Termite Management in Tropical Agroforestry

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FOREWORD

This book is a synopsis of termite biology, ecology and its management in agroforestry, which is an integration of crop production, livestock and forestry practices, on the same piece of land. Indeed, trees are one of the most promising means known to better adapt farming systems to climate change, and to act as sinks for absorbing carbon dioxide. This book shall assist researchers, students, farmers, extension officers, policy makers and Non-Government Organisations (NGOs) to understand the significance of termites in agroforestry.

Although termites are usually considered pests, some are not pests at all. While the pestiferous species have negative aspects, they can provide many benefits. For example, termites loosen, aerate and enrich soil through tunnelling, litter decomposition and recycling of soil organic matter in conservation farming. Some edible mushrooms such as *Termitomyces* grow mainly around termite mounds. Some termite species are also an important source of proteins to human beings, animals and poultry.

The University of Zambia is appreciative of the initiative by the authors to undertake this project, which will contribute to the body of knowledge of this new and exciting field of termite management in agroforestry. Since the initiation of the project in 2004 by the Department of Biological Sciences, of the School of Natural Sciences, its impact and significance have been acknowledged by researchers not only in Zambia, Malawi and Uganda but as far afield as Australia.

It is my hope that this publication will inspire researchers and other scholars to do further research in this much neglected, but very important area.

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PURPOSE OF THIS BOOK

This book is intended to be used as a guide to management of termites in agroforestry and farmsteads where termites pose serious problems. Emphasis is placed on tropical agroforestry and more specifically in Africa. However, it is also hoped that the book will be of use in other continents where termites pose problems. It has been written in response to the growing need to improve understanding of termite problems and taking appropriate action based on such knowledge. In the past, blanket recommendations for termite control have resulted in inefficient and unsustainable use of resources and have had negative impacts on the environment. Control practices have often been initiated on anecdotal information rather than on sound scientific inquiry into the biology and ecology of the local termite species and their true impact on crops or trees. It is important to note that there is no single method that can be universally recommended for termite control because several species may be found in an area and each species has a unique biology and ecology. Therefore, the level of control depends on the knowledge of the termite species, the tree or crop species, climatic conditions and other environmental factors. Our aim is to promote a more sustainable management of termites, i.e., an approach that ensures (1) control of the pest species without causing ecological damage and loss of the ecosystem services provided by termites, (2) conservation of the non-pest termite species, and (3) utilisation of termites and associated resources without exhausting them. This can be achieved through adequate understanding of termite biology and application of control measures based on ecological principles.

The intended users of this manual are farmers (subsistence as well as commercial), extension officers, researchers, pest control operators and students. The aim is to provide basic information on termites and help people to take more informed actions to manage termites in agroforestry.

This book is presented in six chapters. Chapter one introduces the concept of agroforestry, agroforestry practices, different types of agroforestry, advantages of agroforestry and introduces the subject of termite management in agroforestry. Chapter two provides a description of the biology of termites including their social organisation, life cycle, nesting behaviour, classification and food. Chapter three provides a summary of the beneficial aspects of termites. Chapter four provides a brief discussion on common pestiferous termites and the damage they cause to crops and trees. Chapter five focuses on principles that should be followed for sustainable management of pestiferous termites in agroforestry with less emphasis on control and Chapter six ends with concluding remarks and prods scholars to do further research in this much neglected, but very important area.

Chapter One

INTRODUCTION

There are many traditional land use practices that involve production of trees, agricultural crops and livestock on the same piece of land. These land use systems are collectively called agroforestry, which is a new name for old practices. In most cases, the major objective of these practices is not tree production but production of food and other goods and services. Today, woody plants continue to supply farmers with a number of valuable products such as fruits, fuel wood, timber, fodder, fibre and medicines. Trees, in particular nitrogen-fixing species, also add fertility to soil, thereby increasing yields of agricultural crops. The trees may also be deliberately retained for cultural or religious reasons.

Agroforestry is a concept of integrated land use that combines elements of agriculture and forestry in a sustainable production system. Agroforestry is broadly defined as the set of land use practices involving a deliberate combination of trees (including shrubs, palms and bamboos) and agricultural crops and/or animals on the same land management unit in some form of spatial arrangement or temporal sequence such that there are significant ecological and economic interactions between tree and agricultural components (Sinclair, 1999). In this definition, agroforests, which are complex agroforestry systems looking like and functioning as natural forest ecosystems, are integrated into agricultural management systems. The above definition is preferred to traditional definitions because farmers and forest dwellers, where agroforestry has developed as a significant land use practice, have tended to practice agroforestry using various methods. For instance, either by integrating many tree species in various productive niches on their farms or by managing biodiverse forest resources. Therefore, agroforestry is an approach to land use involving a deliberate and purposeful combination of trees with crops and/or animals.

1.1 Agroforestry Practices

An agroforestry practice refers to the distinctive arrangement of woody species (i.e. trees and shrubs), crops and livestock in space and time. In terms of function, the woody components of agroforestry may be categorised as follows:

1. *Fertiliser trees*: This refers to all nitrogen-fixing leguminous or non-leguminous woody perennials deliberately planted for soil fertility improvement in arable land, pastures or other land use systems. The species may be trees or shrubs that fix nitrogen through associations with symbiotic bacteria such as *Rhizobia* and *Frankia*. The contribution

of fertiliser trees to soil fertility mainly comes from nitrogen inputs via deep capture and biological nitrogen fixation. In addition, fertiliser trees can provide additional products (e.g., firewood, poles, seeds, etc.) and services (e.g., soil and water conservation).

2. *Fruit trees*: perennials that produce edible fruits may be planted in blocks, scattered on farmland, along field boundary or around the homestead.
3. *Fodder trees*: perennial leguminous trees and shrubs that provide protein sources for livestock can supplement pasture and also provide an effective insurance against seasonal feed shortages or during time of drought. Trees may be planted in blocks, along soil conservation and contour bands, field boundary or around the homestead.
4. *Timber trees*: perennials specifically planted for production of timber in a variety of spatial arrangements. However, timber may be a secondary product, harvested only after the tree has served its primary production or service role (e.g., fertilising the soil, controlling erosion and producing fruits, vegetables, fodder, medicines, resins, shade, etc.)

In terms of spatial arrangement, agroforestry practices may take the form of dense mixed stands (as in multi-strata home gardens), sparsely mixed stands (as in many parklands and silvopastorial systems) or strips of varying width (as in alley cropping, boundary planting, contour planting, and intercropping). Temporal arrangements of plants in agroforestry may take the form of shifting cultivation, improved fallow or some silvopastorial systems that involve rotation of grass leys with woody species. The common agroforestry practices are briefly described below.

1.1.1 Multi-strata Agroforestry

The term *multi-strata* agroforestry comprises all tree crop-based land use systems that have two or more vegetation layers ranging from plantations of coffee (*Coffea* spp.), cacao (*Theobroma cacao*), or tea (*Camellia sinensis*) mixed with a monospecific overstorey of shade trees to highly diversified systems such as home gardens and 'agroforests' (Nair *et al*., 2008). In the humid tropics, trees in the genera *Albizia*, *Acacia*, *Entada, Erythrina, Gliricidia*, *Inga, Leucaena* and *Millettia* are among the commonly used trees in cacao and coffee growing countries. Cacao has been grown under gliricidia (*Gliricidia sepium*) shade, and hence the Spanish name for gliricidia is 'madre de cacao', literally meaning 'mother of cacao'. Cardamom (*Amomum subulatum*), the most important perennial cash crop in the eastern Himalayas is cultivated predominantly under *Alnus nepalensis*. In Africa, *multi-strata* agroforestry is represented by the tree-crop farming system and highland perennials farming system where cacao, coffee, palm oil, rubber, yams, cassava, banana, plantain, enset, coffee, sweet potato, beans, maize and livestock are an integral part. Depending on the species, the shade tree can be regularly pruned for soil improvement or left to grow fully to produce firewood and timber.

1.1.2 Agroforestry Parklands

Parklands consist of scattered trees occurring on cultivated land, fallow fields or pasture, and are widespread in the semi-arid tropics of Africa and Asia. In the semi-arid areas of the West African Sahel and parts of Eastern and Southern Africa, the best known parklands are those involving faidherbia (*Faidherbia albida*), *Acacia* spp., *Parkia biglobosa* and *Vitellaria paradoxa*. The trees are derived from natural regeneration, but protected and managed by farmers. In some countries such as Mali, parklands occupy 90 per cent of the agricultural land and support livelihoods of over 2.5 million people (Boffa, 1999). Crops such as sorghum, millet, groundnuts, sesame and livestock form a significant component of these farming systems and hence they represent an agrosilvopastoral system.

1.1.3 Silvopastoral Systems

Silvopastoral systems may be defined as an agroforestry practice that integrates trees with animal production. Silvopastoral systems may be divided into two broad categories: tree fodder (hereinafter called protein banks) and grazing systems. In the protein bank approach, the animals are stall-fed with fodder from trees or shrubs grown in blocks on farms (Nair *et al*., 2008). The usual practice is cut-and-carry management, which involves removing tree prunings and cut grass from the field and feeding stabled animals. In grazing systems, livestock are allowed to graze on pasture under widely spaced or scattered trees. In the more extensive grazing areas, N-fixing trees are increasingly being planted in association with improved grasses to increase carrying capacity and productivity of grazing cattle. In the more intensively managed areas, trees such as *Leucaena* and *Gliricidia* are planted in pasture or protein banks.

1.1.4 Alley Cropping

Alley cropping is defined as an agroforestry practice where trees or shrubs are grown in wide rows and arable crops (cereals, legumes or horticultural) or pasture grasses are cultivated in the alleys between the tree rows. This allows integration of trees into conventional agricultural sites for simultaneous production of crops and woody biomass which enables farmers to diversify the production of marketable goods. Therefore, it is one of the emerging agroforestry practices globally. In the temperate areas, alley cropping of high value (e.g., timber, fruit or nut-bearing) trees with crop or pasture is one of the more common agroforestry practices. In the tropics, alley cropping was developed as an alternative to slash-and-burn agriculture or for erosion control on sloping land, where it is sometimes called hedgerow intercropping (Kang *et al*., 1990). In the humid and sub-humid tropics of Africa, alley cropping is practised in the cereal-root crop mixed and maize-mixed farming systems where it involves growing maize, beans or cassava between rows of perennial woody legumes in the genera *Acacia*, *Albizia*, *Calliandra, Flemingia, Grilicidia, Inga,* and *Leucaena* and *Sesbania*. The woody species may be coppiced and the trees are periodically pruned and their biomass is applied either as mulch or incorporated into the soil.

1.1.5 Improved Fallows and Intercropping

Improved fallows involve the rotation of crops with woody species for the rapid replenishment of soil fertility on crop land (Sanchez, 1999). This is an alternative to natural vegetation fallows, which take longer to restore soil fertility. A piece of land is planted with fast-growing N-fixing trees or shrubs for 2-3 years. Crops are planted after cutting-back the woody species. Tree species used in improved fallows can be either non-coppicing or coppicing. Non-coppicing species used in improved fallows include *Sesbania* spp., *Tephrosia* spp. and pigeon pea, and these do not regrow when cut at the end of the fallow period, typically after 2-3 years of growth. Therefore, after 2-3 years of cropping these species have to be replanted. This constitutes rotational fallowing. Coppicing species include members of the genera *Gliricidia*, *Acacia*, *Leucaena, Calliandra* and *Flemingia*, which do not need replanting. Crops are planted between the rows of stumps, and this can be managed by periodic pruning in an intercropping arrangement. A typical example is gliricidia-maize intercropping in Malawi and Zambia, which has been demonstrated to achieve stable increases in crop yields over several years without the need to invest in inorganic fertiliser (Sileshi *et al*., 2012).

1.1.6 Woodlots and Rotational Woodlots

Woodlots are usually planted in areas not suitable for crop production. Trees can be managed for supply of timber, fuelwood, construction materials and production of non-wood products (e.g., caterpillars, natural dyes, gum, wax and honey). There are a variety of options for planting woodlots. Examples include block planting, boundary planting, contour planting, homestead planting and scattered trees on farm land. The rotational woodlot is a variant of improved fallows, where food crops are intercropped with leguminous trees during the first 2-3 years, and then the trees are left to grow, harvested in about the fifth year, and food crops are replanted.

1.1.7 Relay Cropping

Relay cropping is the planting of herbaceous green manure legumes or fast-growing shrubs and trees between rows of an already established crop. The legumes continue to grow after the crop has been harvested. As farmers prepare land for the next season, they clear-cut the legume and incorporate the biomass into the soil. Trees in the genus *Sesbania*, *Tephrosia* and pigeon pea are recommended for relay cropping. This works well on small farms, and the benefit can be seen immediately after one season of tree growth.

1.1.8 Conservation Agriculture with Trees

The integration of conservation agriculture practices with agroforestry practices is called conservation agriculture with trees. This practice is based on five important principles; (1) minimising soil disturbance, (2) maintaining crop residues for soil cover, (3) crop rotation, (4) good agronomic management practices, and (5) incorporating nitrogen fixing trees and shrubs to ensure a more permanent soil cover and increase soil organic matter.

1.2 Advantages of Agroforestry

Agroforestry ensures a multifunctional agriculture that provides food (fruits, crop yield), saleable products (e.g., fruits, timber, fodder, medicinal and pesticidal) and services such as shade, soil improvement and watershed management. The advantages include labour saving, livelihood strengthening and diversification.

Labour Saving

Many agroforestry practices improve the efficiency of labour through positive interaction between trees and farm enterprises (FAO, 2007). For example, woodlots save time and labour for fetching firewood by increasing supplies and by moving the source of firewood closer to home.

Livelihood Strengthening

The presence of trees often increases security of land tenure. Planting trees reduces environmental degradation while producing by-products like food, fruit, firewood and fodder that strengthen livelihoods.

Livelihood Diversification

Once demand for wood in the community has been satisfied, poles and firewood may be developed as a source of income. Some farmers may also raise tree seedlings or produce seeds for sale.

Agroforestry also offers opportunities for the development of climate-smart agriculture; agriculture that sustainably increases productivity (food security), resilience (climate change adaptation) and reduces greenhouse gas emissions (mitigation) (FAO, 2012).

Despite the enormous social and ecological benefits, agroforestry practices had largely been under-utilised until the formation of the International Centre for Research in Agroforestry (ICRAF) now branded as the World Agroforestry Centre. ICRAF continues to be the global leader in agroforestry research. Recently, agroforestry practices have also gained currency in research, academic and policy circles with the emergency of the concept of sustainability. Several global and regional networks and associations of professionals now spearhead agroforestry education, research and development. The African Network for Agriculture, Agroforestry and Natural Resources Education (ANAFE) was launched in 1993 by seventeen universities and twelve technical colleges in sub-Saharan Africa offering education programmes in agroforestry, agriculture, forestry and natural resource management. In the USA, communication and/or technology transfer at the federal level has been enhanced through the establishment of the joint inter-agency USDA FS/NRCS National Agroforestry Centre in Lincoln, Nebraska. Scientists, practitioners and landowners formed the Association for Temperate Agroforestry (AFTA) in 1991. AFTA, based at the University of Missouri Centre for Agroforestry is now a very large network with membership in the US, Canada and overseas. The European Federation of Agroforestry (EURAF) has membership from seventeen European countries. Several major global agroforestry congresses have also been held, where researchers shared findings. The AFTA has so far held twelve biennial conferences on agroforestry. At the global level, two congresses were successfully conducted. The first World Congress of Agroforestry, held on 27 June 2004 in Florida was attended by close to 500 participants from over eighty countries and 750 presentations were made. The second World Congress of Agroforestry held from 23-28 August 2009 in Nairobi, Kenya attracted 1 200 participants from ninety-six countries. The first European scientific conference on agroforestry organised by EURAF was held in Brussels from 9-10 October 2012, attracting participants from seventeen (17) European countries and more than fifty papers were presented. During the EURAF conference, an event titled 'Agroforestry: Trees for a Sustainable European Agriculture' was also organised at the European Parliament.

Policy support for agroforestry is also increasing. For example, in the European Union (EU), the Rural Development Regulation 1698/2005 (2007-2013) supports agroforestry. In the USA, over twenty states have legislation that pertains either directly or indirectly to agroforestry (Cutter *et al*., 1999). Direct legislation supporting agroforestry is available in Hawaii, Iowa, Maryland, Missouri, Minnesota, Nebraska, South Dakota and Virginia. The states of Delaware, Illinois, Michigan, Mississippi, New Jersey, New Mexico, New York, North Dakota, Utah, Washington and Wisconsin have indirect effect legislation. Under direct legislation, most states provide some type of cost-sharing for approved practices while tax reduction and cost-sharing were favoured in states with indirect legislation (Cutter *et al*., 1999).

As a result of all these developments, agroforestry is receiving long-overdue attention as a resource efficient, eco-agricultural approach to farming. Many government institutions, NGOs, grassroot and community based organisations are widely promoting agroforestry for a variety of reasons. Widespread adoption of agroforestry means intensified cultivation of trees, in time and space. This may bring about a change in the landscape, pest and disease composition. One of the major pest problems in agroforestry in the tropics is pestiferous termites, which may cause complete destruction of tree seedlings and saplings as well as associated crops. This makes them more important in agroforestry than many other pests. Increased termite problems with tree planting, are reported throughout sub-humid and semi-arid regions. Fruit tree planting in drier areas might be more sustainable than annual crops because the latter are generally more susceptible to drought than the former. The aim of this book is to bring to the fore, basic information on the biology, ecology and practical management options for termites in agroforestry.

Chapter Two

TERMITE BIOLOGY AND BEHAVIOUR

‘ .... When we come to consider the order in these insects, and their subterranean cities, they will appear foremost on the list of the wonders of creation.’

H. Smeathman, 1781

2.1. The Structure and Social Organisation of Termites

Termites are wrongly called ‘white ants’, yet they are totally unrelated to ants. Termites are classified in the order *Isoptera*, while ants belong to the order *Hymenoptera*. Termites are structurally most closely related to cockroaches (*Blattodea*) in that one Australian species of termites, *Mastotermes darwiniensis Froggatt*, which has an anal lobe in the hind wing and an egg mass like the ootheca of cockroaches, is looked upon as a sort of connecting link between the termites and the cockroaches. Other differences between termites and ants are that, ants have a constricted (narrow) waist while termites have an unconstricted abdomen broadly joined to the thorax. Ants have elbowed antennae while termites have moniliform or filiform antennae.

Termites are social insects that live in colonies with a caste system involving sterile individuals (workers and soldiers) and reproductive individuals (queen and king). One of the major differences between termites and other social insects, such as ants, bees and wasps, is that the other insects have larval and pupal stages that are not active within the colony, while termites do not have larval and pupal stages. Instead, eggs of termites hatch into workers that are active within the colony. Another difference between termites and other social insects is that the male termite called king remains with the female throughout her lifetime and does not die after mating. Termites are eusocial (‘true social’) insects. Eusociality is defined by three traits which aptly define a termite colony, namely:

1. Division of labour, with a caste system.
2. Co-operation among colony members in tending the young.
3. Overlap of generations capable of contributing to colony fitness.

An excellent introduction to the sociality of termites and the relationship between different castes is given in E.O. Wilson's, *The Insect Societies* (1971). In the following discussion, we will briefly describe the caste system in a termite colony, which consists of reproductives, workers and soldiers.

Larvae on fungus comb (Photo: G.W. Sileshi*)*

2.1.1 Reproductives (Alates)

The primary reproductives (winged adults or alates) are able to fly, and are commonly called flying termites. These comprise males and females, whose sole purpose is to start new colonies and become the future king and queen of their new colony. In the genus *Macrotermes* are found edible alates. The queen lays eggs which hatch into larvae that then develop into workers, soldiers or nymph/ developing alates.

Primary reproductives before shedding wings (Photo: G.W. Sileshi*)*

Future queen (in foreground) and king (in background) after shedding their wings (Photo: G.W. Sileshi*)*

Primary reproductives disperse, mate and found a new colony. Primary reproductives have rounded heads with large compound eyes and antennae which have 10-30 segments. In the period between leaving a colony and the establishment of a new one, these individuals bear two pairs of similar shaped wings. These have simple venation without cross veins and are shed along a basal (humeral) vein, leaving behind four triangular stumps or scales. The queen can sometimes grow up to six centimetres long while the other castes are generally less than one centimetre. The role of the king is to fertilise the queen's eggs. The king closely resembles the queen in appearance with the difference between them being the large size of the queen's abdomen once it is swollen with eggs. This condition is referred to as physogastry. A *Coptotermes* queen can produce one hundred eggs per day but more advanced termite queens, such as *Macrotermes*, can produce 30 000-40 000 eggs per day and up to 10 million a year. Fertilisation of eggs may, in some species, be monthly (Pearce, 1997).

Queen of Macrotermes falciger (Photo: P.O.Y. Nkunika*)*

Gravid termite queen (centre) surrounded by workers (Photo: G.W. Sileshi*)*

2.1.2 Workers

Workers are soft-bodied with rounded heads, pale white in colour and are blind, wingless, sterile and about 3-4 mm in length. They comprise more than 80 per cent of the colony population. They build and repair the colony nest, shelter tubes and galleries. They tend the queen, the eggs and young in the nursery, forage and gather food and feed all the other castes. Workers immediately move away from the light into their colony system when nests or shelter tubes or galleries are broken open. With the exception of the diurnal harvester termites (*Hodotermes* spp.), these insects are generally unpigmented and lightly sclerotised. Worker termites have different roles and are often of two or more sizes. Therefore, polymorphism, based on age and sex, is common in the worker caste. In the families, *Kalotermitidae*, *Termopsidae* and some *Rhinotermitidae*, there is no true worker caste.

Workers of Macrotermes sp.
(Photo: G.W. Sileshi*)*

Worker tasks are performed by late instar nymphs or pseudergates. A pseudergate is a non-reproductive, non-soldier individual that diverges from the imaginal line at a relatively late stage through a regressive or stationary moult (Thorne, 1996). Other worker functions include grooming of individuals of the dependent castes, digging tunnels, locating food and water, maintaining the colony micro-climate conditions, and building and repairing the nest. Worker castes are the ones which cause damage to crops and trees.

2.1.3 Soldiers

Soldiers have larger heads that are longer and wider than those of the workers. Soldiers of most species of termites include both males and females. Although the gonads are present in males, they are undeveloped. The heads are greatly modified, heavily sclerotised, and greatly enlarged, sometimes exceeding the size of the rest of the body. Eyes are usually vestigial or absent and the antennae are moniliform or filiform.

Differing sizes of soldiers are found in some species. Major and minor soldiers are common in some *Termitinae*. In the *Rhinotermitinae* and *Schedorhinotermes*, there are two distinct types of soldiers that differ in size, head shape and mandibles (Pearce, 1997).

In some species, the mandibles are reduced and the head is modified into a long nose from which a toxic glandular secretion is fired from the tip. During attack, the survival of the species depends on this caste system. The soldiers' job is to defend the colony from any unwanted animals.

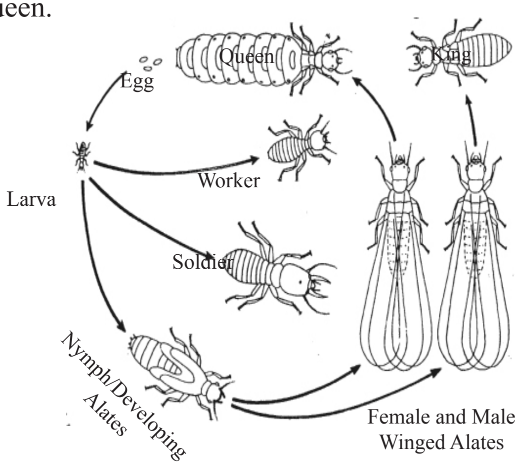
Soldier of Macrotermes sp.
(Photo: G.W. Sileshi*)*

Soldiers that have enlarged jaws, or reduced mandibles, cannot feed themselves and they have to rely on workers for this. This process of feeding of one colony member by another is known as trophyllaxis. Some termite species belonging to the sub-family *Apicotermitinae* have no soldiers (Sands, 1972).

2.2 Life Cycle of Termites

Termites are hemimetabolous insects, which means that the life cycle lacks distinct larval and pupal stages as is the case in, butterflies and moths, which are holometabolous. Although details differ depending on the species, in general the life cycle is as follows: a colony is founded following the release of winged reproductive individuals (alates) from the parent colony. Depending on the species involved, alates may be released at irregular intervals over a period of several weeks, or in some species, all colonies in an area will release their alates at one particular time of the year and often at a specific time of the day. Alates are weak fliers and after a short nuptial flight, they drop to the ground and shed their wings. These wingless individuals are referred to as de-alates. The female attracts the male by holding her abdomen up, presumably emitting a pheromone. Paired males and females then form tandems, which set off in search of a suitable nesting site in the soil or wood, depending on the species.

When a suitable site has been located, the pair becomes the queen and king of the new colony, burrowing into the substrate and sealing themselves in a chamber, where mating takes place. The first eggs are laid shortly after mating and the royal pair tends to the young when they emerge. The first brood produces whitish, soft-bodied immature individuals, which undergo a series of moults and develop into workers. Oviposition is resumed when the initial brood is able to maintain themselves and feed the queen.
Soldiers will then be produced. Egg production steadily increases until it is a continuous, uninterrupted process. Mating occurs periodically throughout the life of the royal pair. Workers and soldiers are produced initially and only when the colony has reached certain age and size, will reproductives be produced.



Life Cycle of Termites

Mature colonies, which take years to develop, may range in size from a few hundred individuals, as in the *Kalotermitidae* to a million or more in some *Termitidae*. A mature colony usually has one king and queen, which reign throughout their lives. However, should one of them die, or if the queen stops laying sufficient eggs, the rest of the colony will detect this, most probably by means of pheromones. The production of secondary reproductives is then initiated. These reproductives do not have the same egg-laying capacity as the queen of the original pair and consequently, several secondary reproductives may be found in one nest (Thorne, 1984).

2.3 Termite Nests

Like other social insects, termites live in colonies which live in underground nests or in above ground mounds. For instance, *Hodotermes*, *Microtermes* and *Ancistrotermes* species build underground nests, which can be difficult to locate. Other termites build their nests in wood, for example, the *Kalotermitidae*, live in dry wood, and the *Termopsidae* live in damp wood (Lee and Wood, 1971). Other termites build mounds above-ground called, termitaria, often containing many thousands of individuals. Some of the most famous examples of termite mounds can be found in Africa, where they may tower nine metres (30 feet) high, contributing to the ecology landscape of the area (Sileshi *et al*., 2009; 2010). Termite mounds are fascinating from an engineering perspective, as they involve immense cooperation and ingenuity to build (French & Ahmed, 2011). The diagrams below show examples of common termite mounds in Africa.

Cubitermes mound
(Photo: G.W. Sileshi*)*

Odontotermes mound
(Photo: G.W. Sileshi*)*

Termite mounds come in all shapes and sizes, ranging from small, soft mounds near the entrance to the underground nest to huge, ornate structures sometimes referred to as cathedral mounds. For example, *Macrotermes* species build large above-ground mounds from which they forage outwards for distances of up to 50m in runways. *Odontotermes* species build both subterranean and above-ground nests. Termites construct shallow subterranean foraging galleries radiating from the nest for distances of up to 50m. The main galleries give rise to a network of smaller galleries from which foraging parties can exploit potential food sources over extensive areas of land.

Macrotermes falciger mound
(Photo: P.O.Y. Nkunika*)*

Macrotermes michaelensis mound
(Photo: G.W. Sileshi*)*

Termites build their mounds using soil and saliva and a complex system of galleries or covered runways which they use in searching for requisites such as food, moisture and soil particles. Vents within the mound facilitate the regulation of mound temperature and humidity (Lee and Wood, 1971). A termite nest typically stretches underground beneath the mound. One of the key features of a termite mound is temperature regulation, with termites opening and closing vents to achieve a stable temperature (French & Ahmed, 2010). Mounds are also used to control humidity, with conditions which can be so stable that the humidity rarely varies by more than one per cent.

Fungus comb inside a Macrotermes mound
(Photo: G.W. Sileshi*)*

Close up of fungus comb and termite larvae feeding on fungus (spherical white objects)
(Photo: G.W. Sileshi*)*

Termites in the sub-family *Macrotermitinae* cultivate fungus gardens inside the mound. These termites live in a symbiotic relationship with fungi of the genus *Termitomyces*. Termites cultivate the fungi on a special medium called the fungus comb, made by the termites. The termites continuously supply the fungus gardens with plant material including wood, leaves or grass. On these combs, the fungi form white blobs called fungal heads containing spores, which are eaten by termites. However, different termite species use the fungi and the comb in different ways; some eat the fungus for food (and do not eat anything else), others eat the fungi for their enzymes and eat plant or comb material as well.

Macrotermes bellicosus mound (Photo: P. Nyeko*)*

Macrotermes subhyalinus mound dug to remove the queen (Photo: P. Nyeko*)*

2.4 Termite Classification and Identification

Table 1 gives a summary of the classification of the major groups and approximate number of species known to occur in Africa, together with their feeding habits. Termites are usually divided into lower and higher termites. The lower termites in Africa belong to the families *Kalotermitidae*, *Termopsidae*, *Rhinotermitidae* and *Hodotermitidae*. Members of the family *Kalotermitidae* feed mainly on dry wood, do not construct definite nests, and live in small colonies in sound or dead wood. Members of the family, *Termopsidae* feed on and nest within damp and decaying wood. The family, *Rhinotermitidae* consists of mainly subterranean, wood-eating termites. The family, *Hodotermitidae* consists of the harvester termites, which are among the most destructive pests of pasture, crops and structural timber (Uys, 2002). This family is represented by the genus *Hodotermes* in East Africa and *Hodotermes* and *Microhodotermes* in Southern Africa. Both species build subterranean nests and feed on grass.

The higher termites all belong to the family *Termitidae*. This group shows considerable variation in feeding and nesting habits and social organisation. Unlike the lower termites, their feeding is not limited to wood; some feed exclusively on soil, while others 'cultivate' and consume fungi. In Africa, the *Termitidae* are represented by over 600 species (>90 per cent of all known species) in the four sub-families (*Apicotermitinae*, *Termitinae*, *Macrotermitinae* and *Nasutitermitinae*). In Africa, the sub-family *Apicotermitinae* currently consists of seventy species, while the sub-family *Termitinae* consists of about 270 species. The sub-family *Nasutitermitinae* consists of fifty-six species, which mainly feed on grass, leaf litter and wood including logs, stumps and standing dead trees. The genus *Trinervitermes* specialises in feeding on grass.

The last sub-family is the *Macrotermitinae* (fungus growing termites) consisting of over 160 African species, and arguably the most destructive crop/wood-feeding insects. The main genera include *Odontotermes*, *Macrotermes*, *Pseudacantotermes*, *Microtermes*, *Ancistrotermes* and *Allodontotermes*. *Odontotermes* species consume a variety of plant material and are serious pests of crops, trees and wood. Some species build massive and tall mounds, others build low, flattened mounds, while others do not build mounds at all. *Macrotermes* species dominate the termite fauna in arid environments and build the most massive mounds that are characteristic of African savannas. While many *Macrotermes* species have a narrow range, some such as *Macrotermes bellicosus*, *Macrotermes falciger*, *Macrotermes michaelseni* and *Macrotermes subhyalinus* occur throughout most of the African savanna. *Macrotermes bellicosus* occurs from Eritrea in the North to South Africa in the South, from sea-level to 1 800m, under moist conditions. Members of the genus *Pseudacanthotermes* exhibit a wide range of feeding and nesting habits. The remaining genera (i.e. *Microtermes*, *Allodontotermes*, *Ancistrotermes* and *Synacanthotermes*) build subterranean nests without any surface structure indicating the presence of a colony in the soil. They feed mainly on wood, litter, dung and occasionally damage trees and crops. Of these, the most destructive and economically important genus is *Microtermes*, which consists of serious pests of trees, wood, crop plants and lawns.

Many species are readily identified using the characteristic of the soldiers' heads and mandibles. The 'key' used in the identification and classification of termite species is thus based on morphology and characteristics of the soldier caste (see Appendix 1).

About 1 000 termite species are known to occur in sub-Saharan Africa and most of them are of great importance in recycling plant material. A few of them (about 5 per cent) are serious pests of crops and tree species. In Africa, the reputation of termites as pests is coupled with the presence of large mounds in crop fields or close to trees. Termites are widespread in Africa, restricted mainly by desert areas and the lower temperatures found at higher altitudes. There are approximately 20-50 damaging termite species in savanna and forest ecosystems in the family *Termitidae* (fungus-growing termites). The *Termitidae* contain over 80 per cent of the known genera and over 70 per cent of the known species. In Zambia, for example, there are about twenty-seven genera with forty-one fully identified species (Nkunika, 1982). Doubtlessly, several more species and a few more genera could be added in future research before the list is complete.

Table 1: Approximate Number of Termite Species with Known Distribution in African Savannas and their Feeding Habits (modified from Sileshi *et al*., 2010)

Family	Sub-family	Genus	Number of species	Feeding/damage
Kalotermitidae	Kalotermitinae	*Bicornitermes*	4	Dry Wood
		Bifiditermes	7	Dry Wood
		Cryptotermes	4	Dry Wood
		Epicalotermes	4	Dry Wood
		Kalotermes	3	Dry Wood
		Neotermes	17	Dry Wood
Hodotermitidae	Hodotermitinae	*Hodotermes*	2	Grass, crops
Termopsidae	Termopsinae	*Microhodotermes*	1	Grass, litter
		Porotermes	3	Damp wood
Rhinotermitidae	Coptotermitinae	*Coptotermes*	6	Wood, trees, crops
		Psammotermes	4	Wood, trees, crops, dung
	Rhinotermitinae	*Schedorhinotermes*	2	Wood
	Apicotermitinae	*Acholotermes*	4	Soil
Termitidae	Termitinae	*Amitermes*	17	Soil, wood, litter, dung
		Angulitermes	6	Soil, wood
		Cubitermes	70	Soil, dung
		Microcerotermes	46	Soil, wood, crops, dung
		Noditermes	9	Soil
		Ovambotermes	1	Wood
		Procubitermes	20	Wood, dung
		Promirotermes	10	Soil, wood, dung
		Termes	7	Soil, wood, dung
	Nasutitermitinae	*Baucaliotermes*	2	Grass, litter, wood, dung
		Fulleritermes	5	Wood, litter, dung
		Nasutitermes	10	Wood, trees, crops
		Rhadinotermes	1	Wood, litter
		Spatulitermes	1	Wood
		Trinervitermes	17	Grass, litter, wood
	Macrotermitinae	*Acanthotermes*	1	Wood
		Allodontotermes	3	Wood, trees, crops, dung
		Ancistrotermes	10	Wood, trees, crops, dung
		Macrotermes	14	Wood, grass, trees, crops, dung
		Microtermes	42	Wood, grass, trees, crops, dung
		Odontotermes	78	Wood, grass, trees, crops, dung
		Protermes	5	Wood
		Pseudacanthotermes	8	Wood, grass, trees, crops, dung
		Synacanthotermes	3	Wood

2.5 Termite Food

The normal food of most termites consists of cellulose (dead wood), fungi or soil. Some termites feed directly on dead plant tissue; others collect plant materials on which to grow fungus gardens in their nests and the rest consume huge amounts of organic matter to derive nutrients. The fungus-growing termites are the most troublesome in agroforestry. They feed on organic material such as crop residues, mulches and soil organic matter (humus). However, when this type of food is not available, they will feed on live plant material including crops such as groundnuts, millet, maize, cassava and trees. Harvester termites collect live green plant material and cause damage to pasture grasses, crops and tree seedlings. They readily attack weak plants that are wilting or damaged. Termite damage in agroforestry and agricultural fields appears to have intensified due to climate change.

Chapter Three

BENEFICIAL EFFECTS OF TERMITES

3.1 Livelihood Benefits

3.1.1 Termites as Human Food

In many African societies, the winged, reproductive adult termites are regarded as a delicacy (Sileshi *et al*., 2009). The queen and soldiers of some species are occasionally eaten. Local people easily tell the edible termites from those unsuitable for consumption by vernacular names. The species of termites eaten in eastern and southern Africa are shown in Table 2 below.

Table 2: Termite Species that are eaten in Eastern and Southern Africa

Species	Stage Eaten	Country
Hodotermes sp.	Nymphs	South Africa
Microhodotermes viator	Winged adults	South Africa
Macrotermes falciger	Winged adults and queen	Zimbabwe
Macrotermes natalensis	Winged adults	Zimbabwe
Macrotermes swaziae	Winged adults	South Africa
Odontotermes badius	Winged adults	South Africa
Termes capensis	Winged adults	South Africa
Macrotermes subhyalinus	Winged adults and soldiers	Uganda
Macrotermes bellicosus	Winged adults	Uganda
Odontotermes latericius	Winged adults	Uganda
Pseudacanthotermes spiniger	Winged adults	Uganda
Odontotermes kibarensis	Winged adults	Uganda
Pseudacanthotermes militaris	Winged adults	Uganda
Macrotermes falciger	Winged adults	Zambia

Termites are commonly dried and sold, and hence are a supplementary source of proteins in human nutrition and a source of income.

Edible termites on sale at Chipata market (Photo: G.W. Sileshi*)*

3.1.2 Termite Mounds as Sources of Mushrooms

There is a mutualistic relationship between some edible mushrooms (genus *Termitomyces*) and the fungus growing termites (*Macrotermitinae*). Hence, these mushrooms grow mainly around termite mounds. The common mushroom species include; *Termitomyces titanicus*, *Termitomyces clypeatus*, *Termitomyces microcarpus*, *Termitomyces eurrhizus*, *Termitomyses letestui*, *Termitomyces reticulates* and *Termitomyces robustus*. *Termitomyces titanicus* is the world's largest (up to 90 centimetres in diameter) and one of the tastiest mushrooms. The indigenous knowledge of mushrooms and their association with termites is elaborate in many African communities (Sileshi *et al*., 2009).

A man holding an edible mushroom (Termitomyces) collected from a termite mound (Photo: Super Stock*)*

Termitomyces mushrooms on sale at Chipata market (Photo: G.W. Sileshi*)*

Small Termitomyces mushrooms around mound (Photo: G.W. Sileshi*)*

An edible Termitomyces mushroom from Namibia (Photo: Africa Hunting.com *)*

3.1.3 Termites Improve Agricultural Land

Like earthworms, termites loosen, aerate and enrich the soil by assisting in litter decomposition and recycling of soil organic matter. They also breakdown and release organic matter as they digest soil. Recent analyses by Sileshi *et al*. (2010) show that mounds of the fungus growing termites have 16 per cent more carbon content than the adjacent soil. Total nitrogen (N) was also 42 per cent more in the mound soil compared with the surrounding soil. Termite mounds were significantly enriched in exchangeable calcium (232 per cent, more) potassium (306 per cent more), magnesium (154 per cent more) and sodium (78 per cent more) than the surrounding soil (Khalil *et al*., 1990). Termite mound soils were 85 per cent more enriched in cations than the surrounding soil. This is probably because termites transport cation-rich clay from the subsoil for the construction of the mounds (Bignell, 2006). Soil pH also increased by 8 per cent in the termite mounds compared with the adjacent soil (Sileshi *et al*., 2010). Throughout the semi-arid regions of Africa, crop growth variability related to termite activity has been utilised by subsistence farmers in low-risk farming strategies for crop production. Farmers grow vegetables and cereal crops around mounds to take advantage of the fertility (Sileshi *et al*., 2009).

As soil from termite mounds is rich in macro and micro nutrients, African farmers crush and use mound soil as fertiliser in crop fields. In many parts of Africa, farmers apply termite mound soil to the field where they plant cereal and legume crops. In Uganda, farmers plant crops such as pumpkins, tomatoes, onions and maize adjacent to mounds. Similarly, okra, pumpkins, sweet sorghum and late crop of maize, which require good water and nutrient supply are grown almost exclusively on termite mounds in Zimbabwe (Sileshi *et al*., 2009). In Malawi and Zambia, vegetables are grown on termite mounds while maize is grown on the soil around them. In southern Zambia and Zimbabwe, farmers apply termite mound soil to the field, where they plant maize, soya beans, cowpeas and other local cereals and legumes (Siame, 2005; Sileshi *et al*., 2009). They do this every three years. It was found that where termite mound soil had been incorporated, maize harvests were 33 per cent higher than they had been when inorganic fertilisers were used and the positive effects were long lasting.

3.2 Provision of Ecosystem Services

3.2.1 Termites as Food for Animals

Termites form the major dietary component of many animals. For some animals such as the aardvark, termites are the main food. Termites are also the most nutritionally important insects in the diet of chimpanzees and gorillas. During swarming, termites form a major source of protein rich food for many amphibians, reptiles, birds and mammals (Sileshi *et al*., 2009).

3.2.2 Termite Mounds as Sources of Minerals

Termite mounds are a source of minerals for animals and humans (Sileshi *et al*., 2009). Both domestic and wild animals use mounds as salt-licks because the soil is rich in essential minerals such as manganese, cobalt, copper and selenium. Even well fed cattle on commercial ranches cannot resist termite mounds, eating away the soil to form a grotto and eventually demolishing the whole mound (Noirot, 1970). Humans also deliberately ingest termite mound soil. This is called geophagy, and it has been practised by humans since antiquity. Consuming soil has often been considered as an aberrant behaviour. However, recent studies show that this is a perfectly normal behaviour. In Africa, geophagy is common especially among nutritionally vulnerable populations, pregnant and lactating women and children. Termitaria are the major sources of the soil consumed by women and children in Zambia and Zimbabwe (Nchito *et al*., 2004). There is also a growing body of evidence suggesting that mound soil can be a source of iron to anaemic and iron-deficient individuals. African termite mounds, which concentrate minerals up to 500-fold over adjacent soils, probably supply most or all of the recommended daily allowances of minerals for pregnant women. Among the positive health benefits of geophagy during pregnancy are improved maternal calcium status, improved foetal skeletal formation and birth weight, reduction in pregnancy-induced hypertension, and decreased risk of embryonic exposure to teratogens and loss of nutrients through emesis. Another adaptive function of consuming termite soil is the ability of clays to adsorb toxins from plants eaten by humans. This may enable people to rapidly adapt to some of the many toxic plants (Rowland, 2002).

3.2.3 Termite Mounds are Hotspots of Livestock Feeding

There is growing evidence demonstrating that termite mounds are 'hotspots' of foraging by herbivores and 'keystone' resources in nutrient-poor rangelands (Sileshi and Arshad, 2012). For example, in Africa, animals preferentially feed on termite mounds, compared to the adjacent areas. The higher concentration of soil nutrients, especially nitrogen, phosphorus and potassium around termite mounds creates conditions that attract herbivores by providing concentrated sources of high quality forage.

3.2.4 Termites help Regenerate Degraded Land and Tree Establishment

Termitaria have long been known to have a profound effect on soil, vegetation composition and structure. In uncultivated land, termite mounds can help in the establishment of vegetation patches through several mechanisms. Termites concentrate nitrogen, phosphorus, potassium and bases and elevate clay content in and around mounds. Increased clay and organic matter around termite mounds also enhance nutrient and water retention (Sileshi *et al*., 2010). The mounds also alter the hydrology and drainage of the site. This can stimulate growth, diversity and composition of woody plant species (Joseph *et al*., 2012; Sileshi *et al*., 2010). For example, on savanna sites in Burkina Faso, seedling regeneration was more abundant on *Macrotermes* mounds than adjacent areas. *Acacia* spp. survived better around the mounds than in the inter-mound area at two sites in Kenya. In the Sahel, manipulation of termite density and activity has been shown to increase woody plant regeneration and speed the restoration of degraded areas (Mando *et al*., 1999). For example, tree species such as *Faidherbia albida* used in traditional agroforestry, desertification control and re-greening of the Sahel have been shown to regenerate faster around termite mounds (Sileshi *et al*., 2010).

3.2.5 Termite Mounds are Hotspots of Biodiversity

There are many organisms that live in symbiotic or mutualistic associations with termites. These include bacteria, protozoa and fungi. Microbial communities that inhabit termite nests are also of great genetic and functional diversity (Breznak, 2000). Among the fungi, members of the genus *Termitomyces* live in a mutualistic association with the *Macrotermitinae*, and produce edible mushrooms. Termite mounds also provide habitat for a variety of termitophilous animals. These include insects and many other arthropods. Many termite species that are not mound-builders themselves make their nests within the fabric of existing termite mounds.

Other animals such as ants, spiders, centipedes and assassin bugs live in or near the nests and regularly prey on the termites. In addition, birds, reptiles (e.g., geckoes, lizards and snakes) and mammals preferentially nest in termite mounds (French and Ahmed, 2010). The Nile monitor buries its eggs in termite mounds for incubation. Mongooses are largely dependent on termite mounds for safe den sites.

Plant communities that grow on termite mounds are often different from the surrounding matrix vegetation (Joseph *et al*., 2012; Sileshi *et al*., 2010). Thus mounds can also be hotspots of plant diversity.

Chapter Four

TERMITES AS PESTS

Termite attacks on annual and perennial crops, especially in the semi-arid and sub-humid tropics cause significant yield losses. It is, however, to be emphasised here that not all termites are pests since the normal food of most termites consists of cellulose (dead wood), fungi or soil. Out of over 1 000 known species of termites in Africa, only about 5 per cent of these are serious pests of crops and tree species. Some of the pest species can cause considerable damage in agriculture, forestry and wooden fittings in buildings. Harvester termites collect live green plant material and cause damage to pasture grasses, crops and tree seedlings. *Hodotermes* and *Trinervitermes* species specialise in grass-eating, which makes them a serious pest of pasture and rangeland. The fungus-growing termites are the most troublesome in agriculture and forestry. They feed on dead organic material such as crop residues, mulches and humus. However, when this type of food is not available, they will eat live plant material including crops such as groundnuts, millet, maize, cassava and trees. They readily attack weak plants that are wilting or damaged.

The greatest pest potential is within the genera *Macrotermes, Odontotermes, Pseudacanthotermes, Ancistrotermes* and *Microtermes*, which consist of serious pests of trees, structural timber, wood, crop plants and lawns. *Macrotermes* species attack plants at the base of the stem, ring-barking or cutting them through completely. *Odontotermes* damage is due to feeding either under soil sheeting on the outer surface of the plants or on the roots.

Macrotermes bellicosus damage Eucalyptus grandis sapling in Uganda (Photo: P. Nyeko*)*

Microtermes and *Ancistrotermes* species attack plants from below ground by entering the root system and tunnel into the stem, hollowing it out and frequently filling it with soil. In Africa, the reputation of termites as pests is coupled with the presence of large mounds in crops or close to trees (Sileshi *et al*., 2009; 2010).

Termites attack most of the exotic and indigenous tree species used in agroforestry. Exotic trees such as *Acacia* and *Leucaena* species are especially susceptible to termite damage. Damage to trees and crops is especially severe during the dry season and dry spells during the rainy season. In eastern Zambia, several farmers who planted *Acacia crasicarpa* as woodlots have completely lost them due to termite attack (Sileshi *et al*., 2008).

In Busia district of Western Kenya, complete destruction of *Casuarina* seedlings were reported. In Rwanda, it is reported that planting of trees is badly hampered by termites. In eastern Uganda, losses of up to 100 per cent have been attributed to termites on *Grevillea robusta* (Nyeko and Olubayo, 2005). In southern Zambia, termites cause serious economic damage to agroforestry plantations. The damage that occurs in this area ranges from 20-80 per cent particularly during drought periods.

Macrotermes bellicosus damage on Grevillea robusta sapling in Uganda (Photo: P. Nyeko*)*

Fruit tree orchards of citrus, mangoes, avocados, guavas, macadamia and indigenous fruits, particularly those planted to newly cleared and prepared lands, are vulnerable to attack by termites. Sometimes their attack results in the total destruction of entire orchards. The termites implicated are *Macroterme*s, *Odontotermes* and *Ancistrotermes* species. Trees are most at risk during the seedling stage and the first year of establishment in the field. Seedlings are either cut just below or above the soil surface. In the latter case, termites gain access from soil-covered galleries impinging on the base of the plant. Usually, the seedlings are completely severed, resulting in lowered plant populations. Damage to mature plants is largely caused by *Microtermes* and *Ancistrotermes* species. These species enter and consume the root system, which directly kills the plant or indirectly lowers yield through decreased translocation of water and nutrients. Attack to the root system can also lead to increased susceptibility to pathogens and other secondary pests.

Termites also inflict severe damage to agricultural crops especially groundnuts, maize, sugarcane and cassava throughout Africa. *Microtermes* and *Odontotermes* species are the commonest groundnut pests in semi-arid tropical countries of Africa. The smaller fungus-growing termites (*Microtermes* spp. in particular), attack and invade growing groundnut plants through the roots and stem near ground level, hollowing them out and causing the plants to wilt and die. Stem bases are sometimes severed by *Macrotermes*, with 25-100 per cent of plants being lost in this way. As the crop ripens, the outer layers of the pods are scarified by termites, allowing contamination of the seed with soil fungi (e.g., *Aspergillus*), which produce aflatoxins. Infected plants are not obviously diseased and are frequently harvested with the fungi and contaminate the rest of the crop. In South Africa, up to 30 per cent of the groundnut pods may be scarified. *Microtermes* also penetrate the shell to feed on the soft inner lining, filling the pod with soil. This form of attack leads to additional loss through premature germination of kernels. Stacks of plants left drying in the fields are also frequently attacked by *Odontotermes*, which can cause 30-40 per cent crop loss at this stage. Termite damage is generally most serious towards the end of the growing season, just prior to harvesting, with drought being an aggravating factor.

Among cereal crops, maize is most seriously damaged by termites in Africa. *Microtermes* and *Ancistrotermes* attack seedlings and mature maize plants while *Macrotermes* species cause damage to seedlings. *Odontotermes, Allodontermes* and *Pseudacanthotermes* can consume the entire seedlings. Maize plants attacked early in the season can compensate damage with new growth. Lodging of mature maize plants is one of the obvious symptoms of termite damage. Grain from lodged maize or groundnut may be invaded by soil fungi that produce aflatoxins. Maize yield losses of between 30-60 per cent have been reported in some parts of Africa (Sileshi *et al*., 2005; 2009).

The most damage to sugarcane is done by *Amitermes, Pseudacanthotermes, Macrotermes, Odontotermes, Microtermes* and *Ancistrotermes.* Yield losses of 18 per cent were reported in Sudan, 5-10 per cent in the Central African Republic, and germination failure of up to 28 per cent was reported in Nigeria. The most common damage to sugarcane is the destruction of the setts (planting material).

Macrotermes falciger damage on cassava cutting in Magoye, Zambia (Photo: P.O.Y. Nkunika*)*

Cassava, which is grown from stem cuttings is consistently attacked as seed pieces by *Amitermes,* a species that predominantly is a root-feeding. Other species like *Ancistrotermes, Macrotermes Odontotermes, Microtermes* and *Pseudacanthotermes* also damage the maturing crops and trees by hollowing out stems at ground level. *Allodontermes, Ancistrotermes, Hodotermes, Microtermes* and *Odontotermes* often damage cotton, especially in the drier parts of Africa.

Chapter Five

TERMITE MANAGEMENT

We would like to make a distinction between termite control and termite management. Pest control refers to the elimination of a species perceived as a pest through measures such as application of pesticides, fire, etc. Termites are much maligned as pests. Destruction and poisoning of their mounds have been actively pursued as the main control measures in cropland as well as rangelands (Sileshi *et al*., 2009). Unfortunately, control measures are usually taken based on wrong assumptions as demonstrated by the case study below.

Case Study

> Wood (1991) documents a good example of a failed attempt to control termites in rangelands in eastern Ethiopia. Farmers and government officials were reluctant to accept overgrazing as the primary cause of rangeland denudation. Instead, they regarded termites as the major problem and launched campaigns to poison mounds using pesticides. In two districts alone, over 600 000 *macrotermes* mounds were poisoned with 12 000kg of aldrin at the cost of over 200 000 man-days, which turned out to be ineffective.

On the other hand, management focuses on long-term prevention or reduction of pest damage rather than eliminating the pest. Appropriate management of the crop and prevention of pests from becoming a threat are the first lines of action in management. This is usually achieved through a combination of techniques such as habitat manipulation, cultural practices and use of resistant varieties. Pest control is instituted only when preventive methods are no longer effective or available. It is futile and counterproductive to attempt to control termites in agroforestry. But it is possible to manage them.

It is important to note that there is no single method that can be universally recommended for termite control. Methods of control are more effective if used in conjunction with each other, with maximum use of local knowledge and resources. In that sense, we advocate termite management rather than controlling them. The first part of this chapter, therefore, focusses on general principles that help in reducing termite damage. The recommendations given are not restricted to a specific species. They are meant to reduce the impact of pests and other factors on the growth of the plant. The second part focuses on specific management methods tested on some termites and found effective.

5.1 General Principles for Reducing Termite Damage

The suggestions given below are based on review of a wide range of literature. Some of them come from individual research studies and have not been widely tested. Most of the principles may not necessarily reduce termite numbers, but only reduce damage to trees and crops.

Good Nursery Management

Seedling quality represents the most important economic aspect of forestation and agroforestry. To meet future demands for planting material, high quality and quantity of tree seedlings must continue to be available to the farmers. Increased planting of agroforestry species confronts nursery managers with a wider array of potential pest problems. When major problems do occur, nursery owners can utilise integrated pest management practices. This means the integration of suitable techniques and procedures into one concerted, harmonious effort for effective and efficient control of nursery pests. Integrated Nursery Management (INM) is the most practical and ecologically sound approach for control of nursery pests because it also involves all other nursery management procedures. INM is accomplished through good nursery management (Jaenicke, 1999) in combination with tactics that prevent pest damage from reaching economically damaging proportions, while protecting the environment from potential hazards. These tactics include preventing pests (exclusion) from multiplying in the nursery, use of good and healthy tree seeds, planting seeds at the right time and density, watering, sanitation, and controlling pests through chemical or biological means. Hence, INM is not only aimed at termites but at all other problems (including pests) that induce stress, leading to termite damage once seedlings are out-planted. The objective of INM is to produce good-quality healthy seedlings consistently and profitably.

Protecting Tree Seedlings

The first year is a critical period when tree seedlings are most at risk. In general, termite attack becomes minimal after canopy closure. Therefore, management may be mandatory during the nursery and seedling stages, with some exceptions in a few older plants. The presence of termite mounds or foraging activities in the field in well-established plantations does not necessarily indicate a termite hazard.

Providing Substitute Sources of Food

There is a common belief that dead plant materials attract termites to live trees. This is a myth because fungus-growing termites, which are the most serious pests of trees, prefer to eat dead plant material. The solution is rather to provide termites with an alternative source of food such as mulching with wood and dry leaves. This may not only divert termites from live plants but also add organic matter to the soil. Therefore, farmers should avoid leaving bare, dry soil around seedlings or trees. It is important to leave as much plant debris (dry wood, leaves, grass) as possible on the soil surface when preparing planting sites. Mulching with items such as hay, manure, wood shavings, wood ash or maize stover has been shown to dramatically decrease termite attack on live plants. Termites are attracted to the mulch rather than the crop or tree. Vetiver grass leaf mulch has been shown to prevent termite attack around the base of trees.

Maintaining Soil Organic Matter

The damage by many termites becomes severe on soils with low organic matter content. This is because such soils do not contain enough food for termites to live on and they resort to feeding on living plant material. Adding compost or well-decomposed manure to the soil and sowing green manure legumes and cover crops helps to increase the organic matter in the soil. However, attack may increase if there is an abundance of undecomposed organic matter such as manure that attracts root feeding termites such as *Odontotermes*. This may also increase nesting by ants, which are the worst enemies of termites.

Ensuring Overall Plant Health

Termites rarely attack healthy plants but may do so following weakening of plants. Anything that weakens the plant such as drought, neglect of cultural practices, low soil fertility and lack of essential nutrients, overcrowding and competition, weed infestation, injury by fire and insects or fungal attack will predispose the plant to termite damage. In dry areas, seeds should be sown at the beginning of the wet season to give the plants a chance to establish themselves and remain healthy in the field. It is also recommended that only healthy and vigorously growing tree seedlings be transplanted into the field. Plants which are suffering from disease or lack of water are generally more susceptible to termites than healthy plants. It is, therefore, important that plants are kept healthy and not stressed. The following practices are recommended to reduce stress:

Watering

Give nursery stock enough water just before planting out. Plants become susceptible to termite attack during the dry season if they are allowed to dry due to inadequate or incorrect watering. Water seedlings to the point of water logging with the first sight of termite damage.

Root Pruning

Root pruning is a necessary operation in tree nurseries. After root pruning, allow enough time for recovery of damaged roots before transplanting seedlings. In nurseries, it is important to schedule root pruning to allow sufficient recovery and repair of damaged tissues before transplanting. Field root pruning may cause less stress to trees if conducted during rainy periods. Alternatively, raising seedlings on a raised bed ensures air-pruning, hence reducing the risk of termite damage.

Transplanting

Transplant seedlings on time (at the beginning of the wet season) and when the soil is sufficiently wet or when the ground is moist (in instances where irrigation systems are practised).

Observing Planting Date

In unimodal rainfall and dry areas, it is recommended that seeds should be sown at the right time to give the plants a chance to establish themselves before the onset of the dry season. As a general rule, begin planting out seedlings with the first good rains or when the soil is wet to a depth of 20-30cm.

Correct Planting Density

Plant tree seedlings using the recommended densities to reduce competition.

Timely Weeding

Weed the field promptly to reduce weed competition.

Avoiding Planting Susceptible Species

In areas where termite damage is severe, it is prudent to opt for species that are tolerant or resistant to termites and avoid those that are prone to termite damage. However, resistance is a relative concept, which depends on the tree species, origin of the tree, age and condition of the tree, termite species and soil and climatic conditions where the tree is growing. Some indigenous tree species are more resistant to termite attack than exotic species. There is little knowledge about crop resistance to termite attack. However, in general, indigenous crops and tree species are more resistant to termites than exotic species because indigenous species are better adapted to the local ecology. For instance, in Africa, sorghum and millet are more resistant to termites than maize and cowpea. Bambara nuts are not attacked while groundnuts suffer serious damage.

Encouraging Natural Control of Termites

Termites have a wide variety of enemies including black ants, beetles, bugs and spiders. Ants are the greatest enemies of termites in all regions of the world. Decomposing materials such as dead animals, fish bones, manure or sugary substances (e.g., sugarcane husks) attract ants. This has been traditionally applied by farmers in Africa (Sekamatte, 2000; Sileshi, 2008). A recent test in maize fields in Uganda has shown that protein-based baits such as molasses and fish bones attract significant numbers of ants and more ants establish nests near maize plants (Sekamatte, 2000). This in turn reduced termite damage and increased grain yields. Other predators of termites include frogs, lizards, snakes, birds and bigger animals such as aardvarks, pangolins, bats, monkeys and humans. Encouraging this kind of wildlife will help to reduce the number of termites. Bushes and trees are a home for many of these useful creatures. Areas of natural habitat should always be left around fields where crops and trees are grown. If these areas are destroyed, then there is an imbalance between the populations of predators and termites. Agroforestry can also increase natural enemies of termites and reduce termite damage on crops.

Intercropping and Mixed Cropping

These are the most effective cultural practices used by small-scale farmers in sub-Saharan Africa to manage insects that have specific host ranges. However, controversial results have been reported for termites. For example, intercropping maize and beans resulted in significant reduction of tunnelling by termites but did not reduce termite damage on the plants. On the other hand, intercropping in forestry has been suggested as a means of retaining termite diversity in the crop in order to prevent them from achieving pest status. Certain grasses are intercropped with different crops in West Africa to repel termites. Mixing trees with crops also can reduce termite damage to either the crop or tree component. For example, in eastern Zambia, planting maize between rows of tree stumps reduced termite damage on maize (Sileshi *et al*., 2005).

Crop Rotation

Planting the same crop on the same land year after year reduces soil fertility and structure. Crops growing in such conditions will be weaker and susceptible to termites. Crop rotation means that different crops are grown on the same piece of land each year. This can prevent pest and disease build up and also help the soil to recover nutrients.

5.2 Specific Control Methods

5.2.1 Chemical Control

In the past, chemical control of termites was largely based on the use of organochlorine insecticides such as lindane, aldrin, dieldrin, chlordane and heptachlor. These were applied as seed dressing or to the soil in planting holes or furrow treatments or poisoning the mound. However, termites soon developed resistance to these chemicals. Resistance to aldrin, for instance, had been reported as early as the 1970s in *Eucalyptus* plantations in Zambia. Following increasing restrictions on the use of persistent organic pollutants, less persistent insecticides such as the organophosphates (Chlorpyrifos, Isofenphos), carbamates (Carbosulfan, Carbofuran), and pyrethroids (Permethrin, Decamethrin) have been used as alternatives; but their low persistence often necessitates repeated applications. Recently, controlled-release formulations of some non-persistent insecticides were tried and found to be effective and long lasting. However, these formulations are not cost-effective for the majority of low-income farmers in developing countries.

5.2.1.1 Alternative Control Options

There are a number of alternatives to using chemical pesticides for termite control. Some of these methods work within the natural system and help promote natural pest control mechanisms. For instance, organic control methods do not pollute the environment and are not harmful to beneficial animals, or to the people using them. Organic methods aim to use locally available materials and do not rely on importing expensive materials from elsewhere. Organic methods are thus cheap and easy to use. These methods regulate termite numbers rather than eliminate them so that the benefits provided by termites are not lost.

Plant Preparations (Botanicals)

The pesticidal properties of many plants have been known for a long time and natural pesticides based on plant extracts such as rotenone, nicotine and pyrethrum have been commonly used in pest control. There are many other plants with insecticidal and repellent properties. However, the effectiveness of plant extracts vary depending on the target insect, concentration used, the plant part, the maturity of the plant and the condition under which it has been grown. Most farmers like to see pests drop dead right away. However, plant extracts including those of the famous neem do not have this effect. Their main effect is as a repellent or antifeedant, which means insects avoid the treated plants. Different plant parts may be used as a natural insecticide. Concoctions of plant parts, such as toxic fruit juices, pulps or shavings can be applied directly. The advantage of plant extracts is that, unlike synthetic pesticides, they leave no residue on crops as they breakdown within a few days after application.

Farmers have traditionally used plant extracts for millennia and a rich indigenous knowledge still exists in some communities. Farmers in different areas use different methods of preparing plant extracts. Here, we will only provide a few examples of plants commonly used by farmers to control termites (Sileshi *et al*., 2009).

Tephrosia vogelii

Leaves and pods are crushed into a fine powder and mixed with water, then sprayed on affected plants.

Lantana camara

Leaves are boiled in water for 30 minutes, and then sprayed on the crop.

Neem (Azadirachta indica)

Leaves or fruits are crushed and soaked in water; the solution is sprinkled on the crop.

Euphorbia tirucalli

Roots are soaked in water for 24 hours; the solution is sprinkled on insects and on the crop.

Bobgunnia* (*Swartzia*) *madagascariensis

Pods are crushed and put in water, then sprinkled on the crop.

Melia azedarach

Roots and bark are soaked in water for 24 hours and then sprayed preventively or directly on attacking insects.

The list of plants above is not exhaustive. There are probably many more plants that could be locally available and as effective as the ones above. Appendix 2 gives examples of plant species used in Zambia, along with brief descriptions of the method of extraction and application. These are farmers' recipes and may not be effective under all conditions. The limitation of farmers' recipes is that different farmers give different versions. Therefore, users should carry out their own experiments to find the plants and application rates most appropriate to their field conditions. Most plant materials also breakdown rapidly in the soil and do not give prolonged protection from termite attack. Unlike conventional pesticides, little is known about the active ingredients of local indigenous pesticides and their mode of action (see Appendix 3). In addition, the hazards they present to humans and the environment is often unknown. Therefore, greater care is required in their use.

5.2.1.2 Microbial Preparations

Preparations of the fungus *Metarhizium anisopliae* has recently been developed for control of termites in buildings in the USA, Brazil and Australia. Colonies of some species could be killed when nests were inundated with conidia. Research conducted at the International Centre of Insect Physiology and Ecology (ICIPE) has indicated the effectiveness of the fungus for the control of termites in pasture, nursery trees and mounds in Kenya (ICIPE, 1997). The potential for control of termites in maize has been demonstrated (Maniania *et al*., 2002). The Centre for Agriculture and Biosciences International (CABI) has a large collection of *Metarhizium anisopliae* and *Beuvaria bassiana* isolates which have shown varying levels of efficacy against termites. CABI and ICIPE have also developed formulations, storage and application techniques for these isolates, which are effective for protecting tree seedlings especially if applied to potted seedlings. The fungus formulated as granules and applied as seed treatment reduced plant lodging and increased yield of maize. Conidia of *Metarhizium* could be spread through the colony and nest by contact and grooming between contaminated and uncontaminated termites. Application methods, including inundating termite nests or sites of high termite activity with formulated products and use of low doses of the insecticide imidacloprid in combination with fungus have improved control of termites.

5.2.1.3 Wood Ash

Wood ash is widely used by Zambian small-scale farmers. It may be as effective as chemical pesticides, but has great advantage in that it is harmless to human health and cheaply obtained from firewood and crop residues. A bit of soil is removed around the plant and then ash is sprinkled around the affected plant. Ash is alkaline and it may, therefore, repel termites. Besides, wood ash blocks the tracheae of small insects such as termites, thereby suffocating them.

5.2.1.4 Cow Dung and Urine

Cow dung and urine have been used for termite control by farmers in many parts of Africa (Sileshi *et al*., 2009; 2008). In Machakos district of Kenya, farmers smear cow dung on posts to protect them from termite attack. In Monze district of Zambia, farmers used fresh cow dung to reduce termite damage to maize. Similarly, farmers in south-western Nigeria believe that goat and cow dung reduce termite damage. Reduction in termite damage to rangeland using cow dung has been demonstrated in an experiment conducted in the 'Cattle Corridor' of Uganda. Cow dung is suspected to reduce termite damage through the accumulation of organic matter in the soil. However, the precise mechanisms are not yet known.

5.2.1.5 Destruction of Mounds and Colonies

There are different ways of destroying a colony, including digging the nest and removing the queen, burning wood, grass or cow dung to kill the colony with smoke, pouring hot water and flooding the nest with rain water. Although destruction of a colony has been advocated by researchers, success has been limited due to various constraints including labour requirements and lack of knowledge about termite biology (Sileshi *et al*., 2009). As this practice is directed towards mature colonies of the mound-building species, it overlooks species that do not build mounds (e.g., many *Odontotermes* and *Microtermes* spp.). It must be noted that non-mound building species are often the more serious pests especially in arid areas. For example, the non-mound building termites such as *Microtermes*, *Trinervitermes* and *Microhodotermes* spp. destroy rangeland much more than the mound building termites, including *Macrotermes* and *Odontotermess* pp. Those that build mounds are also subterranean for the first few years. Even if mature colonies are killed, the immature colonies could spread to take over the area. Many farmers also do not destroy the mounds even when they are live or very easy to flatten. Some farmers also resist destruction of mounds as they are considered sacred places among many communities in Africa.

Chapter Six

CONCLUSION

The key message is that not all termites are pests. It must be noted that the pest activity is a part and parcel of the termite's beneficial role to various ecosystems. Therefore, it is important to assess the costs and benefits of termites before any control measure is taken against the insect. Since not all termite species are pestiferous, control measures that target only damaging species could provide the best option. Local communities have comprehensive indigenous knowledge of termite taxonomy, ecology and apply various indigenous control practices. These must be strengthened in the face of global climate change and the world ban on persistent organic pollutants.

We would like to emphasise that it is futile and counterproductive to attempt to control termites in agroforestry. But it is possible to manage them through a combination of techniques. Chemical control should be instituted only when preventive methods are no longer effective or available. This book raises more questions than answers. This calls for further research in this much neglected, yet a very important area in tropical agroforestry.

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APPENDICES

Appendix 1

Key to the termite genera based on the soldier caste (After Mitchell, 1980)

1.	Pigmented compound eyes present.. Pigmented compound eyes absent..	2 3
2	Compound eyes conspicuous. Head rounded. Pronotum with broad median anterior lobe... Compound eyes small. Head rectangular. Pronotum without median anterior lobe..	*Hodotermes* *Epicalotermes*
3	Head drawn out into long conical tube. Mandibles reduced....................... Head not drawn out into long conical tube. Mandibles well developed…..	30 4
4	Fontanelle absent………………………………………................... Fontanelle present………………………………………...................	5 7
5	Head square, front of head vertical. Mandibles short and angled in the middle ……………………………………...................................... Head rectangular, front of head not vertical, mandibles well developed. Pale, unpigmented eye spots present …………....................................	*Cryptotermes* 6
6	Pronotum large and kidney shaped with sides evenly rounded into posterior margin……………………………….. Pronotum smaller with sides straight and almost parallel…......................	*Neotermes* *Bifiditermes*
7	Pronotum flat without anterior robes……….................…………….. Pronotum never flat, often saddle shaped…………………....................	8 10
8	Head pear shaped. Fontanelle very well developed, directed forwards. Mandibles without marginal teeth. Soldiers monomorphic…………… Head not pear shaped. Fontanelle on top of head. Mandibles with marginal teeth. Soldiers dimorphic or polymorphic..............................	*Coptotermes* 9

9	Head long with parallel sides. Left mandibles with five or more marginal teeth, right mandible with three marginal teeth grouped about half way along. Soldiers polymorphic..	*Psammotermes*
	Head round. Left mandible with two well developed. Marginal teeth, right mandible with only one marginal tooth. Soldiers dimorphic……	*Schedorhinotermes*
10	Labrum more or less tongue-shaped, rounded or pointed, with or without hyaline tip………………………………..........................	11
	Labrum of various shapes, square, emarginated or trilobed, without hyaline tip……………………………………..........................	18
11	Mandibles with conspicuous marginal teeth……………................…	12
	Mandibles without marginal teeth or with microscopic serrations only	14
12	Single large marginal tooth in right jaw. Several smaller marginal teeth in left jaw……………………………...	13
13	Mandibles sickle shaped. Jaws symmetrical with single marginal tooth in each……………………………………	*Amitermes*
	Mandibles not sickle shaped with or without marginal tooth in right jaw. Dentition asymmetrical…………………….......................................	*Odontotermes*
14	Two spine-like points projecting forwards from front edge of Pronotum. Soldiersdimorphic………..	
	Pronotum without spine like projections. Soldiers monmorphic or dimorphic………..……………………	
15	Labrum without hyaline tip. Large species. Soldiers dimorphic………...	*Macrotermes*
	Labrum without hyaline tip. Small species. Soldiers monomorphic or dimorphic……..………………..…	16
16	Head and long rectangular. Mandibles thick with minute serrations along inner Margin………………..	*Microcerotermes*
	Head rounded. Mandibles slender without serrations along inner margin	17
17	Soldiers dimorphic. Mandibles of major soldiers strongly curved inwards at tip……………………...	*Ancistrotermes*
	Soldiers monomorphic. Mandibles curved in lightly at tip .……..…......	*Microtermes*

18	Contents of the abdomen light grey to almost black............................ Contents of the abdomen white to creamy yellow................................	19 24
19	Labrum abnormally large, emarginate, bilobed with thick rounded lobes .... Labrum normal size………………………………........................	*Euchilotermes* 20
20	Mandibles massive and powerful…………...................………….. Mandibles not abnormally heavy……………………........................	21 22
21	Mandibles short and thick. Labrum triangular, about as long as broad, tapering to rounded acute angled pointed…………………………… Mandibles long and thick with sides evenly and convexly curved from base to tip, the cutting margins finely serrated………………......…………	*Apicotermes* *Ovambotermes*
22	Labrum forked, deeply bilobed………………………....................... Labrum not deeply bilobed……………………………........................	*Cubitermes* 23
23	Mandibles straight, shorter than length of the head, curved inwards at the tip. Labrum as broad as long, very slightly emarginated, the corners drawn out in two fine points…………………………………………...... Mandibles long and slender with the inside of the tips flattened and adapted for 'snapping'. Labrum longer than broad with concave tip....	*Crenetermes* *Termes*
24	Mandibles grotesquely asymmetrical, the left with a cork screw-like twist, the right straight….. Mandibles symmetrical…………………………...........................	*Pericapritermes* 25
25	Gula with definite ridge or swelling………………….......................... Gula without ridge or swelling………………………..........................	26 27
26	Eminence on gula a rounded knob. Labrum deeply forked ………… Eminence on gula with two spines directed forwards and outwards. Labrum wider than long, anterior margin slightly concave with the corners drawn out to points…………………………………………....	*Noditermes* *Unguitermes*

27	Mandibles, in plan view, more or less straight but slightly angled outwards, the inner faces of the tips slightly cupped and adapted for 'snapping' .... Mandibles, in plan view, curved inwards and adapted for biting …….	28 29
28	Inside view the front of the head drawn out into a protuberance ending in an acute angled point. Sides of head more or less parallel. Mandibles about as long as the head including the frontal projection……........... Protuberance on front of head in lateral view usually rounded but may have a rather flattened facet. Sides of head usually convex but may be flattened. Mandibles usually definitely longer than head……………...	*Angulitermes* *Promirotermes*
29	Front of labrum almost straight, slightly emarginated. Mandibles very finely striated………………………….................... Front of labrum slightly trilobed. Mandibles not striated………………………………………………	*Lepidotermes* *Basidentitermes*
30	Head capsule, in plan view, triangular, tapering smooth from near the back to tip of 'nose'…………………….................... Head capsule, in plan view, not triangular, the 'nose' part being distinctly more narrow than the head ....……	*Mimeutermes* 31
31	Head constricted behind antennae……………………...................... Head not constricted behind antennae ......………………......................	32 34
32	Head and 'nose' covered with minute spatulate bristles …………… Bristles on head normal, with pointed tips………………......................	*Spatulitermes* 33
33	Colour of head capsule orange or reddish, darker on 'nose'………… Colour of head capsule septa brown. 'Nose' darker' with reddish tip ..….	*Fullerritermes* *Rhadinotermes*
34	Soldiers monomorphic…………………………………. Soldiers dimorphic……………………………………..	*Nasutitermes* *Trinervitermes*

Appendix 2

Plant species used in Southern and Central provinces of Zambia (Nkunika, 1998; Nkunika, 2002)

a. **Muyongolo (*Bobgunnia madascariensis*)**
Grind ten dry pods in a mortar and mix into 2.5 litres (Kachingubuli) of water. Leave the mixture for 24 hours. Shake the mixture well before using. Some foam should be seen on top of this mixture. Pour or splash the mixture directly on the bases of the affected tree. Do this for 5 days, after that continue with normal watering. This concoction was very effective against termites.

b. **Muleyembezo (*Crossopterix febriguga*)**
Dig and cut 10 pieces of roots about (15 cm) long. Peel off the bark and grind. Using two handful of the crushed powder soak together with roots in 5 litres (Chingubuli) of water. Leave for 24 hours. Pour the mixture around the base of the tree. This mixture is very effective against termites.

c. **Mumba (*Jurbanadia globiflora*)**
Collect and put a handful of leaves in 2.5 litres of water and soak them for 24 hours. Sieve the mixture and pour around the bases of the effected tree. The mixture was effective against termite pests.

d. **Mululwe (*Cassia abbreviata*)**
Get two hands full of the bark of mululwe, grind and mix with 5 litres of water together with the dry preparation of muyongolo. Pour on the affected tree. This concoction is very effective against all termite pests. Mululwe can also be used on its own and get equally effective results.

e. **Ntuntulwa (*Solanum incanum*)**
Cut the fruit of Ntuntulwa into quarters or halves and pound. Put the pounded fruit into a container and add 2.5 litres of water. Leave the mixture to stand for 12 -24 hours. Shake the mixture before use. Pour or splash the mixture on the affected plant. This was reported to be effective against termites.

f. **Kanunka (*Bidens pilosa*)**
First collect a cupful of the mature seeds. Mix with water, boil for ten minutes or soak for 24 hours. If boiled, allow to cool, and then add 1 litre of water and a teaspoon full of soap. Spray immediately. This mixture was less effective against termite pests.

g. **Mbono (*Ricinus communis*)**
Soak green seeds and leaves in water for 24 hours. Filter and spray or alternatively put green seeds into hole around the target plant. The concoction deters the termites.

h. **Mbala (*Euphobia tirucalii*)**
Pound the leaves; soak in water for 24 hours and spray. The mixture should be slightly milky before spraying. Though effective against termites, this plant is toxic to humans and must be treated with caution.

i. **Ububa (*Tephrosia vogelii*)**
Collect 1kg of fresh leaves and grind and soak in 20 litres of water. Leave for 24 hours. Strain and then spray on the affected plant. Though effective against termites, this is a recent introduction and most farmers are not familiar with it.

j. **Impili- pili (*Capsicum frutescens*)**
Grind 500g of chilly fruits and soak in 20 litres of water for 24 hours. Sieve the mixture and use as a spray. This concoction was very effective on tree seedlings.

k. **Muwi (*Strychnos cocculoides*)**
Remove bark and pound together with fruits. Soak in water for 24 hours. Sieve the mixture. Measure 500 ml and dilute to 10 litres of water. Pour solution around stem base of affected plants.

l. **Mulombe, Muzwamalowa (*Xerodenis stuhmaanii*)**
Strip the bark and soak overnight. Pour solution over affected area. This mixture was effective depending on the preparation.

m. **Tombwe (*Nicotiana tabacum*)**
Crush 3 kg fresh leaves, soak in 20 litres of water and add soap. Use the mixture to spray around the plant or crush dry leaves of tobacco and add fresh chillies and soak in water. Use mixture to sprinkle affected plant. The termites were killed instantly.

n. **Muntamba (*Strychnos spinosa*)**
Pound fresh fruits and soak in water and leave overnight. Spray to the affected area.

o. **Sozwe (*Cubonia glauca*)**
Spread leaves or roots over and under maize. Highly poisonous and repellent to termites. It should not be handled by children or animals.

p. Paw Paw (*Carica papaya*)

Add 1 kg of finely shredded leaves to one litre of water and shake vigorously then filter and add four litres of water, two spoons of paraffin and 20 g of soap. Spray around the bases of the tree. This concoction has a repellent effect against termites.

Appendix 3

Active principle and mode of action of some indigenous plants with pesticidal properties found in Zambia

Vernacular Name	Botanical Name	Active Principle	Mode of Action
Muyongola	*Bobgunnia* (*Swartzia*) *madascariensis*	Plant contains saponins	Pesticidal, Repellent
Mbala	*Euphoria tirucalii*	Nicotine, Tar	Insecticidal, toxicant against termites
Tombwe	*Nicotiana tabaccum*	Not identified	Repellent to termites
Ntuntulwa	*Solanum incunum*	Ricin	Toxicant to termites
Mbono	*Ricinus communis*	Ricin	Toxicant to termites
Mutandezyelo	*Targetes minuta*	Terpine	Insecticidal, Repellent to termites