering and maturity stages were damaged was significantly different.

Levels of termite attack to maize, teff and sorghum were compared among the five Kebeles in the study area. Even though minor variations were observed, the differences were not significant.
Denuded rangelands which were fenced to exclude the effect of grazing by livestock showed marked regeneration of grasses within a period of six months. When unprotected and protected rangelands were compared for density of termite foraging holes per m^2, it was found to be greater

by far in the former. This indicated that foraging activity of termites was relatively higher in denuded rangelands.

It could be proposed that pressure due to heavy grazing by livestock, together with erosion, particularly on hillsides, played significant roles in denuding rangelands. This, however, did not mean that termites had no roles in reducing the amount of cover grass from rangelands. Termites were observed foraging on living grasses in rangelands. Unless the level at which termites removed surface grasses is investigated and quantified, concluding that livestock were exclusively responsible for denuding rangelands would not be scientific.

6.2. Recommendation

- During this study, it was observed that foraging activity of termites was higher on eroded and dry hillsides. Therefore, mechanisms for stopping runoff on hillsides should be devised.
- Any termite control program that may be held in the study area should be able to deal with both subterranean and epigeal mound building termites.
- Further experiments, which may indicate the level of moisture content of soil that may minimize activities of termites, should be performed for possible recommendations of water catchments and usage, in combating termite problems.
- To evaluate the level of economic damage that termites cause to rangelands by removing living grasses, and losses due to termite foraging of crops, should be scientifically assessed.
- Means by which grazing pressure, by livestock is minimized should be searched out for sustainable use of pasturelands.

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Appendix 1. Analysis of variance (ANOVA) for mean percent damaged maize, teff, and sorghum by termites

Source of Variation	Sum of squares	df	Mean Square	F	P
Between Groups	2014.37	2	1007.18	333.66	.000
Within Groups	36.22	12	3.02		
Total	2050.59	14			

Appendix 2. Analysis of variance (ANOVA) for mean percent damaged maize by termites at vegetative, tasseling and maturity stages.

Source of Variation	Sum of squares	df	Mean of squares	F	P
Between Groups	1067.92	2	533.96	111.16	.000
Within Groups	57.64	12	4.80		
Total	1125.56	14			

Appendix 3. Analysis of variance (ANOVA) for mean percent damaged teff by termites at vegetative, flowering and maturity stages

Source of variation	Sum of squares	df	Mean of squares	F	P
Between Groups	2168.99	2	1084.49	80.18	.000
Within Groups	162.30	12	13.53		
Total	2331.29	14			

Appendix 4. Analysis of variance (ANOVA) for mean percent damaged sorghum by termites at vegetative, heading and maturity stages

Source of Variation	Sum of squares	df	Mean of squares	F	P
Between Groups	6.43	2	3.21	9.51	.003
Within Groups	4.05	12	.338		
Total	10.45	14			

Appendix 5. Analysis of variance (ANOVA) for mean percent damaged maize by termites in different Kebele administrations in the study area

Source of Variation	Sum of squares	df	Mean of squares	F	P
Between Groups	26.90	4	6.72	1.8	.206
Within Groups	37.38	10	3.74		
Total	64.28	14			

Appendix 6. Analysis of variance (ANOVA) for mean percent damaged teff by termites in different Kebele administrations in the study area

Source of variation	Sum of squares	df	Mean of squares	F	P
Between Groups	81.46	4	20.36	1.09	.413
Within Groups	87.18	10	18.72		
Total	268.64	14			

Appendix 7. Analysis of variance (ANOVA) for mean percent damaged sorghum by termites in different Kebele administrations in the study area

Source of variation	Sum of squares	df	Mean of squares	F	P
Between Groups	.15	4	.037	.08	.98
Within Groups	4.55	10	.46		
Total	4.70	14			

Appendix 8. T-test for equality of means for mean percentage vegetation cover per m^2 in protected and unprotected neighboring plots of rangelands of the study area

Source of variation	t-test for equality means		
	t	df	P(2-tailed)
Equal variances assumed	9.37	28	.000
Equal variances not assumed	9.37	19.87	.000

Appendix 9. T- test for equality of means for mean percentage vegetation cover per m^2 in protected and unprotected neighboring plots of Oddo Kello locality

Source of variation	t-test for equality means		
	t	df	P(2-tailed)
Equal variances assumed	6.95	8	.000
Equal variances not assumed	6.95	4.62	.001

Appendix 10. T- test for equality of means for mean % vegetation cover per m2 in protected and unprotected neighboring plots of Oddo Kabba locality

Source of variation	t-test for equality means		
	t	df	P(2-tailed)
Equal variances assumed	5.823	8	.000
Equal variances not assumed	5.823	5.483	.002

Appendix 11. T- test for equality of means for mean percentage vegetation cover per m2 in protected and unprotected neighboring plots of Serbi locality.

Source of variation	t-test for equality means		
	t	df	P(2-tailed)
Equal variances assumed	4.81	8	.001
Equal variances not assumed	4.81	4.572	.006

Appendix 12. T- test for equality of means for mean number of termite foraging holes per m^2 in protected and unprotected neighboring rangelands of the study area.

Source of variation	t-test for equality means		
	t	df	P(2-tailed)
Equal variances assumed	- 4.052	28	.000
Equal variances not assumed	- 4.052	27.378	.000

Appendix 13. . T- test for equality of means for mean number of termite foraging holes per m^2 in protected and unprotected neighboring rangeland of Oddo Kello locality

Source of variation	t-test for equality means		
	t	df	P(2-tailed)
Equal variances assumed	- 1.927	8	.090
Equal variances not assumed	-1.927	7.614	.092

Appendix 14. T- test for equality of means for mean number of termite foraging holes per m^2 in protected and unprotected neighboring rangeland of Oddo Kabba locality

Source of variation	t-test for equality means		
	t	df	P(2-tailed)
Equal variances assumed	- 2.392	8	.044
Equal variances not assumed	- 2.392	6.738	.049

Appendix 15. T- test for equality of means for mean number of termite foraging holes per m^2 in protected and unprotected neighboring rangeland of Serbi locality

Source of variation	t-test for equality means		
	t	df	P(2-tailed)
Equal variances assumed	- 2.873	8	.021
Equal variances not assumed	- 2.873	7.870	.021

Appendix 16. Questionnaire on assessment of termite problems and related aspects in Manasibu District.

I. Personal information

1) Age_____. Sex_____. Educational Status_____.

2) How long have you lived in this area?

____________________ Yea.

II. General information

3) Which crops are most seriously damaged by termites in your area?

____

4) When production before and after occurrences of termites are compared, what are the annual yields of maize, teff and sorghum?

Before occurrence of termites; Maize: __________ quintal/hectare.

Teff: _________ quintal/hectare.

Sorghum: _________ quintal/hectare.

After occurrence of termites; Maize: ____________ quintal/hectare.

Teff: ______________ quintal/hectare.

Sorghum: __________ quintal/hectare.

5) What do you think the reason(s) for such differences (if any) could be?

____

____

6) Do termites damage pasturelands in your area?

Yes ______. No ______.

7) Is there any relation between termite damages to rangelands (if any) and livestock population?

Yes ______. No ______.

8) If yes, what types of relations are there?

____

____

9) Are there differences among different localities in your areas in termite infestations?

Yes ______.   No ______.

10) If yes, what do you think the reason(s) could be?

____

____

11) Do you think that termite problems have increased from time to time since you had first encountered the problems?

Yes______.   No______.

12) If yes, what factors do you think have aggravated the problems?

____

____

13) Apart from immediate economic impacts, what further problems do you think that termites would cause in the future in your areas?

____

____

14) Is there termite problem with no mound on field crops and rangelands in your localities?

Yes ______.   No ______.

15) What control measures are used to minimize or avoid termite damages?

Indigenous ______________________________________

Modern ______________________________________

16) Any more ideas ______________________________________

____

____