IMPACT OF LAND USE ON VEGETATION RESOURCES WITH EMPHASIS ON WOODY VEGETATION IN THE SEMI-ARID AREA OF ABALA DISTRICT, NORTH AFAR, ETHIOPIA

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DECLARATION

I hereby declare that this thesis is my original work and has not been submitted for a degree in any other university

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DEDICATION

This work is dedicated to my father who passed away while I was in Kenya for this study He had the love to the family and good vision to all of us but departed from our midst at an early age. Fondly remembered and sadly missed by your family, relatives and friends Continue to enjoy eternal peace in the presence of God

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ABSTRACT

This study aimed at investigating changes in vegetation resources with emphasis on the woody component in relation to land use changes (i e settlements, cultivation and grazing) It also made an attempt to understand the perception of local communities as regards these changes in their land-based resources The study area was characterised by a semi-arid type of climate, where agropastoral production system was the predominant land use practice The methods employed were interpretation of aerial photographs taken at two points in time i e 1964 and 1994, field vegetation survey and analysis, interviews using a structured questionnaire, and informal and formal discussions

The results of aerial photograph analyses indicate that conspicuous changes occurred in land use and vegetation types (physiognomically) over the 30-year period between 1964 and 1994 Changes in land use have apparently caused changes in vegetation structure These changes have resulted from introduction of settlements and subsequent practices of flood recession cultivation Clearance of vegetation for cultivation in the flood plains was found to be the major cause of depletion of vegetation resources and overgrazing of the uncultivated areas thereby leading to environmental deterioration The size of land under cultivation increased from 0 27% (97 5 ha) to 7 34% (2,605 ha) of the total area Settlement increased from 0 01% (5 ha) to 0 51% (180 ha) and vegetation cover decreased from 87 88% (31,252 5 ha) to 75.52% (26,787 5 ha)

Field vegetation survey results showed that there was still a moderate woody vegetation cover dominated by *Acacia ethaica* wooded bushland in the uncultivated plain areas, the hills and ridges However, herbaceous cover was very poor and the understorey vegetation was mainly dominated by *Euphorbia* and *Aloe* species Woody vegetation identified and recorded included *Acacia, Grewia, Balanites, Salvadora, Cordia, Commiphora* and other related genera A locational comparison of six selected woody species i e *Acacia ethaica, Acacia mellifera, Acacia nubica, Acacia tortilis, Grewia erythrea* and *Salvadora persica* showed no significant difference (P>0 05) among three study sites (Abala, Shugala and Murga) for species composition, percent crown cover, density and diversity Comparison

among distances (in a 10 kilometre transect ran from each of the three selected land uses) within each site for percent cover and density also showed no significant difference (P>0.05). Comparison among species for each site and among distances for each species, however, showed a significant difference (P<0.05). *Acacia etbaica* had higher species composition, percent cover and density than other species in all the three study sites.

From the socio-economic survey, it was possible to retrieve information on characteristics of the indigenous Afars and settled Tigrians, woody vegetation use and perceptions of environmental degradation. These communities are already aware that settlement and cultivation in the area hampered the pastoral form of life style and thus forced them to shift to agricultural practices. They acknowledged the vital role of trees and shrubs since they provide a range of products and services in their daily life. In sum, declining vegetation cover, formation of big gullies, declining water availability, reduction of wildlife numbers and species diversity are the outcomes of recent settlement, cultivation and recurrent drought in the area.

Based on the findings of this study, recommended actions to mitigate and prevent negative environmental impacts include encouraging participation of local communities in the management of natural resources so as to utilise their indigenous technical knowledge, introducing soil and water conservation measures, protecting the existing grazinglands from encroaching cultivation, protecting and regenerating important woody species, and selective clearing and establishment of grazing reserves. The study also recommends further research on long-term vegetation monitoring, soil and vegetation relationships, ethnobotany/ethnoveterinary practices, assessment of herbaceous and woody vegetation biomass, and evaluation of the nutritive value of browse species and crop residues as dry season feed for livestock.

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CHAPTER ONE

1. INTRODUCTION

Arid and semi-arid lands (ASALs) cover an area of 12.4 million square kilometres in Africa which is about 50% of the total area of tropical Africa (Darkoh 1992). These areas cover about 60% of Ethiopia's land surface and are home to 12% of the human population and 26% of the livestock population (Coppock 1994). Various forms of pastoralism and agropastoralism dominate land use. The uncertainties of rainfall and primary production in the rangelands of Ethiopia have promoted animal based life-styles that enable people to be mobile and opportunistic.

Pastoralists in Africa's drylands have over a long period of time developed well managed and basically sound ecological strategies to enable them live in harmony with their environment utilising vegetation on a sustainable basis (Darkoh 1992). Trees and other woody species are recognised by the people as being especially important in this system since they can survive and produce well even through the long dry season, during which they are particularly important for livestock feed. Trees and other woody species are sources of livestock feed especially in dry seasons when there is lack of other forage resources. They also provide firewood and/or charcoal, building and handicraft materials, food and drinks for humans, medicine for man and his animals, shade from direct hot sun, shelter, and protection. Shifting cultivation and traditional grazing have been practised for centuries in Ethiopia. As a result, Ethiopia's high forest estate has been reduced to 3.6% of the total area (Tassew 1995). Other types of woody vegetation consisting of woodlands, bushlands and shrublands cover 4.7, 16.6, and 21.25% of the total area respectively. Lowland woodland, bushland and shrubland include a wide variety of woody vegetation, mainly *Acacia, Boswelia, Commiphora, Balanites, Euphorbia*, and many others (Tassew 1995). Woodlands are the natural results of either progressive or retrogressive succession of climax vegetation and are located in the transitional zones of the country. Abala is situated in one of such zones.

As elsewhere in Africa, Somali, Afar and Borana pastoralists in Ethiopia and their production systems are under pressure by internal as well as external factors which render their systems unsustainable. Population pressure, recurrent drought, ill-conceived development policies, encroachment of cultivation into pastoral areas and disruption of their traditional institutions are some of the causes of pressures and instabilities on the systems (Helland 1980, ILCA 1981, G/Mariam 1991, Ali 1995). Degradation of range resources is prevalent in Ethiopia, particularly in the northeastern rangelands. This is mainly attributed to large irrigation schemes, encroaching cultivation, overgrazing, and national parks. Of the major pastoral groups of Ethiopia, the Afars have suffered most due to man-induced and natural disasters. For perhaps thousands of years, the Afar have maintained a nomadic pastoral way of life in the harshest arid areas. The area was inaccessible to outsiders until the 1970s (Helland 1980). At present, the Afars are caught up in a cycle where drought, starvation and death can be expected to occur every few years. Drought occurrence is a frequent phenomenon in Afar land and occurs at least every ten years (Helland 1980, ILCA 1981, G/Mariam 1991).

The main production systems in the northern part of the Afar Regional State are pastoral and agropastoral. Pastoral production system dominates in six districts (weredas) of north Afar i.e. Irepti, Afdera, kuneba, Dalul, Megale and Berahile. Abala wereda, the centre of north Afar (Zone 2) is economically an important area where both livestock production and flood based agricultural system are practised. Culturally, the indigenous Afars mix with settled Tigrigna speaking peoples in Abala (formerly called Shiket). These two peoples have co-existed peacefully for at least three decades benefiting each other. In the *wereda*, an extensive plain area is cultivated, the uncultivated area being occupied mainly by pastoral nomads (Hunting and Macdonald 1976). Substantial quantities of grain, mainly sorghum and tef are transported to Mekelle and Quha towns. Flood recession cultivation practised by both groups of people in the study area resulted in the loss of prime grazing land for the Afars. Overgrazing and physical damage done on the uncultivated grazing land also appears to be another factor in the degradation of the land resource base, especially herbaceous cover. In an effort to improve the livelihood of the pastoralists, rangeland development projects have been implemented in southern and northeastern rangelands of the country for the last 20 years. The NorthEastern Rangelands Development Unit (NERDU) was functioning in the Afar pastoral area from the 1970s However, its efforts were limited to some areas, especially to south and western Afar, where there is relatively better security

Since the area has been isolated from main stream national development for many years due to insecurity, research has not been conducted on both herbaceous and woody vegetation In light of the recurrence of drought and man-induced degradation of natural resources in the study area, the need for carrying out studies related to land use, natural resource management and development become imperative

It is believed that this study would partly bridge the gap and perhaps provoke other researchers to undertake similar endeavours in the future It is also believed that it will have significant importance and value for policy makers working in the field of natural resource management It is in the light of the foregoing that this study was conceived and initiated

1.1 Objectives

In a broad perspective, this study was designed to investigate changes in vegetation resources in relation to land use practices with emphasis on woody component in a semi-arid area of Abala district, North Eastern Ethiopia The specific objectives of the study were

- To assess changes in vegetation resources over 30 years, between 1964 and 1994, in relation to changes in land use practices
- To determine changes in some selected woody species among three land use practices and along a sampling transect that run 10 kilometres within each of the three land use practices
- To obtain and catalogue people's perception about changes in natural resource base and indigenous knowledge on management and utilisation of vegetation resources with emphasis on woody vegetation

1.2 Hypothesis

This study has one operational hypothesis that changes in land use practice have no impact on vegetation resources in semi-arid areas

CHAPTER TWO

2. LITERATURE REVIEW

2.1 A changing perception of African drylands: An overview of land use changes

The arid and semi-arid lands (ASALs) of the earth cover 35% of the earth's land surface (Sandford 1983) and produce one fifth of the world's food supplies (Grove 1984). ASALs constitute more than 50% of tropical Africa (Dregne 1983, Sandford 1983, Darkoh 1992). Skoupy (1988) divided the drylands of Africa into three categories

- Countries with more than 66% arid and semi-arid areas include Botswana Cape Verde, Chad, Djibouti, Kenya, Mauritania, Niger and Somalia.
- Countries with over 30% arid and semi-arid areas include Burkina Faso, Ethiopia, Gambia, Mozambique, Senegal, Sudan, Tanzania, Zambia and Zimbabwe.
- Countries with below 30% arid and semi-arid areas include Angola, Benin, Cameroon, Madagascar, Nigeria and Uganda

Drylands in sub-Saharan Africa are dominated by arid to semi-arid climates characterised by low and unreliable rainfall (which rarely exceeds 750mm); low soil fertility; high temperatures and elevated evapo-transpiration (Pratt and Gwynne 1977, Le Houerou 1980, Coppock 1994). A successful adaptation to these dry ecologically fragile ecosystems is pastoralism. These areas are home to a diverse array of pastoral, agropastoral and mixed farming people who depend to a high degree on livestock for their subsistence (Coppock 1994). According to Pratt and Gwynne (1977), these areas can be referred to as rangelands that support wildlife and extensive livestock operations

Over the years, patterns of land use have significantly changed and threatened the productive capacity of vast areas in ASALs (UN 1977, Dregne 1983). Transformation of land use is perhaps the most important process affecting the ecological characteristics of grassland systems within the last few centuries. With continued growth of human population, competition for land resources has steadily increased over recent years forcing people in nearby agricultural areas to migrate into marginal lands which are often key grazing areas used by nomadic peoples (Helland 1980, Hadley 1993, Bourn and Wint 1994). As a result, large areas of fertile natural grasslands have been converted into arable lands and settlements. Although pastoralism has evolved over a millennium and is, in many ways, a successful adaptation to the dry ecologically fragile and ecosystem, recent interventions and trends in ASALs work against its continued survival. Most livestock production programs and similar interventions failed in the drylands of Africa since they have literally neglected the social, cultural and ecological particularities of mainly pastoral production systems (Galaty *et al.* 1981, Sandford 1983, Tadingar 1994, Tadingar and Farah 1996, Farah 1996). Many researchers and concerned institutions emphasise that the foremost causes of environmental degradation in drylands are inappropriate land use coupled with recurrent drought. Studies in Africa have tended to confirm that cultivation of marginal areas, overgrazing and fuelwood collection caused climatic as well as biotic deterioration which led to desertification of ASALs. For example, Ayoub (1988) and Darkoh (1992) emphasised that the rapidly increasing population pressure on the drylands of Africa resulted in over-exploitation of land, forest, water and pasture resources through over-cultivation, overgrazing, deforestation and poor irrigation practices. According to Helland (1980), ILCA (1981), G/Mariam (1991) and Ali (1995), land resources in northeastern Ethiopia are under increasing pressure due to population pressure and recurrent drought. High population pressure and associated low yields in the highlands have forced people to penetrate into vulnerable marginal areas to increase the cultivated area. Abala district is also situated in this part of the country which has experienced cultivation of flooded grazing lands in the last three decades.

Scholars of various disciplines have different views on the causes of degradation in drylands. Hjort (1985), for instance, explained the causes as ecological degradation of a sensitive environment, political and economic marginalisation of a local population, starvation and disaster. Studies done in northern Kenya, for example, showed that direct human activities and overgrazing of rangelands are the major causes of land degradation (Lamprey and Yussuf 1981, Lusigi 1984, Lusigi *et al.* 1986). Settlements have become centres of localised overgrazing and tree destruction, as is evident in the Rendille settlements of Korr and Kargi (Keya 1991). Peckholm (1977) reported that severe overgrazing and vegetation destruction accompanied by the 1968-1973 Sahelian drought resulted in unrecoverable destruction of fodder plants in many areas On the other hand, evidence from several areas of dryland Africa showed that growing human populations are not always damaging to the resource base Tiffen *et al* (1994), for example, reported that population pressure was found to be a necessary condition for the intensification and more conservative land use practices in Machakos, Kenya

Although many scholars emphasise that land use changes and associated land degradation in drylands is a challenge to achieve an improved and sustainable production, there is too much debate on the term land degradation It has been defined in a multitude of contradictory ways Concepts of degradation are based on unclear definitions which fail to distinguish between temporary declines in secondary productivity, and irreversible, permanent soil and vegetation changes (Abel and Blaikie 1989). For many years, range science and the carrying capacity concept have been built from the equilibrial or climax concept of Climentsian succession The conventional notion of carrying capacity in range management rests on Clementsian theory of plant succession which is defined as an orderly, directional and predictable process where one plant community comprising of several species replaces another until a stable equilibrial and climax stage is reached (Clements 1916, Odum 1971, Stoddart *et al* 1975) Although this concept is now subjected to much criticism (Gleason 1927, Abel 1993, Behnke and Scoones 1993, Ellis *et al* 1993), it is still supported by some scientists Margalef (1968) and Odum (1971) suggested that succession theory might be the basis for resolving man's present environmental crisis Lamprey (1983), for instance, argued that African savanna ecosystems are equilibrial in nature, and pastoralists degrade these ecosystems through overstocking and overgrazing Supporting Lamprey's view, Coppock (1993) indicated that carrying capacity, successional trends and density dependent population dynamics are still viable concepts, based on long-term studies of Borana pastoralists in southern Ethiopian rangelands

In contrast to Lamprey's and Coppock's views, Sandford (1983) expressed the view that pastoral livestock system is distinctly non-equilibrial and reflects the dynamic nature of arid African ecosystem Ellis and Swift (1988), Ellis *et al.* (1993), and Behnke and Scoones (1993) reached a similar agreement in that the system operates far from equilibrium They argued that this paradigm focuses on the hypothesis that vegetation dynamics are largely controlled by external factors such as rainfall. Westoby *et al.* (1989) also argued that standard successional models couldn't account for observed patterns of vegetation change in rangelands not at equilibrium. Most recent definitions of land degradation therefore suggested that degradation is the result of irreversible changes, reflecting loss of ecosystem resilience. In reality resilience is seldom at stake unless vegetation changes are accompanied by soil degradation (Dougill and Cox 1995). Abel (1993) argued that there couldn't be one definition of degradation encompassing all human objectives and land uses. Abel emphasised that the debate would be clarified if degradation were defined in terms of an irreversible decline in output from a specified system of management.

Changes in vegetation communities, whether induced by natural or land use factors, could even be seen as evidence that the resilience of this ecosystem is still intact (Dougill and Cox 1995). Stability and resilience of savanna were defined by Walker and Noy-Meir (1982). They stated that a stable system is one which changes very little over time and which respond slowly and little to outside pressure. A resilient system, on the other hand, is one which can change quite markedly as a result of a disturbance, but which then returns towards its original equilibrium conditions. Based on their experience in Kalahari, Abel and Blaikie (1989) reported that resilience is seldom at stake unless grazing is accompanied by soil degradation and the changes in vegetation communities that have been observed are likely to be reversible provided soils have not been changed greatly.

2.2 Vegetation change in relation to land use changes in drylands

Drylands or savannas can be described as a mixture of grass and woody species (Le Houerou 1980, Walker and Noy-Meir 1982). Dryland vegetation is a fundamental resource that has been used by pastoralists for centuries. However, changes have been taking place from one form of vegetation to another. For instance, grasslands are changed to bushlands due to overgrazing and in some cases changed to cultivated fields. This imposes enormous risks to the inhabitants and their continued survival. Vegetation changes may be of several kinds and the causes of change have been the subject of considerable debate, ranging from natural fluctuations in weather patterns to man caused perturbations (e.g. Pratt and Gwynne 1977, Walker and Noy-Meir 1982, Ellis and Swift 1988).

Harbouszky *et al.* (1986) reported that rangelands are under pressure everywhere as the demand for land use rights grow He explained that the situation stems from the political, demographic, socio-economic and technical changes Negative trends such as desertification and bush encroachment have been commonly attributed to overgrazing (Pratt and Gwynne 1977, Warren and Hutchinson 1984, Coppock 1994) In contrast, Ellis and Swift (1988) contend that vegetation dynamics are most attributable to external factors independent of human activity Behnke and Scoones (1992) also reported that different combinations of factors, of which grazing pressure is but one element, might be required to cause alterations in rangeland vegetation Several studies have been made in many parts of dryland Africa and other drylands of the world, and most of them have revealed that the change and/or loss of dryland vegetation resources for various reasons depend upon the local conditions However, in disagreement with these views, Farah (1991) reported that present grazing management in Machakos is neither irrational nor inherently degradational in its impact on the natural vegetation He argued that increasing woodiness is not here an unwanted by-product of cattle heavy grazing but the result of protecting trees in recently settled areas of southern Machakos

Initially, the process of degradation of range vegetation starts with a reduction in the density of the most palatable perennial species followed by a reduction in the total cover of the herbaceous layer and an increase in the woody component of the vegetation (Tietema *et al.* 1991). An increase of trees and shrubs has been widely reported in the rangelands of Australia and the United States (Friedel 1986) The increase of woody vegetation is attributed to various factors such as overgrazing, soil erosion, changed fire regime, and climatic change acting alone or in combination (e.g. Walker *et al.* 1981, Walker and Noy-Meir 1982, Friedel 1986, Medina 1987) Based on the two-layer model of the environmental change study, Walker and Noy-Meir (1982) explained that competition for soil moisture is the main determinant of the woody component in arid and semi-arid savannas Skarpe (1991) also reported the relative importance of inter- and intraspecific competition for water and of disturbance by fire as a regulatory mechanism for total amount and spatial distribution of woody plants in an arid savanna of Botswana Many researchers emphasise that encroachment of woody plants into grassland or wooded grassland areas are closely correlated with the activities of man Herbel (1986) reported that restriction of naturally occurring fires, attempts to cultivate lands unsuited for crops, and continued grazing pressure have influenced changing plant cover of grasses. A study of vegetation in the Simanjiro plain of Tanzania, for example, indicated that regeneration of woody species is pronounced due to overgrazing, mounting pressure for cultivation and lack of annual fires (Kahuranga 1979). Coppock (1994) also reported that the Borana society in Ethiopia is in crisis mostly due to human overpopulation although rangelands in Borana had the highest ecological potentials than other rangelands in the country. He further argued that ecological sustainability is threatened by increased cereal cultivation on upland soils and woody encroachment as well as soil erosion which can be attributed to heavy grazing by cattle.

It is a widely held belief that most rangelands suffer from woody vegetation encroachment. Today most dryland areas in developing countries face not only woody vegetation encroachment but also destruction of important woody vegetation due to various human interventions. People in drylands recognise trees and shrubs as being especially important since they can survive and produce well even throughout the long dry season when they are particularly important. However, trees and shrubs have been and still are subjected to indiscriminate destruction, particularly in low lying areas, to make room for flood recession and irrigated agriculture (Lamprey and Yussuf 1981, Medina 1987, Keya 1991). Trees and shrubs are also prevented from forming closed stands in the uncultivated areas by human disturbances, including fire and herbivory, and/or by soil conditions (Medina 1987).

Local communities continue to exercise traditional land use practices or resource management in drylands for many years and they clearly recognise the extreme weaknesses of their own resources. However, throughout dryland Africa, herders have lost prime grazing lands particularly in low-lying areas to make room for flood recession and irrigated agriculture (Keya 1991). Destruction of grasses by fire, overgrazing, competition for soil moisture and other related causes, increase the competitive abilities of woody vegetation since more water in both deeper and surface soil becomes available for woody vegetation growth (Walker and Noy-Meir 1982, Medina 1987). It has been estimated that approximately 30-40% of Kenya's ASALs are quickly degrading due to institutional administrative boundaries, wildlife reserves, forest gazettement, and encroachment of farming (Keya 1991). Lamprey and Yussuf (1981) estimated that between six and ten trees are felled by each family of six people at each nomadic move, and that 50,000 trees are destroyed annually for village camp or animal pen construction in Rendille country in northern Kenya. Similarly most of the vegetation in the major dry season grazing areas of Afar area in Ethiopia are degraded and rated from poor to fair due to expansion of large scale irrigation development, wildlife game reserves and parks, and tree cutting by irrigation scheme workers. For instance, cutting important trees like *Acacia tortilis* and *A. nilotica* which serve as dry period fodder reserve and shade for Afar livestock has had severe impact on Afar pastoralism (Ali 1995).

From this scenario, it is evident that drylands in Africa have undergone serious vegetation change due to changes made in land use. The changes are from one form of vegetation type to another (such as from grassland to bushland) and also reduction in all types of vegetation cover.

2.3 Role of woody vegetation in drylands

2.3.1 Indigenous knowledge on woody vegetation use

Indigenous knowledge is composed of the whole system of knowledge known as traditional wisdom or ethnoscience, that has evolved over generations as a product of man-environment interactions (Tadingar and Farah 1994). Many scholars especially in pastoral areas appreciate local people's knowledge on the uses of plants, also known as ethnobotany. Local people have information that cannot be obtained by conventional science (Tadingar 1994).

Almost all plants are used for some purpose and most pastoral groups identify and protect plant species with special uses. Many uses are associated with trees and shrubs and the major uses include provision of firewood, charcoal, building materials, food for humans and livestock, and medicinal value for man and his animals.

A number of plants with information on their uses have been collected in some parts of Africa. Hiene *et al.* (1988) studied traditional uses of 300 plants in Samburu, Kenya and described each use from the total as animal forage (70%), medicinal value (40.7%), human consumption (27.3%), firewood and charcoal (26.7%), manufacture of household goods (15.7%), religion and custom (15.3%) and miscellaneous uses (17%). The Turkana are also shown to make a great use of range plant species available to them Of the 222 species on which use or non-use was determined, 64% had one or more domestic uses and 87% of the species were eaten by one or more of the livestock kept Fifty-three species were recorded to be of use as human food, 67 of the species of medicinal value and 65 of the species for various domestic uses (Morgan 1981) One hundred and fourteen plants have been identified as being of use by Borana pastoralists of Ethiopia (Wilding 1984 quoted by Coppock 1994) These plants serve many traditional uses including fencing and firewood (26 species), home construction (16 species), wood and fibre for making household utensils (38 species), medicines for people and livestock (44 species); food for people during years of average or below average rainfall (49 species), extracts for leather tanning and dyes (10 species), charcoal for incense, fumigation of insects and microbial fumigation of milk processing containers (15 species), and for festival and ceremonial purposes (12 species) On average each species has about two uses but some have over seven to nine uses

The whole area of traditional resource use and its potential for environmental conservation and sustainable utilisation in drylands, thus, calls for further scientific research Based on studies in north-eastern Kenya, Farah (1997) reported that past development initiatives have blundered by disregarding the "role and significance of indigenous technical knowledge in natural resource management" with the result that "projects in ASALs are characterised by failure due to faulty project premises "

2.3.2 The role of browse in drylands

In drylands, where cropping is impossible or unreliable, man depends on ruminants for subsistence Trees and shrubs survive harsh climatic conditions and are an important perennial source of livestock browse in drier parts of Africa, in particular goats and camels, the two main browsing domestic animals in this area Due to the highly irregular rainfall of drylands and virtual disappearance of nutritious grasses during the dry seasons, trees and shrubs are an essential part of the pastoral environment (Le Houerou 1980, Woodward 1989)

The drylands of Africa have an important component of ligneous species, many of which are browsed and/or lopped as dry season feed In these areas, browse trees and shrubs often have higher crude-protein and mineral content, and sometimes-higher dry-matter digestibility, than associated grasses, particularly during the dry season (Rocheleau *et al.* 1988) Menwyelet (1990), quoted by Coppock (1994), reported that the most important fruit producing trees for livestock include *Acacia tortilis* in dry seasons of all years and *A. tortilis* and *A. nilotica* in drought years in Borana, southern Ethiopia In northern Nigeria, it has been found that nomadic Fulani cattle spent 5% of their feeding time on browse during the rainy season and 15% to 20% during the dry season (Le Houerou 1980) For example, browse from woody plants was found to constitute 92% of dry season goat fodder in Kenya's Turkana District (Rocheleau et *al.* 1988) It is clear from this brief account that the drylands of Africa are still rich in indigenous plants of browse value that are perceived as a necessity by traditional herders

2.3.3 Impact of utilisation on woody vegetation

Dwindling vegetation cover in ASALs is currently affecting all facets of people's lives. The use of trees and shrubs for fuelwood is a major factor that contributes to the reduction of vegetation cover. Today, depletion of the natural vegetation in drylands has increased ecological fragility Large areas have been severely degraded as a result of deforestation, unwise cultivation of annual crops and overgrazing, which fail to take into consideration the vulnerability of the ecosystems and their slow restoration once disturbed (Bensalem and Palmberg 1985)

In arid and semi-arid regions of less industrialised countries, the remaining forests and trees are being systematically cleared for woodfuel (i.e. fuelwood and charcoal) as well as for other purposes (Najib 1993) Woodfuel demand is increasing in these countries as population grows and as petroleum costs force countries to turn to non-petroleum fuel sources As traditional woodfuel resources have been depleted in these areas, the energy to support vital basic needs is becoming increasingly difficult to obtain for millions of households As a result, people in these regions are forced to exploit the woody vegetation without care to conservation (Najib 1993) The need for construction material for livestock night enclosures, bush fence in cropping fields and fuelwood has led to wanton destruction of trees particularly *Acacia* species around settlements (Lamprey and Yussuf 1981, Tietema and Goche 1987) The disappearance of *A. tortilis* and *A. nilotica* around Awash valley irrigation schemes can be cited as an example Even when under such heavy use, woody vegetation can be managed on a sustained basis, through strengthening traditional practices (that foster wise utilisation) which have been developed for centuries in the drylands of Africa

2.4 The potential of woody vegetation for dryland management

ASALs face severe problems of land use as evidenced in African drylands In such areas the use of trees and shrubs combined with cultivation, commonly referred to as agroforestry, has an important role to play in avoiding degradation of the environment and destruction of the resource base while at the same time maintaining a balanced local economy Agroforestry is, thus a collective name for land use which can be grouped into practices involving trees and shrubs with crops, pastures, animals and nested into a special place in the landscape (Rocheleau *et al.* 1988, Young 1988)

Many pastoral and agropastoral peoples throughout Africa have traditionally used and managed woody plants to produce fuelwood, fodder, building poles and other products for sale and domestic use According to Nair (1989), the most predominant agroforestry systems in this part of Africa are

- various forms of silvopastoral systems,
- windbreaks and shelterbelts, and
- multi-purpose trees on croplands, notably *Acacia albida*-based systems

Trees and shrubs have been used traditionally as part of rotation cropping in many areas of the dry zones The bush fallow system of gum arabic in the Sudan is an example of rotation cropping Apart from restoring soil fertility and protecting against wind erosion, *A. senegal* trees growing during the fallow period provide substantial income from gum arabic in addition to fuelwood, fencing material and fodder (Bensalem and Palmberg 1985) Trees and shrubs can also be grown, with advantage, in symbiosis with agricultural crops Numerous examples can be quoted, such as *Acacia albida*/millet and sorghum system in West and East Africa (Nair 1989).

Combining woody plants with grasses and other herbaceous fodder plants (silvopastoral system) are widespread throughout sub-Saharan Africa (Rocheleau *et al.* 1988). Silvopastoral systems on rangelands usually involve the selective protection and management of naturally occurring trees and shrubs of particular value for animal fodder. For example *Balanites aegyptiaca, Tamarindus indica* and *Acacia tortilis* are all prized and protected in lands inhabited by the Pokot people in northern Kenya (Rocheleau *et al.* 1988). Agropastoralists and farmers in the savanna lands of eastern Kenya maintain *Terminalia brownii, Combretum* species and *Acacia tortilis* in pastures and grazing lands to provide leaf fodder and pods for their goats and draught oxen during the annual dry season, as well as during more prolonged periodic drought (Rocheleau *et al.* 1988). However, the intensive management or purposeful planting of woody plants in dryland pastures is less common

In view of the above, there is an urgent need for improving the livelihood of people and maintaining a stable ecological balance in African drylands by developing sustainable land use practices in which the full potential of trees and shrubs is realised

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Description of study area

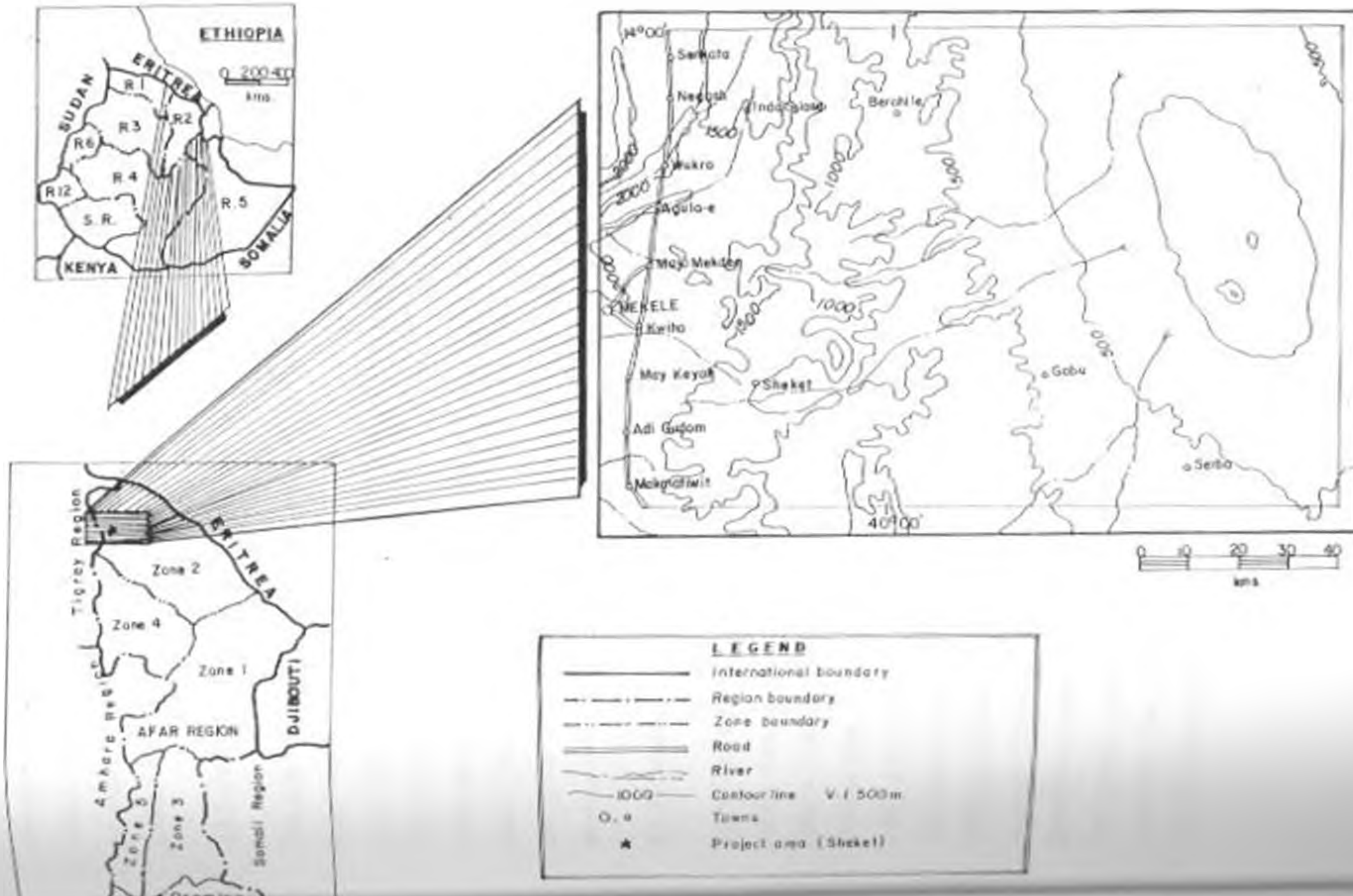
Since the study area has been isolated from mainstream national development for a long period of time due to insecurity, there was no research or survey available on physical and biological characterisation except some descriptions by Hunting and Macdonald (1976) As a result, description of the study area was made based on the work of Hunting and Macdonald (1976) and survey made by the author of this thesis

3.1.1 Location and physiography

The study was carried out at Abala (formerly called Shiket) in the northern part of Afar Regional State, northeastern Ethiopia Afar Regional State consists of five (5) administrative zones (a zone is part of a Regional State comprising different districts), twenty nine (29) *weredas* (districts) and twenty eight (28) towns The study area is located in Abala *wereda* of Zone Two and lies approximately between 13° 15' and 13° 30' N latitude and 39° 39' and 39° 55' E longitude about 55 kilometres east of Mekelle town (Fig 3 1). Mekelle is the major town of Tigrai Regional State located approximately 780 km north of Addis Ababa, the capital of Ethiopia. The area is situated on the transition zone between the eastern Tigrai escarpments and the northern Afar lowlands The only means of communication in the area is the 55-km dry weather road from Mekelle The Shiket plain occupies an area of 2,050 square kilometres including Kala (Hunting and Macdonald 1976)

The study area consists of flat plains occasionally interrupted by a few undulating hills and a series of elongated ridges, surrounded by high broken hills with very few outlets joined to other areas The average elevation of the area is approximately 1500m above sea level with a range of 1300-1700m

Figure 3.1 Location map for the study area



Shugala and Abala rivers are the main perennial rivers which supply water to the study area throughout the year Murga and Liena are seasonal rivers Both perennial and seasonal rivers meet at the lower part of the plain during the rainy seasons and leave Abala plain through a mountain at Megulele The plain area which receives flood from these rivers forms the arable fields and flat grazing lands.

3.1.2 Geology and soils

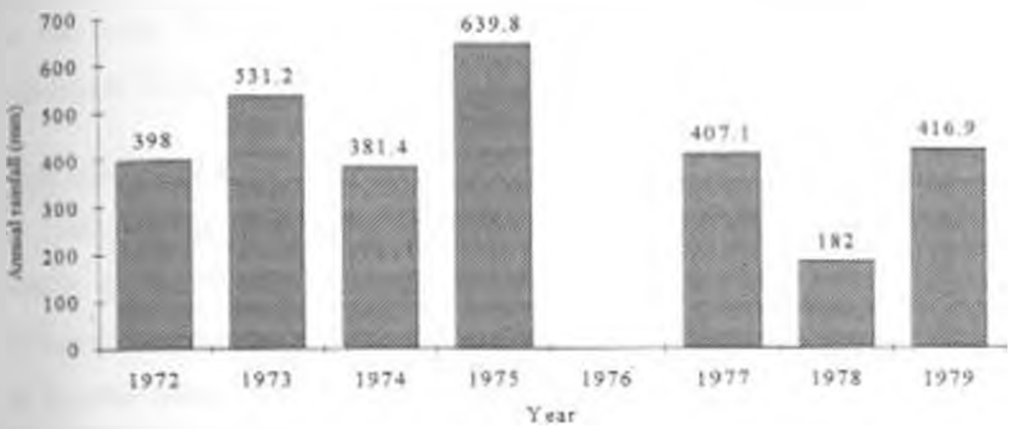
The area falls entirely within the Garben Valley of the Shugala drainage system along with three other tributaries to the east of Tigrai escarpment Fluvial alluvium occurs along incised river valleys and sheet flood alluvium occurs in the plains (Hunting and Macdonald 1976) The area is a product of volcanic activities, which formed the Great Rift Valley Exposed rocks and stones dominate most of the hills and ridges, while alluvial deposits cover the plains The soils are generally sandy and silty. The texture is fairly coarse, with both sands and gravel present Sheet flood alluvium consists of deposits of silt, and occasional thin sands occur in the plains (Hunting and Macdonald 1976)

3.1.3 Climate

A semi-arid type of climate characterises the area receiving bi-modal rainfall The long rains usually occur in the months of mid-June to mid-September, while the short rains usually come in March and April The occurrence of rainfall periods is associated with the north and south oscillation of the Inter-Tropical Convergence Zone (ITCZ) Although climatic data are scanty due to absence of a weather station in Abala or nearby areas, in some years one or both seasons may fail resulting in severe droughts (Hunting and Macdonald 1976) Based on Ethiopian Meteorological Agency, Shiket station records for the period 1972-1979, the area received 422mm of rainfall annually (Fig 3.2) The Ethiopian Meteorological Agency discontinued taking rainfall data in the area after 1979 due to the civil war According to the local people, a major shift has taken place in the amount and distribution of rainfall in the study area The area appears to have been affected greatly during the 1968-1973 Sahelian and 1984/85 drought periods

Rainfall intensity is usually high and this leads to high runoff rates. High run-off rates coupled with high evaporation rates make the available rainfall insufficient especially for crop production. Instead, the agropastoral societies in the area depend highly on the floodwater coming from the Tigrai highlands through Shugala, Abala, Murga and Liena rivers to produce dryland crops. In general, the study area is hot with high diurnal temperature and it experiences severe heat, locally known as *hagai*, during the dry periods (especially in May and June).

Figure 3.2 Annual rainfall in Abala (Shiket) for the period 1972-1979



Source: Compiled from data of the Ethiopian Meteorological Agency, Shiket weather station.

3.1.4 Vegetation

According to Hunting and Macdonald (1976), two main vegetation types dominate the eastern escarpment of Tigrai including the study area: (i) montane dry evergreen forest originally composed of *Juniperus procera* and *Olea africana*, and (ii) montane evergreen thicket and scrub, which cover most of the escarpment in varying density, and is composed largely of *Acacia etbaica*, *Tarchonanthus camphoratus* and *Cadia purpurea* and other small trees and shrubs. The latter type of vegetation is typical of the study area dominated by *Acacia*, *Grewia* and allied genera. In general, the vegetation of the study area consists wooded bushland dominated by *A. etbaica* with many associated vegetation types. Few annuals, *Aloe* and *Euphorbia* species with little or no perennial grasses mainly dominate the herbaceous cover. Only very few perennial grasses such as *Cynodon* and *Cenchrus* species are available in some sites The herbaceous cover is highly degraded probably due to grazing pressure and subsequent erosion over a long period Grazing pressure is increasing as a result of expansion of flood recession agriculture into flood plain grazing lands Although information on vegetation of the area is not detailed, significant changes have taken place due to climatic changes and continuous human pressure

3.1.5 History of settlement and life style

The indigenous Afars and settled Tigrians coexist peacefully in the study area The Afars comprise the largest ethnic group and depend both on pastoral and agricultural economy to meet their needs The Tigrians are mainly dependent on agronomic practices with only very few livestock Other activities such as salt caravan and firewood sale are practised

As was established from discussions made with elders during the study period, until the early 1960s, almost all areas in Abala *wereda* were used only for pastoral grazing and browsing. In the 1960s, Mengesha Seyoum, the former governor of Tigrai Region, constructed a dry weather road to the area and started commercial agriculture by clearing some wooded bushlands in the flooded areas Since then, people settled in the area and started cultivating flat flooded areas

The newly opened settlement schemes in the area caused a large influx of people from the Tigrai highlands especially in the 1970s As a result, most of the wooded grasslands and grasslands in the plains were cleared to pave way for cultivation A limestone factory and commercial charcoal production in the same period also aggravated the degradation of woody vegetation, mainly *Aepto* (*Acacia tortilis*), *Gessalto* (*A.nilotica*) and *Sekako* (*A etbaica*) The land proclamation in 1975 encouraged not only the settlers but also the indigenous pastoral Afars to settle and start farming All these events resulted in a transformation of pastoralism to agropastoralism in Abala

3.1.6 Population

According to Central Statistics Authority (CSA) (1996), the Afar Region's total population is 1,106,383 of which 27,259 are found in Abala *wereda* (Table 3 1) Based on the 1994 and 1996 population and housing census about 16,163 people live in the study area, distributed in seven villages (Whidet or Abala town, Adihara-meli, Wahrigubi, Hidimo, Dergamo/Irkudi, Hassengola and Demum) comprising 3,454 families or households

Based on the CSA survey, the population distribution in the Afar region as a whole shows a high male to female ratio The average houschold size in the study area is 6.2 As far as ethnicity is concerned, 83% of the people in the towns of the district are Tigrians and 12% are Afars The remaining 5% belong to other ethnic groups This indicates that the majority of Afars live in rural areas or villages

Table 3.1 Human population of the study area, 1996

Zone (Wereda)	No. of people	No. of households
Afar Region (Total)	1,106,383	168,482
Zone One (6 *weredas*)	327,901	49,547
Zone Two (7 *weredas*)	218,721	32,970
Erebti	38,667	5,907
Kuneba	37,122	4,956
Abala*	27,259	3,948
Megale	19,664	3,490
Berhale	33,322	4,627
Afdera	15,654	2,242
Dalul	47,033	7,800
Zone Three (6 *weredas*)	150,346	32,331
Zone Four (5 *weredas*)	126,455	21247
Zone Five (5 *weredas*)	282,960	42,874

* *Study area*
Source: CSA, 1996

3.1.7 Livestock and crops

The economy of Abala is predominantly agropastoral whereby both livestock and crop production are practised Crop production is mainly based on floods coming from the highlands through Shugala, Abala, Murga and Iiena rivers Sorghum is the major crop cultivated in the alluvial flood plains Other crops include maize, tef, barley, chickpea and vetch Livestock production systems are of two types, namely sedentary and semi-nomadic pastoralism The sedentary groups (i e settled Tigrians) keep a few cattle, sheep, and goats The semi-nomadic groups (i e Afars) keep mainly goats and camels with a few cattle and sheep Both groups of people keep one or two donkeys for transporting water, firewood and crops Salt trade and firewood sales are locally practised as off-farm income purposes

3.2 Methods of study

3.2.1 Selection of study sites

Prior to the actual fieldwork, visits were made in order to identify study sites Three different sites were selected for the vegetation study based on the land use practices observed, namely (i) Abala, where cultivation and grazing are practised by the settled Tigrians, (ii) Shugala, where cultivation and grazing are practised by the indigenous Afars, and (iii) Murga, where only grazing is practised by both groups of people These land use practices were identified based on personal observations and in consultation with informed sources such as local elders, development agents and local administrative officers

3.2.2 Analysis of trend in vegetation and land use from aerial photographs

Vegetation and land use changes were assessed by use of aerial photographs taken between two points in time that were 30 years apart i e 1964 and 1994 Black and white aerial photographs of the study area were taken in 1964 and 1994 by Ethiopian Mapping Agency at a scale of 1 50,0000 for the purpose of topographical mapping. Portions of the photographs that covered the study area were used for analysis

The method adopted in this study was mapping of settlements, land use and vegetation cover types Other related features such as sand deposits, roads, rivers, gullies and valleys were also delineated All the mapped units were then subjected to aerial coverage analysis using a plani-meter to detect changes in vegetation and land use. Aerial photographs of the same area at different times have been widely used for many years in the semi-arid rangelands where sampling requires a substantial amount of labour, money and time to retrieve information (e g Hientz *et al* 1979, Owens *et al.* 1985, Farah 1991, Turner *et al* 1998)

3.2.3 Woody vegetation data collection and analysis

To collect woody vegetation data, a ten (10) kilometre transect was established in each site to assess the impact of the land use practices. This was done in the period January to June 1997. The first transect ran from Abala town perpendicular to Abala river towards the northeast. The second one ran from Shugala river where flood diversion is practised towards the southeast. Lastly, the third one ran eastwards across Murga flood plain and ridges.

Six sampling points were marked out along each transect at regular intervals of 2km. Four plots of 10m X 10m were established at each sampling point. These plots served as replications or sampling units. The number of individuals of each species and two perpendicular crown diameters of each woody species were recorded. The records were then used to calculate the vegetation attributes under consideration (density, frequency, cover and diversity). Woody species were identified at the Addis Ababa University National Herbarium and listed using both vernacular and botanical names. A few perennial grasses were also identified and recorded. The principal vegetation variables under consideration are discussed below.

(i) Density: This is the number of individuals or count of species per unit area (Dix 1961, Kershaw 1973). In this study it was calculated and expressed as follows:

$$\textit{Density per hectare} = \frac{\textit{No. of individuals of a species inside a plot}}{\textit{Area of a plot}} \times 10{,}000$$

$$\textit{Relative Density} = \frac{\textit{No. of individuals of a species}}{\textit{Total No. of individuals}} \times 100$$

(ii) Crown Cover: This refers to the vertical projection of the aerial parts of individuals of the species under consideration on to the ground (Kershaw 1973, Mueller-Dombois and Ellenberg 1974). The crown diameter method (Mueller-Dombois and Ellenberg 1974) was used as an estimation of cover of woody species.

$\textit{Crown Cover} = ((D_1 + D_2) \div 4)^2 \times \Pi$ *where,*

D_1 and D_2 are diameter measurements of crown perpendicular each other.

$$\textit{Relative Cover} = \frac{\textit{Crown cover of a species}}{\textit{Crown cover of all species}} \times 100$$

(iii) Frequency: Frequency is the chance of finding a species within any one quadrat in a given sampled area (Kershaw 1973)

$$Frequency = \frac{No.\ of\ plots\ in\ which\ a\ species\ is\ present}{Total\ No.\ of\ plots}$$

$$Relative\ Frequency = \frac{Frequency\ of\ a\ species}{Total\ frequency\ for\ all\ species} \times 100$$

(iv) Species Diversity: This refers to the evenness and richness of species in a community or habitat. In this study, Shannon-Wienner Index was used in measuring species diversity (Muller-Dumbois and Ellenberg 1974)

$H' = -\sum p_i \log p_i$ *where, H' = Shannon-Wienner index*
$p_i = N_i/n_i$
N_i = *Total number of individuals in the sample*
n_i = *Number of individuals of the i^{th} species in the sample*

(v) Importance Value Index (IVI): This is the sum of the relative density, relative frequency and relative cover values (Mueller-Dombois and Ellenberg 1974). Note that IVI ranges from 0 to 300%. This attribute was used to select the most abundant species (IVI>10%)

3.2.4 Soil physical and chemical analysis

Soil samples were collected from each sampling point along a 10km transect at 0-10cm, 10-15cm and 15-30cm soil depths in each site by auguring. Most of the hills and ridges were too rocky for deep profile sampling. Hence only shallow pits up to 30cm deep were dug to take soil samples. Samples were air-dried and passed through a 2mm sieve to separate debris and gravel. The samples were then analysed for texture, organic matter, moisture, pH, EC and bulk density at Mekelle University College (MUC) soil laboratory

3.2.5 Questionnaire survey

Data on land use change, vegetation change, woody vegetation uses and natural resource management were collected using a semi-structured questionnaire, formal and informal discussions and personal observation. In this study, stratified sampling was found suitable since woody vegetation exploitation varies between the two groups of people i.e the indigenous Afars and settled Tigrians. Stratification was based on their origin i.e settlers or indigenous Seven settlements within 10-km radius of Abala town were identified and classified according to the people's/inhabitant's origin Two of them were inhabited by the Tigrians and the rest by Afars. A total of 60 households were interviewed, 30 from each homogenous group Each head of household was asked to give information at a personal interview Both closed and open-ended questions were used

Informal discussions were also carried out with local elders wherever there was a chance especially when people gathered at the DHP river diversion site Information on the history of the area, land use and vegetation changes, production system, and environmental changes were gathered from informed sources such as elders, development agents and government offices

3.3 Statistical analysis

Aerial photograph interpretation results were expressed in simple descriptive statistics such as percentages and in graphs Aerial coverage of land use and vegetation changes between two points in time i e 1964 and 1994 were described to assess the effects of land use change on vegetation cover and related physical features

The two factor with no replication model (Chou 1970, Microsoft Excel 1992) was used to compare the three study sites for each selected woody species and distances within each site for the selected woody species data (conducted on botanical composition, density, and percent crown cover). In this case, four replicates at each sampling point were pooled together for analysis The completely randomised design method (Steel and Torrie 1980) was used to compare changes of each selected species along a 10km distance within each site and diversity of species among the three study sites Descriptive statistics such as percentages were also used to describe woody vegetation data The Duncan's Multiple Range Test was employed to separate the means (Steel and Torrie 1980) after the analysis of variance (ANOVA). Soil physical and chemical analysis results were expressed using simple descriptive statistics The data collected using the questionnaire was summarised, ranked and expressed using descriptive statistics such as percentages

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Aerial photo analysis of change in vegetation and land use

A lot of information was retrieved on vegetation and land use changes by use of aerial photos (scale of 1 50,000) taken at two points in time, 1964 and 1994 The results of photograph analyses for the two years for the study area (mapping of vegetation units, land use and related features) are presented in Figs 4 1 and 4 2 respectively

Results from interpretation of aerial photographs showed cultivated fields, settlements, 11 physiognomic vegetation types, and related prominent features (flooded plains, hills/ridges roads, rivers, valleys, gullies, exposed rocks and sand deposits) Aerial coverage analyses of the major mapping units for each year and observed changes are summarised in Table 4 1

Table 4.1 Vegetation and land use cover types for 1964 and 1994, and percent change over 30 years

Mapping units	Area covered (ha)		Percent change
	1964	1994	
Cultivated land	97 50	2605	2572
Settlement	5.00	180 00	3500
Vegetation units(D1-D11):	**31252.50**	**26787.50**	**-14**
Grasslands(D1)	25 00	87.50	250
Bushed grasslands(D2)	4970 00	2097 50	-58
Shrub grasslands(D3)	55 00	200.00	264
Bushlands(D4)	3300.00	4862.50	44
Dense bushlands(D5)	1392 50	940.00	-32
Bushland thicket(D6)	1350 00	1262 50	-6
Wooded grasslands(D7)	897 50	290 00	-68
Wooded bushed grasslands(D8)	7950 00	6960 00	-12
Wooded bushlands(D9)	8505 00	9495 00	12
Wooded dense bushlands(D10)	1392 50	592.50	-57
Woodlands(D11)	1345 00	0 00	-100
Rivers, gullies, sand Deposits and exposed rocks	4206 50	5900.00	40
Total	35561.5	35472.5	-89

Figure 4.1 Vegetation and land use cover map of the study area (aerial photo interpretation of 1964)

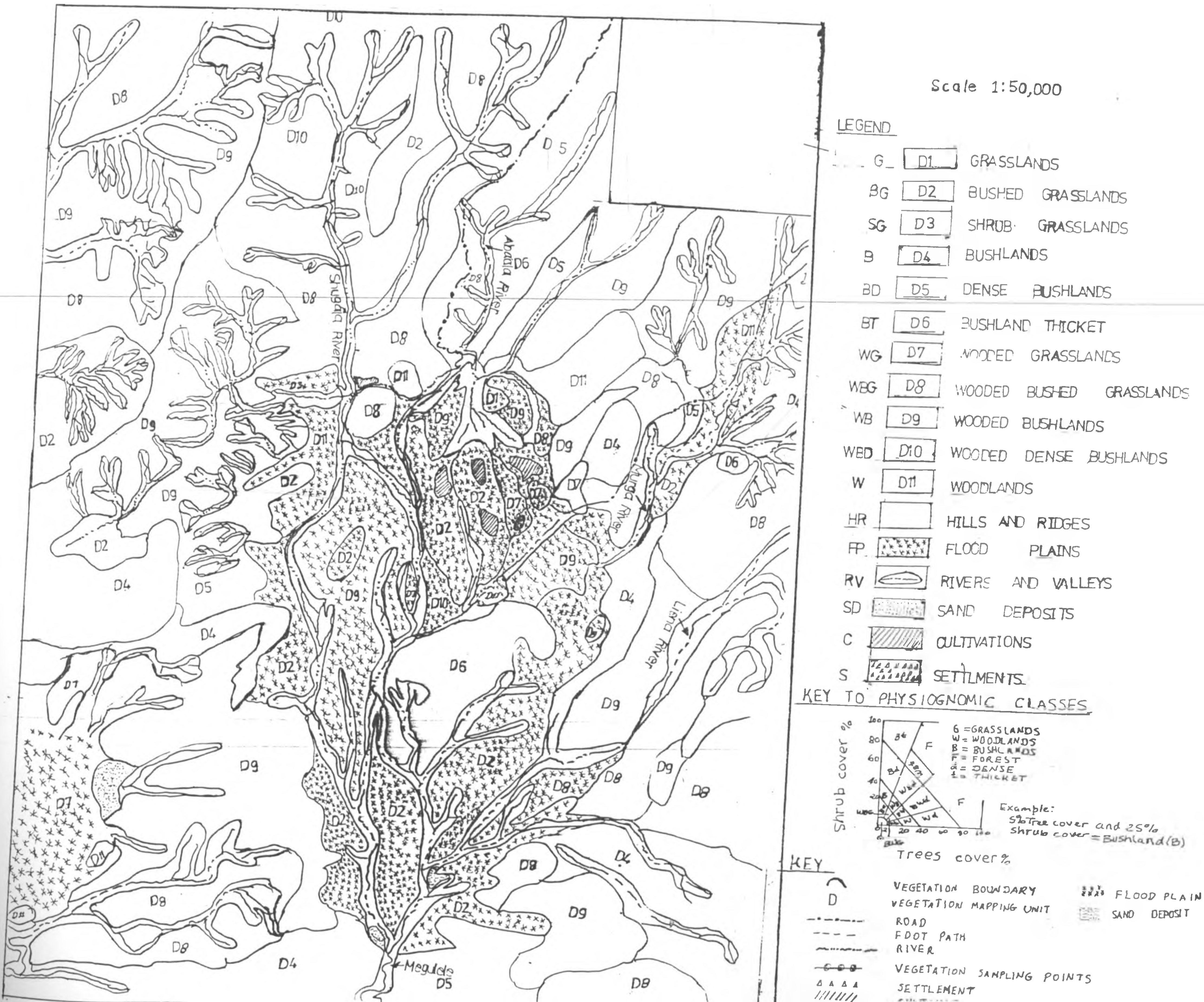
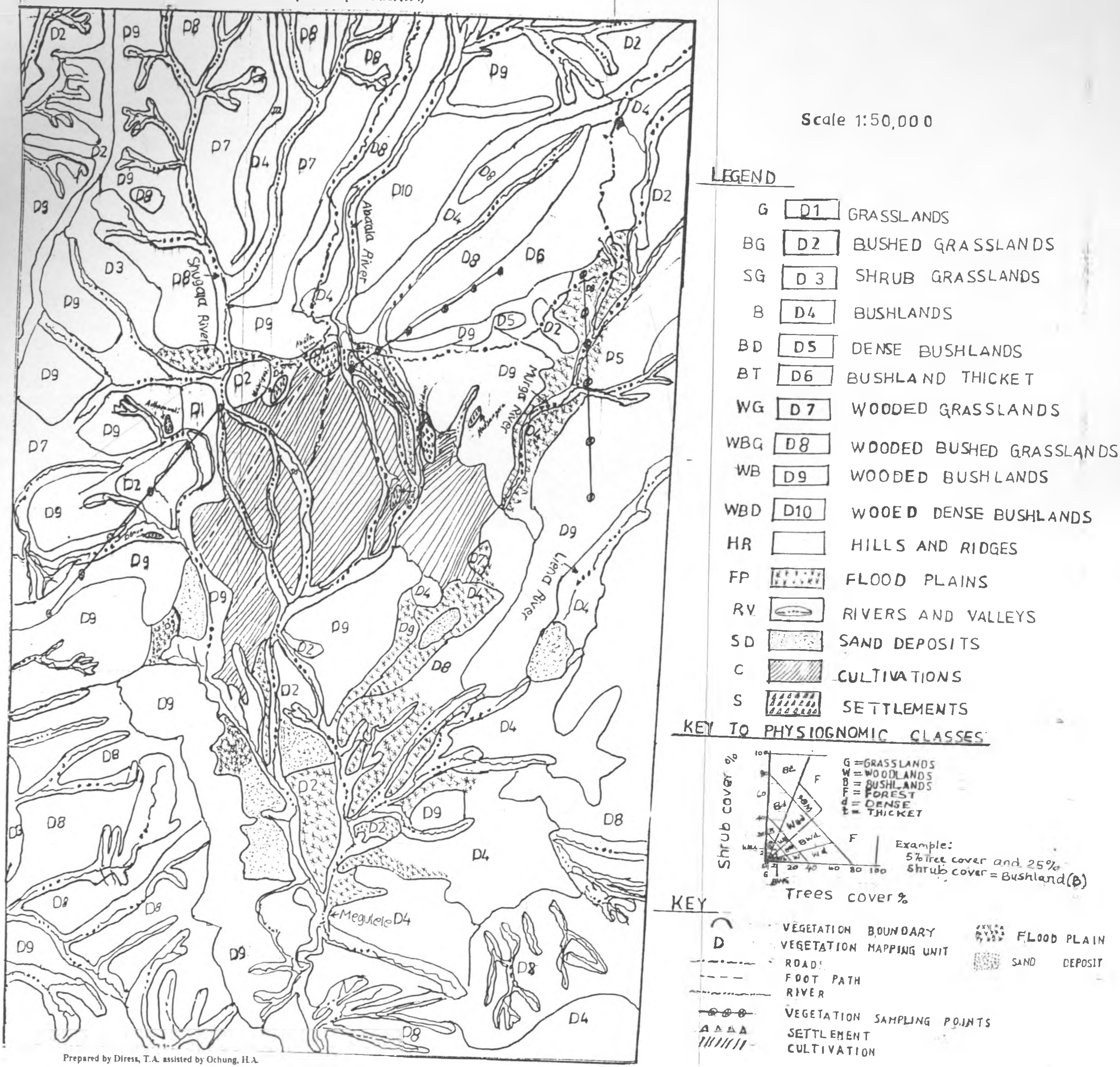


Figure 4.2 Vegetation and land use cover map of the study area (aerial photo interpretation of 1994)

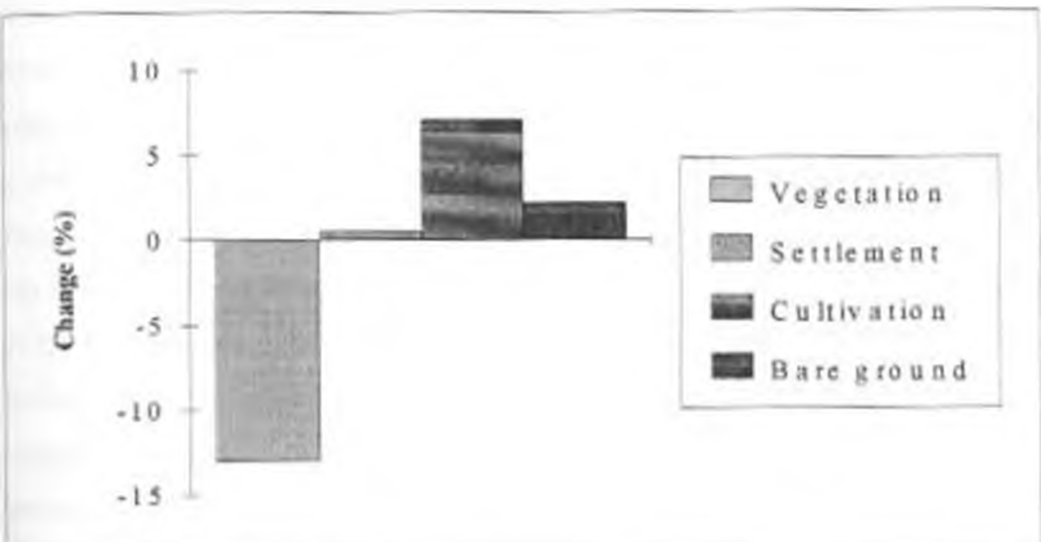


Prepared by Diress, T.A. assisted by Ochung, H.A.

The data in Table 4.1 indicates that total area for the two maps has a difference of 89 hectares. This indicates that the two maps do not exactly fit. This may be due to either the variation of flight height or the precision in taking the pictures. In this study, emphasis is given to the major mapping units i.e. settlement, cultivation and total vegetation mapping units (i.e. in terms of cover).

As depicted in Fig. 4.3, conspicuous changes have occurred in land use between 1964 and 1994 in the study area, indicating that cultivated land, settlements, and bare grounds (gullies, sand deposits and exposed rocks) increased from 0.27% (97.5 ha) to 7.34% (2,605 ha), 0.01% (5 ha) to 0.51% (180 ha), and 7.78% (2,790 ha) to 9.98% (3,540 ha) out of the total area respectively. Vegetation cover, however, generally decreased from 87.88 to 75.52%

Figure 4.3 Percent land use and vegetation cover changes from the total area between two points in time (1964-1994)



Areas covered by settlement increased markedly between 1964 and 1994 in the flood plains as a result of a high influx of people from Tigrai to the study area. Cultivated land accounted for 44.42% of the 5,865 ha of the flood plains in 1994 while only 1.66% was covered by cultivated fields in 1964. This showed that, in terms of extent, cultivation was most conspicuous in the flood plains. The results clearly indicate that the area experienced a progressive expansion of flood recession agriculture to the limited area possible for cultivation as a result of continued settlement in the last three decades. Most herders in sub-

Saharan Africa, including Ethiopia, lost their prime grazinglands particularly in low lying areas to make room for flood recession and irrigated agriculture (Keya 1991, Hadley 1993, Bourn and Wint 1994, Ali 1995) The study area is a case in point where dry season grazing land in the flood plains has been cleared for cultivation

Natural vegetation cover which accounted for 87 88% of the total area in 1964 subsequently decreased to 75 52% in 1994 This decrease was mainly due to the steady clearance of natural vegetation especially woodlands, wooded grasslands, wooded bushed grasslands and bushed grasslands in the flood plains to make room for cultivation and settlement As shown in Table 4 1, cultivated land and settlements had increased by 2572% and 3500%, respectively, during the 30 years period, whereas woodlands, wooded grasslands, wooded bushed grasslands and bushed grasslands had reduced in 1994 by 100%, 67 69%, 12 45%, and 57 80%, respectively, as compared to 1964 The percentages for cultivation and settlements were very high due to large increases in 1994 as compared to their total coverage in 1964 As a result, all woodlands have already been cleared to make room for cultivation and settlement In addition, overgrazing and erosion most likely have resulted in a change of wooded bushed grasslands and bushed grasslands into wooded bushlands and exposed surface especially in the hills and ridges An increase in woody vegetation cover has been commonly reported as a response to heavy grazing elsewhere (Pratt and Gwynne 1977, Le Houerou 1980, Coppock 1994) For instance, Coppock (1994) reported that ecological sustainability in Borana, Ethiopia is threatened by increased cereal cultivation on upland soils and woody encroachment as well as soil erosion which can be attributed to heavy grazing by cattle It can be deduced from the results of this study that the whole area must in the past have been either subjected to heavy use or undergone major climatic change It is difficult, however, to assert at present whether climatic changes have contributed to the observed vegetation trend due to lack of long-term climatic and vegetation data From the present study, it is not also possible to determine the effects of other factors such as fire on vegetation due to lack of data

In general, results from aerial photograph interpretation provided information on patterns of land use, vegetation change, range condition and overall view of the area This was in agreement with Hientz et al. (1979), Owens *et al.* (1985), and Turner *et al.* (1998) who reported that in semi-arid rangelands where sampling requires a substantial amount of resource, aerial photographs of the same area at different times contain valuable information

4.2 Field vegetation study

Data on woody vegetation are presented in Appendices 2 2-2 6 Analysis was based on six selected woody species whose importance value indices were greater than 10%. Species composition, cover, density and diversity were considered to study changes along a 10km distance for each site and among the three study sites ANOVA tables for the tested parameters are presented in Appendices 3 1-3 13 Duncan's Multiple Range Test was used to separate means

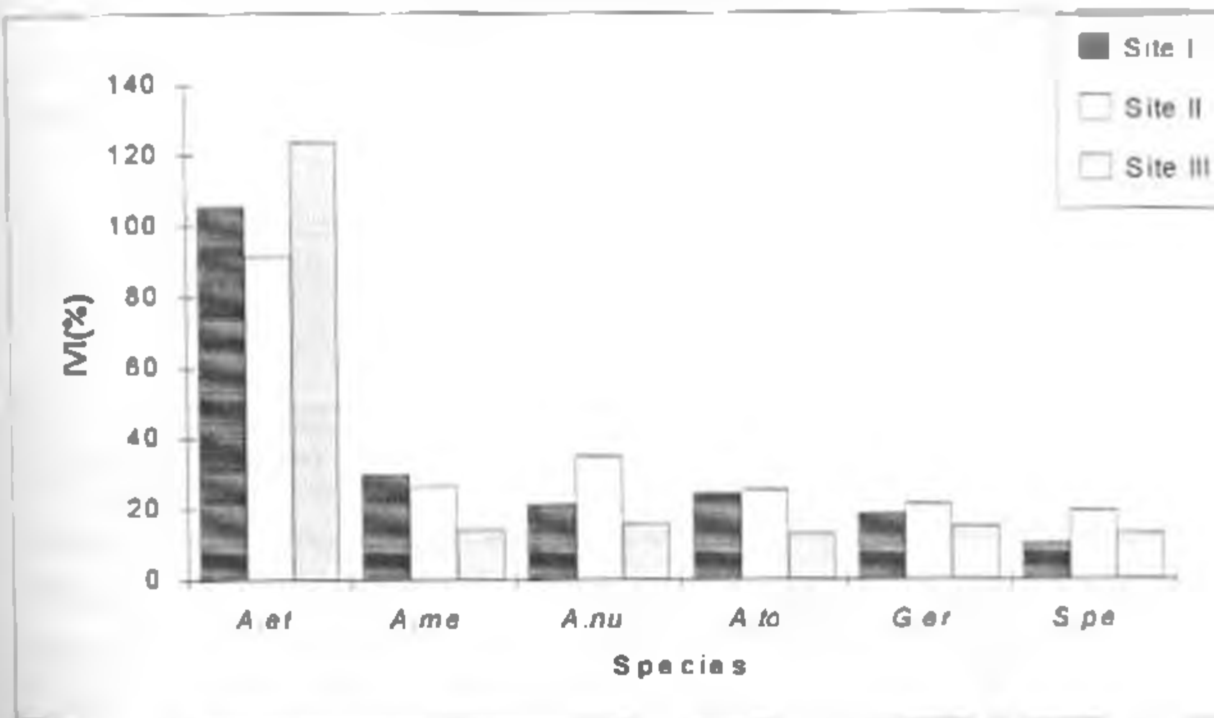
4.2.1 Vegetation inventory

The study area was composed of mixed woody species dominated by *Acacia, Grewia* and allied genera A total of 43 woody species were identified and recorded during the study period (Appendix 2 1) The list is arranged in an alphabetical order of botanical names Of the 43 species, 34 were identified by their botanical names The rest were recorded based on their local names The species of other plant forms encountered during the study period were also identified and recorded These included forbs (*Abutilon anglosomaleae, Aereva javanica, Euphorbia* spp , and *Aloe* spp), and grasses (*Cenchrus* and *Cynodon* spp)

The species recorded and identified were distributed as follows - Leguminosae, nine, Tiliaceae, five, Boraginaceae, five, Capparidaceae, three, Solanaceae, three, Balanitaceae, two; Salvadoraceae, two; and Graminea, two The rest had only one species i.e Rhamnaceae, Combretaceae, Asclepiadaceae, Caesalpinioideae, Sapindaceae, Moraceae, Amaranthaceae, Malavaceae, Liliaceae and Euphorbiaceae Since the vegetation survey covered a short period, one should expect additional species to be listed if the inventory was done over a longer period of time and in different seasons

The number of woody species encountered in the three study sites during sampling (or sampled 10km transects) was 30. Nineteen, twenty-two and twenty-one species were recorded in Abala (I), Shugala (II) and Murga (III) respectively (Appendices 2.2, 2 3 and 2 4) Among the 30 species, 11 species shared dominance and were recorded in all the three study sites Six of the 11 common species had mean IVI > 10% in all the three sites and were selected for woody vegetation data comparison These include *Acacia ethaica, A. mellifera, A. nubica, A. tortilis, Grewia erythrea* and *Salvadora persica* The IVI for six selected woody species (i.e those whose IVI > 10%) is depicted in Fig 4.4 *A. etbaica* was found to be the dominant species with the mean IVI of 105 48%, 91.46%, and 123.89% for site I, II, and III respectively Mueller-Dombois and Ellenberg (1974) reported that species with the highest importance value index are referred to as dominants. Mean IVI (Relative density + Relative cover + Relative frequency) of all species for the three study sites is presented in Appendix 2.5 The species are arranged in order of IVI for each site

Figure 4.4 Mean importance value index (IVI) of six selected woody species for the three study sites (Abala, Shugala and Murga)*



** A.et = Acacia etbaica; A.me = A. mellifera; A.nu= A. nubica; A. to = A. tortilis; G. er = Grewia erythrea; and S. pe = Salvadora persica*

4.2.2 Composition of woody species

The species composition of all woody species encountered in each transect (or study site) is as tabulated in Appendices 2.2, 2.3 and 2.4. *Acacia etbaica* attained relatively high values of abundance with species compositions of 22 89%, 28 21% and 33.09% in Abala, Shugala and Murga respectively. The rest of the species had percent species composition below 11.5% except for *A. mellifera* which had a composition of 18.07% in Abala.

Table 4.2 Species composition (%), crown cover (%) and density (N/ha) for six selected trees and shrubs in the three study sites (mean values)*

Site	Vegetation attribute	Species						
		A. et.	*A. me.*	*A. nu.*	*A. to.*	*G. er.*	*S. pe.*	SE**
Abala	Composition	22.89^{a}	18.07^{ab}	7.23^{b}	6.63^{b}	7.83^{b}	1.81^{b}	±3.26
	Cover	51.19^{a}	3.26^{b}	3.13^{b}	10.61^{b}	0.18^{b}	4.47^{b}	±7.93
	Density	158^{a}	125^{ab}	50^{ab}	46^{ab}	54^{ab}	13^{b}	±22.55
Shugala	Composition	28.21^{a}	11.11^{b}	10.26^{b}	6.84^{b}	10.26^{b}	3.42^{b}	±3.51
	Cover	32.71^{a}	3.83^{b}	11.37^{b}	10.8^{b}	0.19^{b}	5.83^{b}	±4.71
	Density	138^{a}	54^{b}	50^{b}	33^{b}	50^{b}	17^{b}	±17.10
Murga	Composition	33.09^{a}	7.19^{b}	5.76^{b}	1.44^{b}	9.35^{b}	2.16^{b}	±4.81
	Cover	47.76^{a}	3.27^{b}	1.47^{b}	8.04^{b}	0.11^{b}	5.02^{b}	±7.44
	Density	192^{a}	42^{b}	33^{b}	8^{b}	54^{b}	13^{b}	±27.86
SE**	Composition	±2.95	±3.18	±1.32	±1.77	±0.71	±0.41	
	Cover	±5.68	±0.19	±3.06	±0.89	±0.03	±0.39	
	Density	±15.78	±25.95	±5.56	±11.02	±1.39	±1.39	

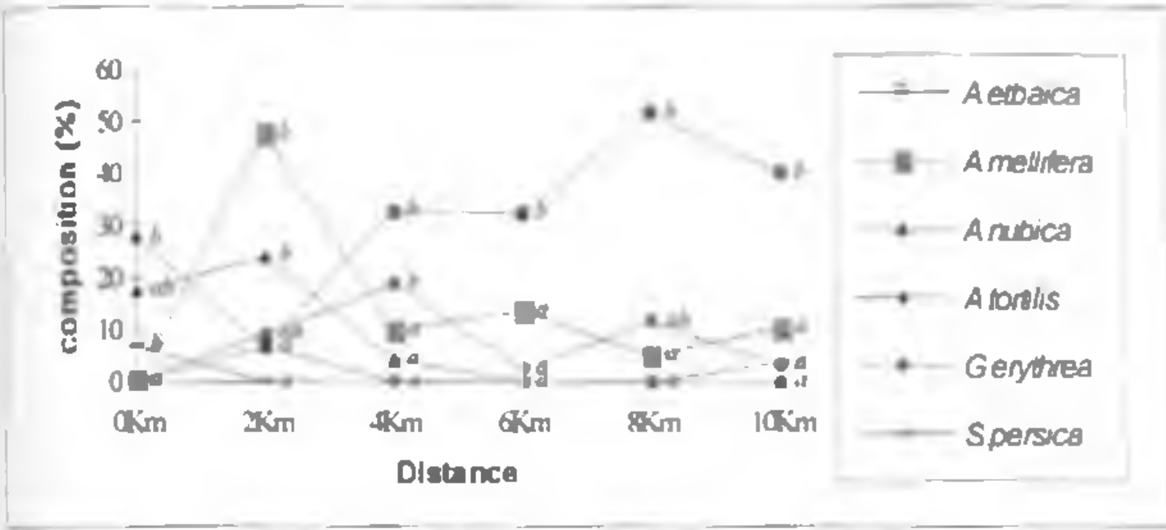
** In a row or column, numbers followed by a common superscript letter(s) for the respective vegetation attributes are not significantly different (P>0.05).*
*** SE = Standard error of mean*

The percent species composition of each selected woody species did not show a significant difference ($P>0.05$) among sites. Percent species composition, however, showed a significant difference ($P<0.05$) among species for each site (Table 4.2) and among distances for each species in each site (Figs. 4.5, 4.6 and 4.7). Mean separation using Duncan's indicated that *A. etbaica* had a higher percent species composition than all other species in the three study sites except with *A. mellifera* in site I. There was no significant difference between other species in the three study sites (Table 4.2). Differences in composition along distances were significant ($P<0.05$) for each selected woody species except for *S. persica* in site II and *A. nubica, A. tortilis, G. erythrea* and *S. persica* in site III (Figs. 4.5, 4.6 and 4.7).

As shown from the result, there was no appreciable variability in woody species composition from site to site However, the result revealed that species composition varied among species and among distances for each species within each site Variation among species may be attributed to the fact that *A. etbaica* had a wider ecological amplitude across the distances, while other species exhibit local dominance For instance, *A. tortilis* and *Salvadora persica* favour plain areas or riversides, whereas *A. mellifera* favour hillsides and rocky sites *A. etbaica*, however, had a wider ecological amplitude and spread over both plain and hilly areas Such species are referred to as ecological dominants (Odum 1971)

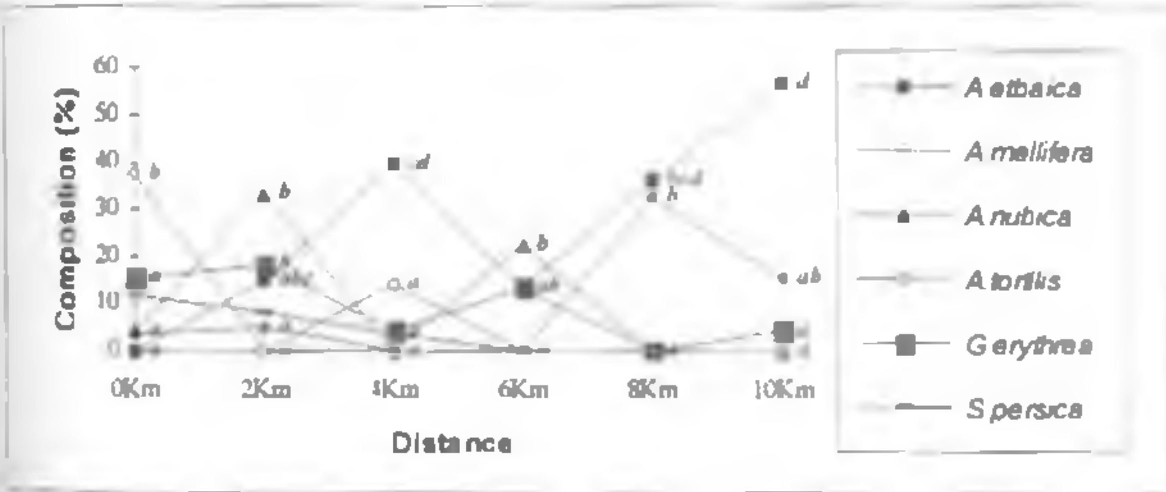
As shown in Figs 4.5, 4.6 and 4.7, the percent composition of *A.etbaica* was relatively higher than that of other species along distances in each site. It was, however, absent nearer to settlements and cultivated fields in sites I and II *A. etbaica* showed an increasing trend as one moved away from settlements and cultivated fields Species such as *A. tortilis, A. nubica* and *S. persica* attained their highest percentage in plains nearer to settlements and cultivated fields The reasons may be due to the purposeful selection of some species like *A. tortilis, A. nilotica, S.persica* and *Balanites aegyptica* for some economic reasons in addition to their occurrence in bottomlands or flooded plains *A. nubica* favoured disturbed sites nearer to settlements and cultivated plains *A. etbaica*, which exhibited a wider ecological amplitude in the study area, reduced nearer to disturbed sites due to its exploitation for firewood and construction poles

Figure 4.5 Species composition (%) for six selected woody species along a 10km transect for site I*



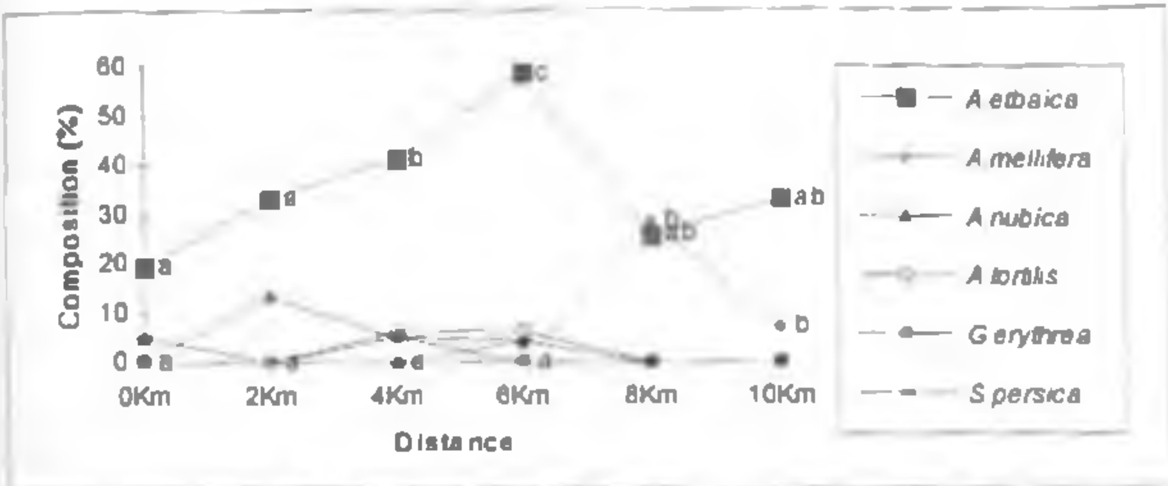
*Different letter(s) along a line graph represent(s) significant difference (P<0.05) among distances.

Figure 4.6 Species composition (%) for six selected woody species along a 10km transect for site II*



*Different letter(s) along a line graph represent(s) significant difference (P<0.05).

Figure 4.7 Species composition (%) for six selected woody species along a 10km transect for site III[a]

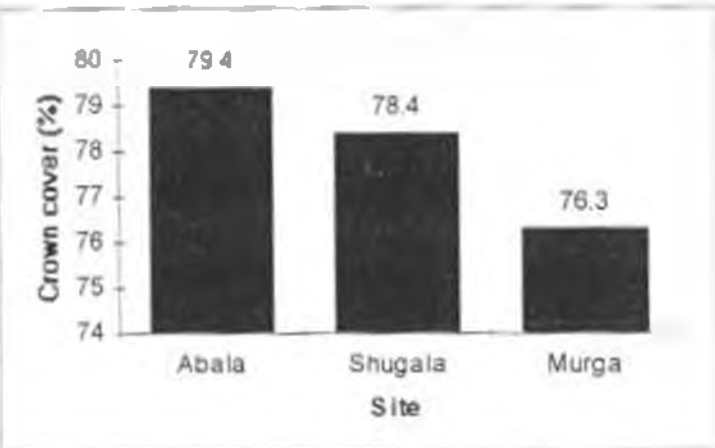


[a] *Different letter(s) along a line graph represent(s) significant difference (P<0.05) among distances, while absence of letter(s) indicate(s) non significant difference (P>0.05)*

4.2.3 Percent cover and density of woody species

As shown in Fig 4.8, the percent crown cover of all trees and shrubs was found to be 79.40%, 78.36% and 76.26% for sites I, II and III respectively. The percent crown cover of each woody species is as presented in Appendices 2.2, 2.3 and 2.4

Figure 4.8 Total woody vegetation cover (%) for the three sites



There was no significant difference (P>0.05) for crown cover (%) of 6 selected trees and shrubs when comparison was made among sites (Table 4.2) and among distances for total cover of six woody species within each site (Table 4.3). As shown in Table 4.2, comparison among species showed significant differences (P<0.05) within sites I and III and no significance difference (P>0.05) within site II. Distances showed significant differences (P<0.05) in all the three sites for *A. etbaica*, in site III for *A. mellifera*, in sites I and II for *A. nubica*, in sites II and III for *A. tortilis* and in sites II for *G. erthrea* and *S. persica* (Figs. 4.9, 4.10, and 4.11). *Acacia etbaica* had higher crown cover (51.19%, 32.71% and 47.76%) than all other species within the three study sites (Table 4.2).

Table 4.3 Percent crown cover (%) and density (N/ha) along a 10km transect within each site for the six selected woody species*

Site	Vegetation attribute	Distance						
		0km	2km	4km	6km	8km	10km	SE**
Abala	Cover	86.88^{a}	37.30^{a}	67.10^{a}	72.98^{a}	87.51^{a}	85.65^{a}	±4.13
	Density	375.00^{a}	850.00^{b}	350.00^{a}	350.00^{a}	400.00^{a}	350.00^{a}	±17.72
Shugala	Cover	89.09^{a}	50.48^{a}	76.37^{a}	55.89^{a}	50.39^{a}	66.16^{a}	±3.10
	Density	325.00^{a}	350.00^{a}	350.00^{a}	275.00^{a}	375.00^{a}	375.00^{a}	±11.81
Murga	Cover	28.36^{a}	41.48^{a}	89.92^{a}	91.01^{a}	83.81^{a}	59.37^{a}	±3.20
	Density	28.36^{a}	475.00^{a}	275.00^{a}	350.00^{a}	375.00^{a}	250.00^{a}	±14.73
SE**	Cover	±4.52	±2.58	±5.40	±5.02	±6.06	±5.74	
	Density	±15.23	±30.30	±17.18	±18.44	±23.15	±19.83	

**In a row, numbers followed by a common superscript letter(s) are not significantly different (P>0.05).*
***SE = Standard error of mean*

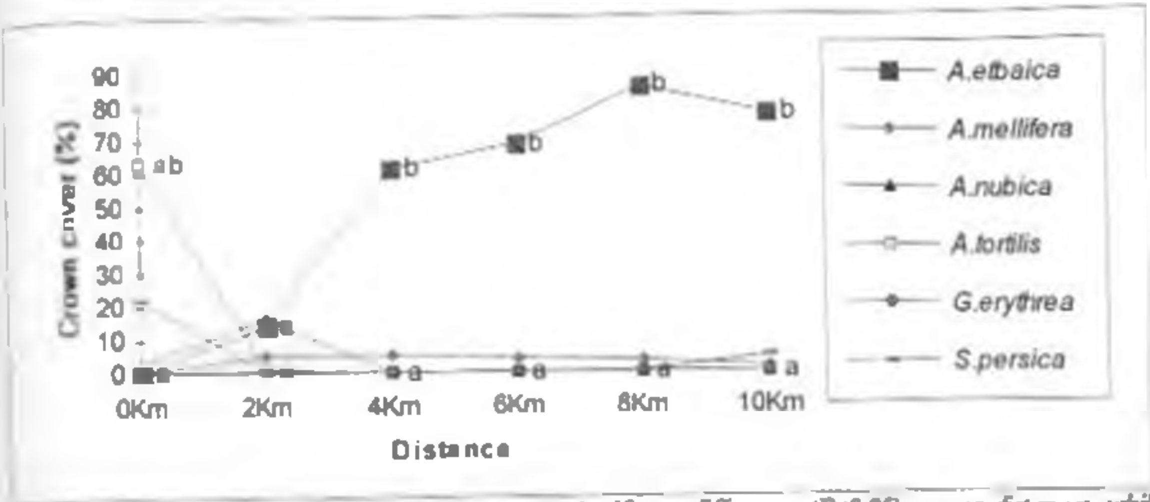
The densities of woody species are summarised in Appendices 2.2, 2.3 and 2.4. It is expressed in numbers of individuals per hectare (N/ha). In terms of total vegetation density, Abala had a higher density per hectare (691.67) followed by Murga (579.17). But site II (Shugala) had 487.50 individuals per hectare. As far as individual species are concerned, *A. etbaica* had the highest density per hectare (158.33, 173.50 and 191.67) for sites I, II and III respectively.

There were no significant differences (P>0 05) among sites for each species (Table 4 2) and among distances within each site for total density of six selected trees and shrubs (Table 4.3) Density between species, however, was significant (P<0 05). As shown in Figs 4 12, 4 13 and 4 14, distances showed significant differences (P<0 05) for *A. etbaica* and *A. mellifera* in all the three sites, and *A. nubica* and *A. tortilis* in sites I and II However, *G. erythrea* and *S. persica* showed no significant differences in all the three sites Mean separation indicated that *A. etbaica* had a higher density than all other species in sites II and III In site I, there were no differences between species except for *A.etbaica and Salvadora persica* As observed for composition, percent crown cover and density for the selected woody species also showed no significance differences among sites

As shown in Figs 4 9-4 14, aerial cover and density also showed a similar trend as observed for composition in section 4 2.2 Although there were no significant differences among sites and among distances in terms of total aerial cover and density for the selected woody species, differences were observed among species in each site and along distances for each species The reasons for such results for the present study can be attributed to one or all land use practices The practices have similar effects on vegetation cover on a wider area Near settlements and cultivated fields where a lot of disturbance had occurred, some shrubs (*A.nubica* and *S. persica*) and some selected trees (such as *A. tortilis, A. nilotica* and *Balanites aegyptiaca*) had the highest cover as compared to other species and replaced or gave way to other species as one moved farther apart from these areas As a result, total vegetation cover did not exhibit a wide range of difference

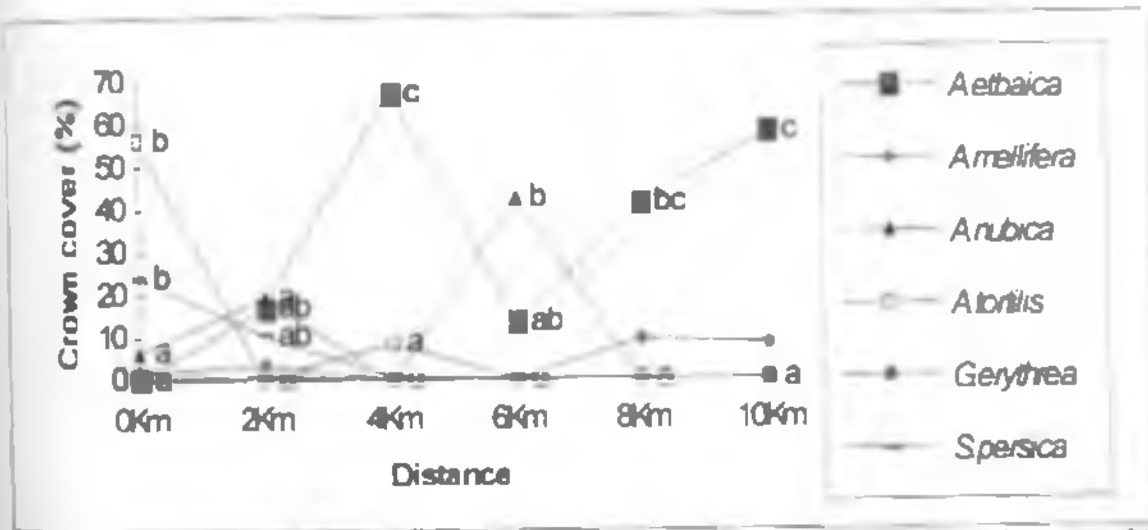
The result is, therefore, not in total agreement with other similar study results in other areas, which consistently confirmed that vegetation cover increases as one moved away from settlement areas and irrigation schemes For instance, Kariuki (1996) found that vegetation cover is very low within 2 to 3 kilometres away from settlements in response to irrigation schemes and human settlements in Malkadaka and Garfassa areas of Isiolo District However, the result is in agreement with that of Amuyunzu and Oba (1991) who reported that woody canopy cover and woody plant density of some key woody species in the flood plains of the woodlands of Turkwel river ecosystem in Kenya were affected more near settlements and irrigation schemes

Figure 4.9 Crown Cover (%) for six selected woody species along a 10km transect for site I*



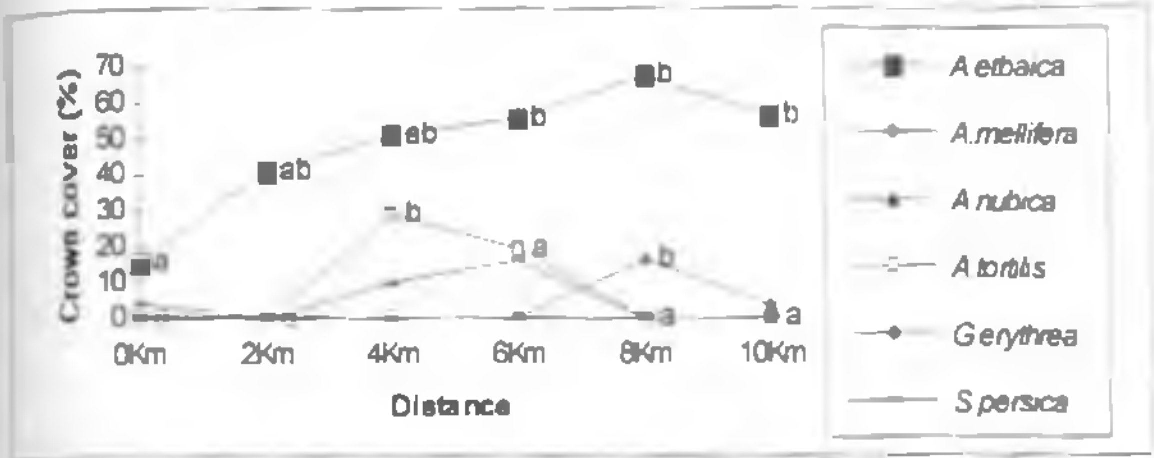
*Different letter(s) along a line graph represent(s) significant difference (P<0.05) among distances, while absence of letter(s) indicate(s) non significant difference (P>0.05).

Figure 4.10 Crown Cover (%) for six selected woody species along a 10km transect for site II*



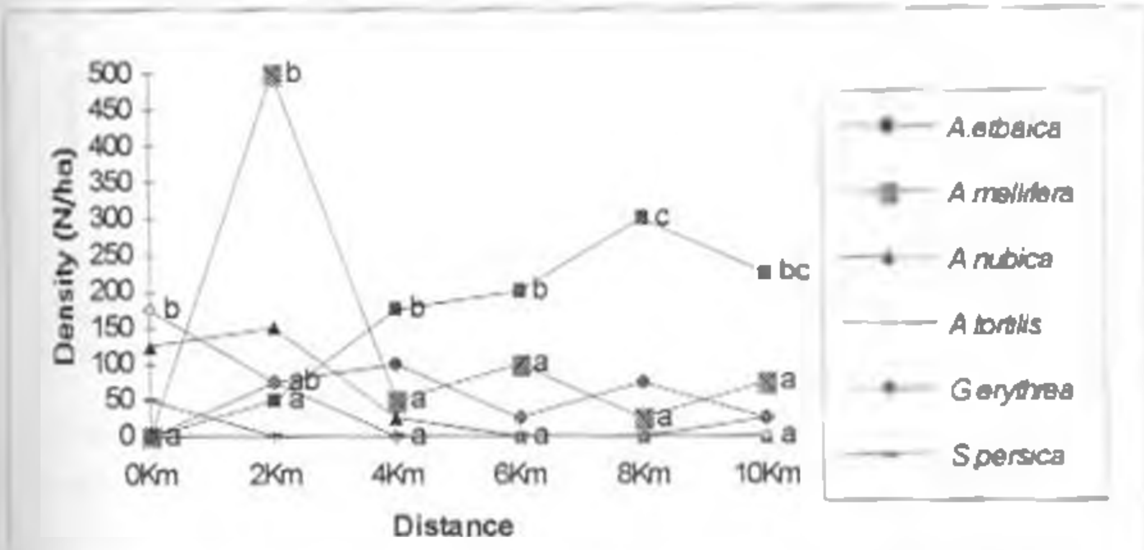
*Different letter(s) along a line graph represent(s) significant difference (P<0.05) among distances, while absence of letter(s) indicate(s) non significant difference (P>0.05).

Figure 4.11 Crown Cover (%) for six selected woody species along a 10km transect for site III*



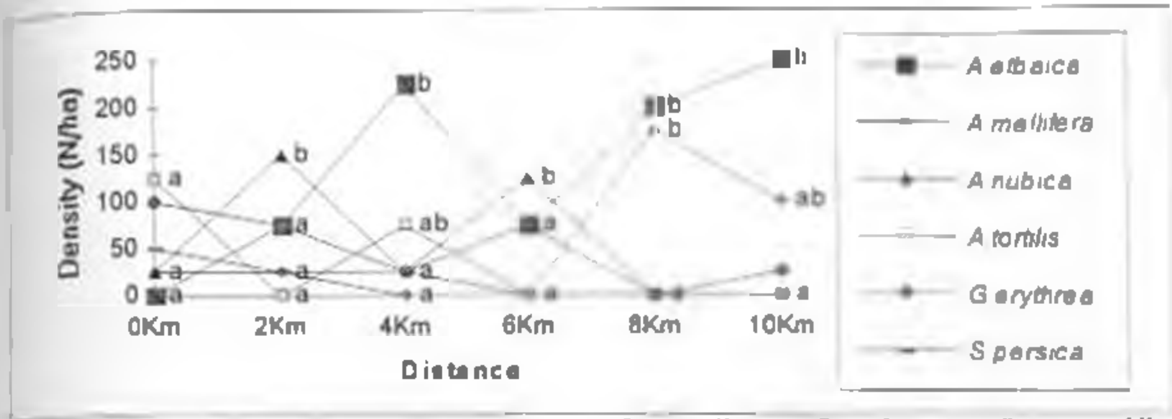
*Different letter(s) along a line graph represent (s) significant difference (P<0.05) among distances, while absence of letter(s) indicate(s) non significant difference (P>0.05).

Figure 4.12 Density (N/ha) for six selected woody species along a 10km transect for site I*



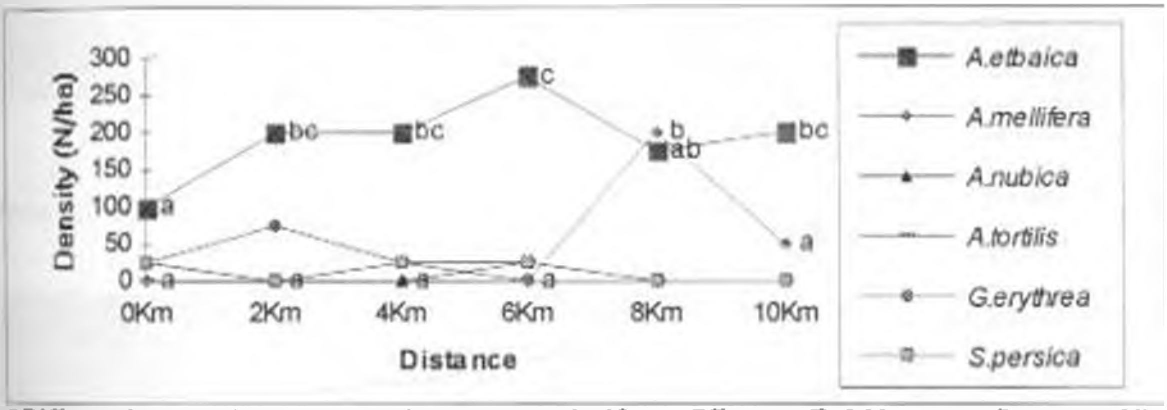
*Different letter(s) along a line graph represent(s) significant difference (P<0.05) among distances, while absence of letter(s) indicate(s) non significant difference (P>0.05).

Figure 4.13 Density (N/ha) for six selected woody species along a 10km transect for site II*



**Different letter(s) along a line graph represent(s) significant difference (P<0.05) among distances, while absence of letter(s) indicate(s) non significant difference (P>0.05).*

Figure 4.14 Density (N/ha) for six selected woody species along a 10km transect for site III*



**Different letter(s) along a line graph represent(s) significant difference (P<0.05) among distances, while absence of letter(s) indicate(s) non significant difference (P>0.05).*

In general, the area had moderate vegetation cover in terms of trees and shrubs (Plate 4.1). However, herbaceous cover was very poor with few or no perennial grasses. Bare ground was common in most sites and the understorey vegetation was composed of *Aloe* and *Euphorbia* species (Plate 4.2). As a result, grazing was very poor during the study period and animals including cattle are adapted to browsing due to the presence of *Acacia* and *Grewia* species. As described in section 4.3, people in the study area reported that degradation of vegetation cover was due to cultivation, overgrazing and erosion. This is a common phenomenon in most rangelands of East Africa (Pratt and Gwynne 1977)

Plate 4.1 *Acacia etbaica* dominated wooded bushland (photo by Diress, 1997)

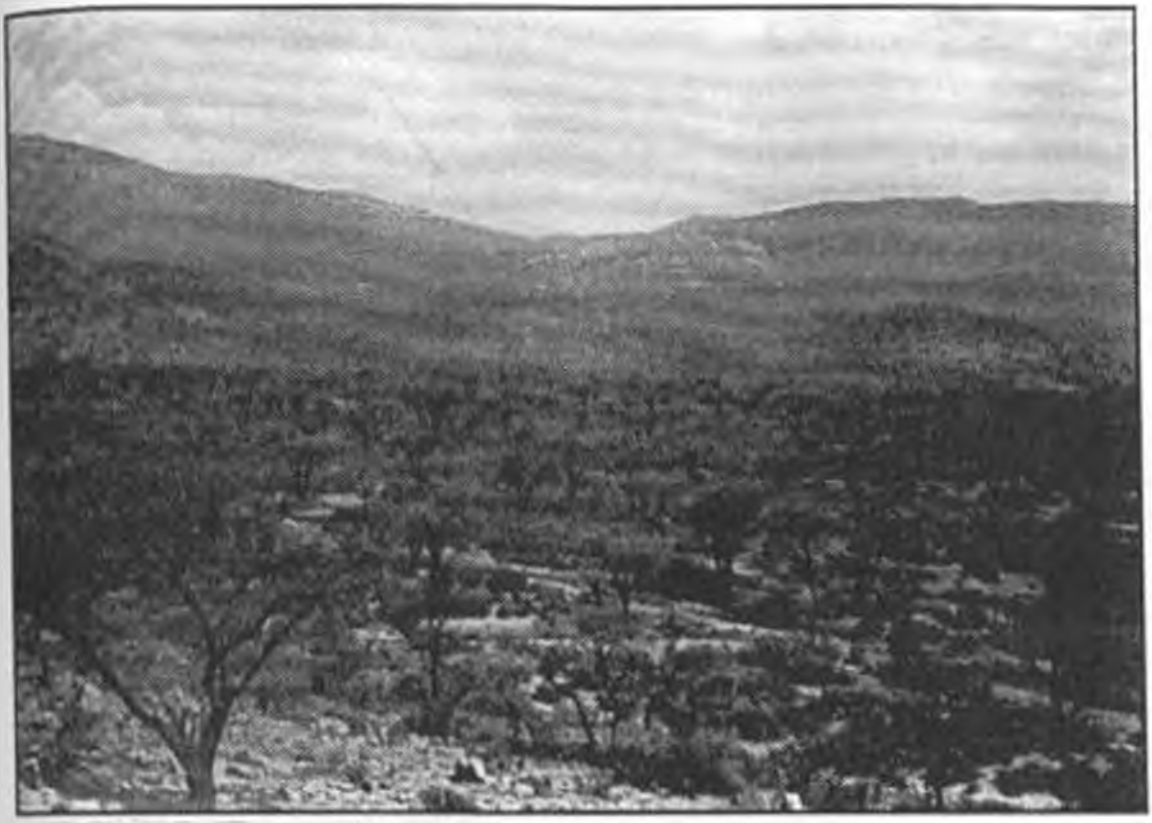


Plate 4.2 Herbaceous cover mainly dominated by *Euphorbia* and *Aloe* species (photo by Diress, 1997)

4.2.4 Species diversity

The woody species recorded during the study period were distributed evenly and total woody species diversity indexes were found to be 1 08, 1 09 and 1 08 for sites I, II and III respectively (Appendices 2 2, 2 3 and 2 4) Mean separation showed no significant differences (P>0.05) for species diversity of six selected trees and shrubs among sites (Table 4 4) Although site II had less individuals relative to others, its diversity index was approximately the same as those for sites I and III This may be due to the even distribution of individuals in site II

Table 4.4 Diversity index for six selected trees and shrubs*

Site	Number of individuals	Diversity index (H')**
Abaala	166	0 78ª
Shugala	117	0 77ª
Murga	139	0 78ª

** In a column, numbers followed by a common letter(s) are not significantly different (P>0.05)*
*** H' = Shannon-Wienner diversity index.*

4.2.5 Description of soil physical and chemical characteristics

The physical and chemical characteristics of soil samples for three sampling depths (0-10, 10-15 and 15-30cm) along a 10km distance for each site are presented in Table 4 5 Values of both physical and chemical properties of soil in the study sites do not exhibit a wide range of variation among sites, depths and along distances for each site

In general, the soil texture was sandy to sandy loam and moisture content ranged between 1 01 and 9 81%. Bulk density ranged between 1 07 and 1 40 gm/cm^3 The soils are mainly non-alkaline, with a pH ranging between 7.62 and 8 68. Soil electrical conductivity (EC) was generally low ranging between 0 10 and 2 00 m Mhos/cm There was no appreciable difference in organic matter (OM) percentage along distances for each site and among the three soil depths The soils in the study sites were lowest in OM content, which ranged from 3.23 to 0.02% The result revealed that soils are poor in OM content in all the three sites This is attributed to the fact that there is no accumulation of litter for decomposition in the hills and ridges due to serious erosion problems The soils from hills and ridges are washed and deposited in the cultivated plain areas From this it is possible to conclude that soils in the cultivated fields may be rich in OM content and other nutrients

Table 4.5 Mean values of soil physical and chemical characteristics along a 10km transect for each site

			Distance					
Site	**Depth**	**Soil factor**	**0Km**	**2Km**	**4Km**	**6Km**	**8Km**	**10Km**
Abala	0-10cm	Bulk density (g/cm3)	1.22	1.40	1.38	1.07	1.15	1.31
		Moisture (%)	4.17	5.26	6.38	1.53	3.11	2.04
		EC(mMhos/cm)	2.00	0.15	0.12	0.23	0.24	0.12
		pH	7.68	8.45	8.28	8.12	8.06	8.25
		Organic matter (%)	0.52	0.55	3.17	0.59	1.03	1.03
	10-15cm	Moisture (%)	5.26	4.17	2.04	2.57	2.57	4.17
		EC (mMhos/cm)	1.88	0.28	0.10	0.22	0.23	0.11
		pH	7.62	8.49	8.25	8.19	8.19	8.25
		Organic matter (%)	0.43	0.48	2.62	0.34	0.52	1.00
	15-30cm	Moisture (%)	4.17	2.57	3.09	4.17	1.53	2.04
		EC (mMhos/cm)	1.21	0.82	0.12	0.42	0.34	0.11
		pH	7.78	8.12	8.25	8.02	8.07	8.35
		Organic matter (%)	0.33	0.34	1.21	0.09	0.05	0.55
Bhugala	0-10cm	Bulk density (g/cm3)	1.27	1.31	1.24	1.23	1.13	1.21
		Moisture (%)	1.01	3.11	2.04	2.57	1.53	2.04
		EC (mMhos/cm)	0.14	0.11	0.31	2.27	0.14	0.11
		pH	8.10	8.68	8.13	7.83	8.27	8.47
		Organic matter (%)	0.14	0.34	0.05	0.09	0.24	3.23
	10-15cm	Moisture (%)	2.04	3.69	3.09	11.11	3.09	2.57
		EC (mMhos/cm)	0.32	0.18	0.73	2.91	0.13	0.32
		pH	8.13	8.33	7.95	7.81	8.38	8.14
		Organic matter (%)	0.10	0.14	0.04	0.05	0.17	2.59
	15-30cm	Moisture (%)	3.12	2.59	9.89	3.65	3.09	3.09
		EC (mMhos/cm)	0.83	0.39	1.06	2.75	0.15	0.15
		pH	7.87	8.08	7.99	7.82	8.51	8.21
		Organic matter (%)	0.05	0.02	0.03	0.03	0.09	2.24
Murga	0-10cm	Bulk density (g/cm3)	1.18	1.15	1.16	1.17	1.14	1.09
		Moisture (%)	2.59	2.05	1.53	2.59	1.53	2.05
		EC (mMhos/cm)	0.46	0.15	0.32	0.77	1.12	0.62
		pH	7.93	8.17	7.98	7.70	7.89	7.78
		Organic matter (%)	0.13	0.69	0.52	1.38	3.38	2.76
	10-15cm	Moisture (%)	3.09	2.57	1.01	3.09	2.04	2.04
		EC (mMhos/cm)	0.54	0.16	0.65	0.76	1.00	0.62
		pH	7.97	8.09	7.78	7.67	7.65	7.72
		Organic matter (%)	0.05	0.69	0.03	1.31	2.45	2.48
	15-30cm	Moisture (%)	2.04	1.01	2.57	2.04	3.09	4.17
		EC (mMhos/cm)	0.59	0.15	0.67	0.50	0.59	0.46
		pH	8.05	8.26	7.87	8.04	7.65	7.57
		Organic matter (%)	0.03	0.05	0.02	1.10	2.26	0.98

4.3 Socio-economic survey

4.3.1 Socio-economic characteristics of local communities

The traditional population in the study area consists of the indigenous Afars and the settled Tigrai tribes Based on the interview carried out with the indigenous Afars and settled Tigrians (30 from each), agropastoral production system is the predominant land use in the study area Three components of this production system - crops, livestock and trees - contribute in a major way to household food security and income

The Tigrians, who number about 3,462 in total (CSA 1996), are Tigrigna speaking people The survey indicated that 55% of Tigrians are agropastoralists and 45% are involved in crop production only Their primary income is derived from crop production, accounting for 88 15% The rest comes from livestock keeping and off-farm income In short, they are mainly practising flood recession agriculture along the Shugala, Abala and Murga flood plains A few people practice irrigation during the dry season using the Abala river. Ninety per cent of the Afars, who number about 12,536 in the study area (CSA 1996), are agropastoralists, practising both livestock keeping and cultivation The rest are pastoralists. Income from their primary activity, i e livestock production, was found to be 64 75%

4.3.2 Reasons for settlement and cultivation in Abala

According to the responses obtained from the Afars, Afar pastoralists inhabited the study area before the 1960s They reported that Ras Mengesha Seyoum started cultivation in the early 1960s after the construction of a dry weather road to the area Since then, permanent settlement and individual farming have taken place especially by Tigrians and they have expanded after the land proclamation of 1975, which made the local people to own private cultivable land

This study considered the reasons for settlement of Tigrians and the process of sedentarization of Afars The Tigrians were originally cultivators, while the Afars were of pastoral descendants The settlers were asked how long and why they have been settled in the study area as shown in Table 4 6 The table shows that the majority (45%) settled 21-30 years ago and only 25% of them have been there for more than 31 years The rest (30%) were settled 11-20 years ago The reasons as to why they settled in the area ranged from being as labourers for road construction and charcoal making (25%), Ras Mengesha farm workers (30%), drought problem (10%), and need for cultivable land (45%) due to shortage of land in their previous place

Table 4.6 Percentage of settled households by duration and reasons of settlement in Abala

Duration of settlement	Settled households (%)
0-10	-
11-20	30
21-30	45
31-40	25
Reason for settlement[a]	
Need for agricultural land due to high population pressure in former place	45
Drought problem	10
Labourer for Mengesha	30
Labourer for road construction and charcoal making	25

[a] The total was over 100% because some pastoralists gave more than one reason.

The Afars, on the other hand, started involving themselves in agriculture 15-20 years ago The driving forces towards sedentarization for the Afars were mentioned as loss of grazing and subsequent reduction of livestock production (35%), loss of livestock following severe droughts (30%), land proclamation in 1975 (20%), seeing others getting better income with minimised risk (10%), and earning additional income by renting land (10%)

Increased settlement and subsequent cultivation in semi-arid lands are evident elsewhere in Ethiopia Ali (1995) reported that the Oromo highlanders settled in western Afar semi-arid lands pushed the Afars from their dry season grazing areas The result in this study, however, revealed that settlement did not result in pushing the indigenous people to the more dry areas, but forced them to sedentarize and changes their life style Pastoralists often start cultivation not because they want to do so, but because only the rights of cultivators to land are recognised by the government and protected by law (Sandford 1983) Many research results in dryland Africa have indicated that expansion of settlements and dryland agriculture have resulted in the transformation of the pastoral way of life into agropastoral or sedentary agriculture Such occurrences have been reported in Ethiopia, Sudan, Kenya, Niger, Mali and other countries of the Sahel (e g Helland 1980, ILCA 1981, Sandford 1983, G/Mariam 1991, Keya 1991, Kariuki, 1996)

4.3.3 Aspects of crop production

The socio-economic survey revealed that the livelihood of the people in the study area is predominantly based on agropastoral production whereby both livestock and crop production are practised Crop production is mainly based on floods coming from the highlands of Tigrai through the Abala, Shugala, Murga and Liena rivers Sorghum is the major crop cultivated in the alluvial flood plains Other cultivated crops include maize, teff, barley, chickpea and vetch

Both groups of people own on average 2.8 ha of land per household for crop production However, only a few Afars are involved in farming the majority rent their land to the Tigrai family in return for an equal share of harvest This relationship has helped the two groups of people to coexist peacefully, benefiting each other for at least three decades Simonsen (1996) also reported that the relationship between the two groups of people in the study area is an important part of the mechanism used to cope with the harsh environment Such land use practices are widely practised else where in Africa, especially in the transition zones where rainfall is insufficient for rain-fed agriculture

Asked to list as the major constraints to crop production, people listed shortage of flood due to drought, shortage of land, flood diversion works, and formation of big gullies and erosion as the major constraints to crop production in the area People spent more than three months to construct diversion spurs using available trees and shrubs before the coming of floods every year (Plates 4.3 and 4 4). Currently, the formation of big gullies and scarcity of trees and shrubs are rated by the people as critical problems in diverting floods to the cropping fields As a result, many cropping fields have been abandoned Elders from both groups reported that cropping land would soon be a critical problem with the current demand for cultivated land and increased abandonment of the cultivated fields

Plate 4.3 Traditional practices of flood diversion work across Abala river before the coming of long rains (photo by Dr. Nashon K.R. Musimba, 1997)

Plate 4.4 Diversion structure built across Shugala river by DHP (photo by Dr. Nashon K.R. Musimba, 1997)

4.3.4 Aspects of livestock production and feed resources

Estimates of livestock holdings were made through interviews with both the Afar and Tigrai households (Table 4.7). The settled Tigrai keep on average 7 cattle, 6 sheep, 10 goats and 2 donkeys. They favour cattle more than other animal species since cattle are used for draught purposes besides milk. They rear sheep and goats mainly for the market. Donkeys are used for transporting crops, fetching water and collecting firewood. The Afar households keep 13 cattle, 17 sheep, 53 goats, 9 camels and 1 donkey on average (Table 4.7). They raise, in order of importance, goats, cattle, camels, sheep and donkeys. They favour mainly goats and camels because (i) camels and goats milk is their favourite diet, (ii) in a situation where grass cover is scarce, these two species can survive better by browsing the available trees and shrubs, and (iii) they can resist drought more than others. The Afars keep more goats than even camels. In addition to the above mentioned reasons, goats have an advantage to the family by giving two births a year (mostly twins) for market purpose, and that they can also easily browse in steep hills where camels and cattle cannot. The Afar sell or slaughter a day or week-old male kid and lamb (traditionally called *bekel*). The reasons mentioned by Afars were mainly to avoid competition for feed when it is scarce, and milk with humans. Male kids or lambs are allowed to grow if they are needed for breeding only. This system is widely practised by Afars throughout the region as a means of avoiding competition for feed during dry season and milk for human consumption (G/Mariam 1991).

Table 4.7 Average livestock holdings in 1997 and 20 years before (1977) by each household for the Afar and Tigrai

Livestock type	Afar (I)		Tigrai (II)	
	20 years before	1997	20 years before	1997
Cattle	38	13	14	7
Sheep	37	17	9	6
Goats	125	53	22	10
Camel	27	9	-	-
Donkey	1	1	1	2

Both groups of people indicated that livestock holding is declining due to shortage of grazing land, drought, animal disease, and insecurity. Goat husbandry is a major effort today due to a decrease in the amount of grass cover and increase in the woody species composition in the hills and ridges. Camel husbandry, however, is on the decline due to the camel's inability to browse in steep hills. The Afar respondents reported that the cultivation of flooded plains have resulted in a decrease of mainly cattle, sheep and camels.

According to the response of both groups of people, communal grazing lands in the hills and ridges form the major feed source for livestock followed by crop residues. During the rainy season, animals graze or browse in areas such as ridges, hills, uncultivated fields and home compounds. At the beginning of the dry season (locally called *gillal*), animals are allowed to graze in cropping fields. When the stubble and feed sources in the area are exhausted before the short rains (end of *gillal*) and during the hottest season (*hagai*), the Afars move to the surrounding extensive rangelands of Kala, Dergha and Bahri. Movement may extend up to Teru (about 150km from Abala) during dry years. The settled Tigrai people, however, reported that they depend mainly on collected crop residues during the dry season. The Tigrians do not usually move except in times of severe drought. They usually collect crop residues of teff and barley. Residues from other crops are fed *in-situ*.

Lopping browse trees is practised, especially by the Afars, during the dry season when grasses/herbaceous cover and crop residues are depleted. Seasons of the year and their description are presented in Table 4.8. In the study area, trees and shrubs are recognised as good sources of feed during the dry season for all types of livestock. According to the respondents, trees and shrubs are particularly important for goats and camels throughout the year. *Acacia mellifera, A. nubica, A. tortilis, Indigofera articulata, Grewia species, Balanites aegyptiaca* and *Salvadora persica* were mentioned as the most common and preferred species by livestock. As observed during the fieldwork, herbaceous cover was very poor in the study area.

Recent settlement and marginal agriculture in the area have considerably increased the pressure on the people's indigenous life-style by reducing flooded grazing areas. As a result, sedentary life is the only choice for the Afars. Moreover, a shortage of grazing land has resulted in overgrazing of the remaining grazing lands and changes in the natural vegetation physiognomy. This result is in agreement with Lamprey and Yussuf (1981), Ayoub (1988), Keya (1991) and Darkoh (1992) who reported that the reduction of dry season grazing land and subsequent overgrazing of marginal areas are caused by flood recession agriculture, irrigation schemes, and overstocking. Although grasses in the plains and hills are depleted, herding is still the main activity among the Afars of Abala. In such a situation, trees and shrubs play a central role in animal husbandry as well as in the material, social and religious culture of the Afars.

Table 4.8 Seasons of the year as described by the Afar and Tigrai

Season	Period	Description
Afar		
1. Karma	July-September	Main rainy season
2. Gillal	October-December	Cool dry season
3. Deda Debaba	January-February	Dry season with some clouds
4. Sugum	April-March	Short rainy season
5. Hagai	May-June	Hottest season
Tigrai		
1. Kremti	July-September	Main rainy season
2. Mekera	October-December	Harvesting time/beginning of dry season
3. Azmara	January-April	Dry season with some rains
4. Dirki	May-June	Hot dry season

4.3.5 Aspects of marketing

The market centre for the study area is Abala where merchants from Mekelle and sellers or consumers from the study area meet. The type of animals sold in the market are mainly old and kids/lambs, mainly males. Butter, mainly from goats, crops and fruits of *Yeluto*, *Zizyphus spina-christi* and *Balanites aegyptiaca* produced in the area are also sold in Abala market.

Market days are very important, especially for the Afars, for information exchange regarding the well-being of their families, animals, and knowledge about the physical environment (Plate 4 5) The system of information exchange (locally called *dagu*), is a very well developed communication system of the Afars *Dagu* is not only limited to local conditions but is also a means of acquiring information about political matters both in the region and at country level This system of knowledge is being practised and transmitted from one generation to the next, and lays the foundation for an adaptive continuity According to Simonsen (1996), the knowledge held by the Afar elders' plays a significant role in their technical management practices

Plate 4.5 Information exchange (*Dagu*) on market days (photo by Diress, 1997)

4.3.6 People's knowledge on woody vegetation use

The woody species of different genera provide a range of products and services in the study area. A list of trees and shrubs with their uses is presented in Appendix 2.1. Based on interviews, people ranked the highest priority uses of trees and shrubs and categorised them into nine major uses (Table 4.9). Among the uses listed, fodder, construction/timber and fuelwood were rated as the best three uses by both groups of people. The Tigrai, however, ranked fodder third. This may be due to the different social backgrounds of the two groups. This means that the Afars who were descendants of pstoralists considered livestock fodder to be the best use of trees and shrubs, whereas the Tigrians who were originally cultivators considered construction as the best use.

Table 4.9 Priority uses of trees and shrubs ranked by type of use

Use	Rank	
	Afar	Tigrai
Fodder for livestock	1	3
Construction	2	1
Fuelwood	3	2
Shade and shelter	4	4
Human food	5	7
Fencing	6	6
Medicine	7	8
Farm implements	8	5
Household utensils	9	9

People in the study area acknowledged the use of trees and shrubs as perennial sources of browse for livestock, particularly for goats and camels (Plates 4.6 and 4.7). Some of the most important browse species listed include *Acacia tortilis, A. nubica, A. mellifera, A. senegal, A. nilotica, A. ethaica, Balanites aegyptiaca, Zizyphus spina-christi, Salvadora persica, Rhus natalensis, Indigofera articulata, Grewia erythrea, G.ferruginea, G.villosa,* and *Cordia gharaf*

Plate 4.6 A camel browsing on *Acacia tortilis* tree (photo by Diress, 1997)

Plate 4.7 A camel browsing on *Salvadora persica* shrub (photo by Diress, 1997)

A. tortilis, Zizyphus spina-christi and *A. nilotica* are usually lopped during the dry season to provide fodder for camels and goats (Plate 4.8). Camels were mentioned as having a wide range of feed habits in addition to the above named woody species. Afar elders reported that species of *Acacia* (especially *A.nubica, A.tortilis* and *A.mellifera*), *Balanites aegyptiaca, Salvadora persica* and *Indigofera articulata* are most preferred by camels. The reasons mentioned by the respondents were availability of these species in the area, high moisture content and salty nature of the plant species.

Species such as *A. nilotica, A. tortilis, Ficus sycomorous, B. aegyptiaca* and *Zizyphus spina-christi* were mentioned by respondents as being used as shelter (Plate 4.9). Some people leave these species uncleared in the cultivated fields and home compounds for their multipurpose use. *Zizyphus spina-christi, Cordia gharaf, C.ovalis, Balanites aegyptiaca, B.rotundifolia, Salvadora persica, Grewia bicolor, G.erythrea, G.ferruginea, G.villosa, Dobera glabra*, and *Yelluito* were mentioned as the most important trees and shrubs in providing food to the people. Fruits of *Zizyphus spina-christi, Yelluito* and *Balanites aegyptiaca* are sometimes sold in Abala market. People boil the fruit of *Dobera glabra* before eating. Fruits and flowers of *Salvadora persica* are mainly used as traditional Afar soup and/or juice.

Plate 4.8 An Afar herder lopping *Zizyphus spina-christi* for his goats (photo by Diress, 1997)

Plate 4.9 ***Zizyphus spina-christi*** **serving as a meeting place in a hot sun (photo by Diress, 1997)**

Although many species are used as firewood or fuelwood, *Acacia etbaica* is the most appreciated firewood. It is the most utilised tree for both charcoal and firewood. As a source of off-farm income, people collect *Acacia etbaica* firewood for sale in Quha and Mekelle towns (Plates 4.10 and 4.11). One donkey load of firewood costs six Ethiopian Birr[1] in Abala. The same load costs 25-30 Birr in Quha and Mekelle towns, which are located 45 and 55 kilometers from the study area. Such an expensive price of firewood seems to aggravate the over-exploitation of woody species for sale in Quha and Mekelle towns.

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[1] 1 US$ = 7 Birr

Plate 4.10 Firewood collected by herders for sale to passing drivers (photo by Diress, 1997)

Plate 4.11 People walking to Quiha town to sell firewood collected in the study area (photo by Diress, 1997)

As shown in Table 4 10, people (mainly Afar elders) reported that trees and shrubs are commonly used as traditional medicines for human and livestock Zeleke (1997) reported that both groups of people have immense knowledge about medicinal plants and the procedures used in the treatment of sick animals with herbal medicine In this study, medicinal uses of 19 plants were recorded from key informants Information from specialised practitioners or herbalists, however, was not retrieved due to the difficulty of meeting such people According to the informants, people rely mainly on traditional medicines since the provision of pharmaceutical medicine is unreliable and expensive The people also believe that some medicinal plants are superior to imported drugs For example, an Afar elder called Sumo Buksa said that the "leaves of *Balanites rotundifolia* is superior to chloroquine for the treatment of malaria with no side effects Seven young leaves are chewed every morning for seven days to treat malaria" They also appreciate the recently introduced poisonous plant, *Nicotiana glauca* (*Adhara*) for treatment of external parasites of sheep and goats

Information on herbal medicine is neverthless scanty in the study area Retrieving information from local herbalists is a big challenge A substantial body of knowledge of medicinal plants has also been lost because most of it has been transmitted orally from generation to generation Abebe and Hagos (1991) reported that ethno-medicinal information that has been built around numerous plants is on the verge of disappearance in Ethiopia The study area is also a case in point where herbalists do not share their knowledge to outsiders Rather they only pass their knowledge to their elder sons orally when they feel that they are too old

The pods and seeds of *Acacia nilotica* and young twigs of *A. etbaica* were mentioned as sources of tanning material *Salvadora persica* is traditionally used as toothbrush, mainly by Afars It is not common to find an Afar without a toothbrush of *Salvadora persica* while herding, going to market or in meeting places *Balanites aegyptiaca* is cherished by the people and used as writing board for Quran teaching The people also believe that this species can protect people from thunder They grow and protect these species in their home compound. Although there are gum producing trees and shrubs such as *Acacia senegal* and *Commiphora* species, people are not adapted to such products

Table 4.10 List of woody species used in traditional medicine in the study area

Species	Parts used	Diseases treated	Form of application
Acacia etbaica	Leaf	Goats and camels eye disease	Extracts or leaf juice
A mellifera	Bark, stem	Stops bleeding, heals wounds of animals and humans	Burned and tied
A nilotica	Bark	Remove after birth for cows	Extracts inserted into uterus
A nubica	Leaf, root, bark	Head ache, common cold, cough and wound	Extracts taken, smelled
A senegal	Leaf	Eye disease	Extracts
A.tortilis	Root	Stomach and tooth ache	Extracts smoked
Balanites aegyptiaca	Root, bark	Malaria and wound	Root extracts taken for malaria and barks tied for wound
B rotundifolia	Root, leaf	Head ache and malaria	Extracts, leaves are chewed
Boscia coriaceae	Root, leaf	Common cold and cough	Extracts
Dobera glabra	Seed	Malaria	Boiled and extracts taken
Calotropis procera	Leaf/latex	Snake bite, cancer, anthrax	Latex applied or burned and tied
Cadaba rotundifolia	Leaf	Internal parasite	Extracts given
Capparis tomentosa	Fruit	Cold and stomach pains	Extracts given
Grewia erythrea	Root	Wound	Extracts
G.vilosa	Root	Wound	Extracts
Nicotiana glauca	Leaf/twig	External parasites of animals	Washed with water
Solanum incanum	Seed, root	Cough and common cold	Extracts smelled or taken
Ziziphus spina-christi	Leaf	External parasite	Washed with extracts
**Hayokito*	Leaf	Heart problem	Extracts taken

Species not identified by its scientific name.

In general, people listed preferred species for each use as fodder (25 species), house building (12 species), fuelwood (10 species), shade and shelter (8 species), food for people (13 species), fence (9 species), medicines for people and livestock (19 species), farm implements (8 species), household utensils (5 species), tanning (2 species), fumigation (3 species), and spiritual purposes (3 species) (Appendix 2.6). Both groups of people listed preferred species for each use in the same way except for a few species. For example, *Grewia bicolor* (locally known as *Dewaito*) is the most preferred species for Afar mat house construction (Plate 4.12), while *Acacia nilotica* (locally known as *Gessalto*) and *A. etbaica* (locally known as *Seraw*) are mostly used to construct the Tigrai mud house (Plate 4.13). The result revealed that indigenous trees and shrubs have a variety of uses as reported elsewhere in the ASALs of Africa. A number of plants with information on their uses in some parts of Africa can be found in Hiene *et al.* (1988), Morgan (1981), Wilding (1984), Woodward (1989), Rocheleau *et al.* (1988), and Le Houeru (1980).

Although this study revealed that the area has indigenous plants of economic value, it is perceived by the people and the researcher that the abundance of most important trees and shrubs is declining and some are on the verge of extinction (e.g. *Zizyphus spina-christi, Balanites aegyptiaca, B. rotundifolia, Cordia gharaf, A. nilotica* and *Yellutto*). This is mainly attributed to clearing of vegetation for cultivation, and cutting of trees for home construction, firewood and charcoal making.

Plate 4.12 Movable mat house (*Cydon*) of Afars (photo by Diress, 1997)

Plate 4.13 Permanent mud house of Tigrains (photo by Dr. Nashon K.R. Musimba. 1997)

4.3.7 Local community's perceptions about vegetation change and environmental degradation

Based on information from the selected households and discussions with local elders, land use changes in the area since early 1960s have resulted in a reduction of natural vegetation cover and subsequent environmental degradation. Clearing land for cultivation, settlements, road construction, firewood collection and charcoal making for sale, and felling trees and shrubs for flood diversion works were indicated as the most detrimental factors for the reduction of important woody species in the study area.

The above mentioned reasons coupled with recurrent drought, overgrazing, and erosion may have also contributed to the disappearance of palatable herbaceous cover both in flood plains, ridges and hills. As already mentioned in section 4.1, grasslands are either replaced by cultivated fields and settlements or turned into bushlands and wooded bushlands Although no evidence was found on the extinction of plant species in the area, people regret the reduction of important woody species and palatable perennial grasses Although all important woody and grass species were said to be declining (e.g. *A. nilotica, A. tortilis, A. senegal, Zizyphus spina-christi, Balanites aegyptiaca, B. rotundifolia, Cordia gharaf, C. ovalis,* and *Yellutto*), *Cenchrus* species and *Cynodon* species were mentioned as the most affected On the other hand, *Tarchonanthus camphoratus, Aloe* and *Euphorbia* species were increasing and were seen and rated by the people as the most unwanted species which replaced the most palatable herbaceous species for livestock feed The declining vegetation cover is also said to have contributed to the disappearance of wildlife in the area Further, many wild animals (including elephant, cheetah, gazel and lion) that were available in the area in the early 1960s have disappeared Currently monkeys and foxes are the most common.

According to the people's perceptions, the outcomes of recent settlements and cultivation in the area include declining vegetation cover (especially important woody and perennial grass species), formation of big gullies and abandonment of cropping fields, declining of water availability, and reduction of wildlife and species diversity The Afar elders are aware that their traditional way of life is changing in several respects. The cumulative effects of cultivation, erosion, and bush encroachment have reduced access to grazing lands and subsequent pressure on the ecosystem has resulted in a declining trend in all natural resources

People also suggested that the next few decades may witness the destruction of the existing vegetation resources as a result of increased demand for cultivable land Dasman (1973) reported that, an ecosystem, no matter how resilient, can be degraded to a 'point where recovery' becomes impossible in a short period of time There is a need therefore to use trees and shrubs of all kinds to assist in the rehabilitation of gullied and degraded areas As reported by Huxley (1981), the use of trees and shrubs is now seen as a key way of assisting in the rehabilitation of degraded areas although woody perennials have often been viewed, in the past, as being detrimental in grasslands

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

The aim of this study was to investigate changes that have occurred in vegetation resources in relation to changes in land use with an emphasis on the woody component This study has utilised a combination of findings (i) the interpretation of aerial photographs taken at two points in time i.e 1964 and 1994, (ii) a field study and analysis of the vegetation, and (iii) a questionnaire survey to gain insight into the local people's understanding of changes in their natural resource base This combination tends to have less degree of bias associated with the findings, as opposed to findings of pure ecological or socio-economic studies Thus, a combination of the two furnishes adequate information of the natural vegetation, people's life-style and their environment

Results of aerial photograph analyses indicate that notable changes in land use (especially settlement and cultivation) and vegetation cover types have occurred in the study area between 1964 and 1994 The progressive expansion of settlement and cultivation in flood plains at the expense of grazing land resulted into a contraction of natural vegetation for livestock production The field vegetation study results showed that there was still a relatively good woody vegetation cover in the uncultivated plains and hills/ridges However, herbaceous cover was very poor and the under-storey vegetation was mainly dominated by species of *Euphorbia* and *Aloe* Goat husbandry is now a major effort due to the decrease in herbaceous cover and increase in the woody species in the hills and ridges Camel husbandry, however, is on the decline due to their inability to browse on steep hills The cultivation of wooded bushland in flood plain areas and overgrazing of the hills and ridges resulted in a decrease of livestock species of cattle, sheep and camels

The three selected study sites within the overall study area showed similar woody vegetation cover, density and diversity In all the three sites, these variables have decreased over the 30-year period between 1964 and 1994 This suggests that recent land use changes in the study area has affected the vegetation over a wider area. In addition to the existing poor herbaceous cover in the uncultivated areas, loss of preferred woody species (for humans and livestock) such as *Zizyphus spina-christi*, *A. tortilis*, *A. nilotica*, and *Balanites aegyptiaca* due to clearance to make room for cultivation in the flood plains was noticed. In general, the study showed that woody species provided most of the perennial cover for site protection, livestock fodder and other services to humans. However, removal of woody species for crop production, firewood and charcoal harvesting, affected the resource to a great extent. Increase in *Tarchonanthus camphoratus* and other unpalatable species for cattle in some sites may have resulted from the disappearance of herbaceous and important woody species.

From the socio-economic survey, it was possible to retrieve information on characteristics of the two groups of people, woody vegetation use and perceptions of environmental degradation. The agropastoral form of production is the most predominant land use activity of the two groups of peoples (the indigenous Afars and settled Tigrians). The introduction of flood recession cultivation in the dry season grazing areas since the 1960s disrupted former pastoral production systems. Three major events have accelerated the process of settlement of the Tigrians and subsequent sedentarisation of the Afars. These include introduction of commercial crop production by clearing the flood plains by Ras Mengesha Seyuom, commercial charcoal making by Hailu Guangul, and high population pressure in the Tigrai highlands. The majorities have been settled in the study area for periods ranging from 20-30 years. The driving forces towards sedentarisation of pastoralists included, among others, (i) the loss of dry season grazing lands (i.e. key pastoral production areas) due to expanding cultivation, (ii) loss of livestock due to drought, and (iii) motivation by the land proclamation of 1975 which recognised the rights of cultivators to land and protected them by law.

People (especially Afars) were aware that the advancement of settlement and cultivation into marginal lands (i.e. dry season grazing lands) which are mainly suited to livestock production hampered the pastoral form of life-style and thus forced herders to involve in agriculture. They acknowledged trees and shrubs as providing a range of products and services such as fodder (*Acacia spp., Grewia spp., Salvadora persica, B. aegyptiaca*), building (*Acacia nilotica, A. tortilis, A. etbaica, Cordia spp. Grewia bicolor*), firewood (*A. etbaica, A. tortilis*), shade (*A. tortilis, A. nilotica, B. aegyptiaca, Zizyphus spina-christi, Ficus sycomorus*), human food (*Zizyphus spina-christi, B. aegyptiaca, Grewia spp., Cordia spp.*), medicine (*Acacia spp., Balanites rotundifolia, Calotropis procera, Grewia* spp.), and household utensils (*Commiphora spp*. *B. aegyptiaca*) Woody species, of which the above are but examples, play a vital role in the daily life of the communities They can be managed on a sustained basis through traditional practices, which have been developed over the ages in many arid and semi-arid areas

As evidenced above, the study area faced land use changes over the last 30 years. Large portions of the plain areas have been severely degraded in terms of vegetation resources as a result of clearance for cultivation and overgrazing which failed to take into consideration the vulnerability of the ecosystem Soil erosion has been made worse due to vegetation removal in the study area In sum, declining vegetation cover, formation of big gullies, abandonment of cropping fields, declining water availability, reduction of wildlife, and species diversity are the outcomes of recent settlements, expanding cultivation and recurrent drought in the area

Currently, both the Tigrians and the indigenous Afars favour flood recession cultivation for their livelihood since they recognise that the uncultivated rangeland is not able to sustain livestock production However, the question is, for how long can the flood plain sustain continuous cropping? Land use changes such as more flood recession and irrigated agriculture will continue to occur in Abala, and will therefore influence change in the range resource to a great extent Consequently, there is a likelihood of negative impacts on existing biodiversity This will negatively affect pastoral strategies involving mobility, especially if all the flood plain grazing lands disappear For example, the long term survival of pastoral production will be questionable considering the increasing human population, which will seek ways to increase food production either through flood or irrigation agriculture

Grazing lands that have not yet been cultivated still have the potential to be managed on a sustainable basis In this context, the concept of multiple land use can be applied with proper resource planning and management The area is poor in herbaceous cover and therefore the browse resource plays a key role in livestock feed supply (especially in the dry season) and other services Therefore, reliable information on browse value is essential To this end, the participation of local people is crucial

On the basis of the foregoing findings, it is recommended that future research and development should focus on the following

- Since very little of the plain area is capable of supporting flood recession or irrigated agriculture, increased demand for land for cultivation can not be fulfilled unless conservation measures (i.e soil and water) are taken on the eroded and abandoned sites Use of trees and shrubs is a key for assisting in the rehabilitation of gullied areas and abandoned cropping fields Research should also focus on the effect of soil on vegetation distribution or vice versa

- Management and future research should look for ways to insure protection and regeneration of preferred multi-purpose trees and shrubs such as *Acacia tortilis, A. nilotica, A. senegal, Balanites aegyptiaca, B. rotundifolia, Zizyphus spina-christi, Cordia* and *Grewia* species. To this end, the use of indigenous technical knowledge of the communities is crucial in the protection and rational use of woody species

- Long-term vegetation monitoring studies are needed to detect vegetation cover and composition changes by use of aerial photographs, sattelite images and ground survey involving area closure

- To sustain livestock production in tha area the existing grazing sites should be protected from encroaching cultivation Establishment of grazing reserve areas in some key sites is also needed to alleviate the shortage of dry season grazing

- Evaluations of the nutritive value of browse species and crop residues as dry season livestock feeds are also important areas for future research Moreover, research should focus on the determination of woody and herbaceous biomass and selective clearing of unwanted species so as to increase herbaceous cover for livestock feed

The study had the following limitations

- Emphasis was placed on the relatively stable woody component of the vegetation Time did not permit an evaluation of the highly variable herbaceous vegetation
- There was no protected area to assess how much the natural vegetation has been changed in reference to the selected three study sites
- Due to time and resource constraints, there was no focus on vegetation and soil relationships except describing some physical and chemical characteristics of soil such as texture, bulk density, moisture content, organic matter, pH and EC

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APPENDICES

Appendix 1 Questionnaire

Date.................. Enumerator/Recorder..........

Location ....

Name of Respondent .... Age ....Sex ......

Tribe...................Clan/group ....

1.1 Household information

1 Household group ....

2 Family size (how many members in your household reside here?)

3 Where were you (or your parents) originally from ? 1 Outside this area 2 This area

4. If you or your parents were not originally from this place, how long have you or your parents been in this place?.........years, and why you moved to this place? ....

5 What is your occupation? 1 Pastoralist 2 Agropastoralist 3 crop production only 4. Others

1.2 Land use practices

6 How much land area you occupy (if not pastoralist)?..ha

7. How do you use the land you have ? 1 Cultivation ......ha 2. Grazing reserve... ha 3 Others (specify) ....

8 Which one is your primary activity (if agropastoralist)? 1 Agriculture 2. Herding

9 Indicate the percentage of your income from your primary activity ....%.

10 Are you practising agriculture throughout your life? 1 Yes 2 No

11 (If no) how long have you been practising agriculture? ....years and what was your major occupation before?..

12 What are the main reasons to start agriculture (if you were descendants of pastoral groups)?.........

13 What are the principal crops you grow?..

14 Which are the means to grow your crops? 1 Rainfed 2. Irrigated 3 Flood recession

15 Which one of the above is more reliable?..

16 What are the major constraints for crop production? 1 Rainfall failure 2 Shortage of water for irrigation 3 Soil fertility 4 Soil erosion 5 Shortage of land 6 Others (specify) ....

17 What are the strategies you employ to avoid crop failure?..

1.3 Livestock Production system

18 How many of each of the following do you have (if agropastoralist or pastoralist)?

Livestock kept	Now	Before 20 years
Cattle	....	....
Sheep	....	....
Goats	....	....
Camels	....	....
Equines	________	________

19 Are the numbers of your animals decreasing? 1 Yes 2 No

20 (If yes) what are the reasons ?..

21 Which animals do you keep more?..

22. What are the reasons?..

23 What are the sources of feed to your animals ? 1. Communal grazing lands 2. Private grazing reserves 3 Crop residues 4 Others (specify) ....

24 Which feed sources are reliable during the dry season ? 1. Grasses/forbs 2 crop residues 3 Trees and shrubs 4 Others (specify)..

25 Do you aside dry season grazing reserves ? 1 Yes 2 No

26 What are the strategies to alleviate food shortages and/ or ways of risk spreading during bad years or season? 1. Mobility 2 Lopping browse trees 3 Selling animals 4 Species diversification 5. Species dispersion 6. Social alliance 7 Others (specify) ....

27 Can you move freely (if you move)? 1 Yes 2. No

28 (If no) what are the reasons?..

29 When you move your animals how much distance you travel usually ? ...... Km or .... days

30 What are the major constraints of animal production in your community? 1 Shortage of grazing land 2 Animal disease 3. Unreliable market 4 Insecurity 5 Drought 6 Others (specify)..............................

31 Which management practices are you using to improve rangeland productivity ? ....

32 What other parallel activities (alternative economic activity) you involve other than agriculture and livestock keeping ?..

1.4 Uses and exploitation of woody vegetation

33 What are the highest-priority uses of trees and shrubs (rank)?..

34 What are the most popular (preferred or important) species for each use mentioned above? ....

35. Are there woody species which are extinct or declining from time to time in your community?Yes/No

36 (If yes) list them ....

37 Which woody species are encroaching the rangelands? ....

38 Do you think woody species are deteriorating? 1 Yes 2. No

39 (If Yes) which activities do you think the most detrimental to the most important woody species?

1 Human activities 2. Livestock 3. Natural hazards 4 Others (specify)..............

40 List human activities ....

41 What are the plant species used as medicine for livestock and human being in your community? ......

42. Are there people in your community who depend on charcoal making for their livelihood?Yes/ No

43 What are the most important woody species which provide edible fruits for man during bad years. and pods and leaves for animals in dry seasons and during drought years?.............................

44 Do you protect trees? 1 Yes 2. No

45 (If yes) list the species and give reasons for protection? ....

46. Are there woody species that are introduced in your community? ....

1.5 People's perception of environmental degradation

47 When the eldest members of the group were young, or when they first settled there what was the area look like? choose (1) if you agree and (2) if you don't 1 Land was fertile and plenty 2 Water was available 3 No soil erosion 4 Vegetation was dense 5 Land use was communal grazing 6 Others.....

48 What major changes in land-use have taken place? ....

49 What are the major changes in the condition of natural resources?...

50 What measures have taken to stop degradation of natural resources?.......................................

51 Agree (1) or disagree(2) on the following statements 1 Woody species are not deteriorating 2 There is too much destruction of the natural resources of our community 3. Large scale environmental problems such as deforestation and desertification are caused by the society rather than by natural causes 4. If we continue to put pressure on our environment, we will be unable to sustain our present state of natural resource use

52 What do you recommend to stop environmental degradation?

Appendix 2 Vegetation attributes

Appendix 2.1 List of indigenous plant species recorded during the study period in Abala

Botanical Name	Local name		Family	Life form
	Afarigna	Tigrigna		
Acacia etbaica	Sekakto	Seraw	Leguminosae	Tree(T)
A. mellifera	Merkito	Teklbe	Leguminosae	T
A. nilotica	Gessalto	Kassal	Leguminosae	T
A. nubica	Germoita	Adjo	Leguminosae	Shrub(S)
A. senegal	Tekeble	Teklbe	Leguminosae	T
A. tortilis	Aepto	Gumero	Leguminosae	T
Balanites aegyptiaca	Oodaito	Bedano	Balanitaceae	T
B. rotundifolia	Alaito	Bedano	Balanitaceae	T
Boscia coriaceae	Denenoita		Capparidaceae	S
Cadaba rotundifolia	Alengalita		Leguminosae	S
Cadia purpurea	Silien	Silien	Leguminosae	S
Calotropis procera	Gelato		Asclepiadaceae	S
Capparis tomentosa	Andalito	Andel	Capparidaceae	S
Combretum molle	Dokhoita	Sesem	Combretaceae	T
Commiphora spp	Adoladi	Anqa	Boragnaceae	S
Commiphora Spp	Kurbita	Anqa	Boragnaceae	S
Commiphora spp.	Teranita	Anqa	Boragnaceae	T
Cordia gharaf	Maderto	Madera	Boragnaceae	T
C. ovalis	Leimaderto	Madera	Boragnaceae	S
Delonix elata	Amaito		Caesalpinioideae	T
Dobera glabra	Gersaito	Gersa	Salvadoraceae	T
Dodonea angustifolia	Sasat	Tahses	Sapindaceae	S
Ficus cycomorus	Sublaito	Shagla	Moraceae	T
Grewia bicolor	Dewaito		Tiliaceae	S
G. erythrea	Hidaito	Artatmoi	Tiliaceae	S
G. ferruginea	Ditita	Dintu	Tiliaceae	S
G. tenax	Hidaito	Artatimoi	Tiliaceae	S
G. villosa	Hivellita	Hibele	Tiliaceae	S
Indigofera articulata	Galela		Leguminosae	S
Lycium shawii	Hidalisaito	Berale	Solanaceae	S
Maerua angolensis	Hidaltifera		Capparidaceae	S
Niconana glauca	Adihara	Cherged	Solanaceae	S
Rhus natalensis	Atemeta	Ateme	Anacardiaceae	S
Salvadora persica	Adaito	Adaimamo	Salvadoraceae	S
Solanum incanum	Kosina	Ingule	Solanaceae	S
Ziziphus spina-christi	Kusraito	Kunslura	Rhamnaceae	T

Appendix 2.1 (Cont.)

Botanical Name	Local name		Family	Life form
	Afarigna	Tigrigna		
* *Yucca*	Asenaito		Agavaceae	T
*	Sinklilsie	Tetemagajen		T
*	hurufili	Tetemenshu		S
*	Numhila			S
*	Hayokaito			Climber(C)
*	Katoita			T
*	Yeluito	Yalo		T
Aerva javanica	Oilaito		Amaranthaceae	Forb(F)
Abutilon anglosomaleae	Hambokto		Malvaceae	F
Aloe spp	lure		Liliaceae	F
Euphorbia spp	Tarto		Euphorbiaceae	F
Cynodon spp			Giramunea	Grass(G)
Cenhrus spp			Giraminea	G

** Species not identified by their botanical names*

Appendix 2.2 Botanical composition (BC), crown cover (CC), and density (D) of woody species in site I

Species	BC (%)	CC (%)	D (N/ha)
Acacia etbaica	22.89	51.19	158.33
A. mellifera	18.07	3.32	125.00
A. nubica	7.23	3.13	50.00
A. senegal	3.61	1.96	25.00
A. tortilis	6.63	10.61	45.83
Balanites aegyptiaca	2.41	1.34	16.67
Cadia purpurea	2.41	0.90	16.67
Cordia gharaf	2.41	0.29	16.67
C. ovalis	1.81	0.26	12.50
Grewia erythrea	7.83	0.18	54.17
G. ferruginea	4.22	0.12	29.17
G. villosa	1.20	0.03	8.33
Lycium shawii	9.64	0.36	66.67
Rhus natalensis	2.41	0.44	16.67
Salvadora persica	1.81	4.47	12.50
Adohadi(Commip.)	0.60	0.02	4.17
Kurbita(Commip.)	0.60	0.30	4.17
Sinklilsie	2.41	0.37	16.67
Aseraito (Yoka)	1.81	0.11	12.50
Total	**100.00**	**79.40**	**691.67**

Total No. of species = 19

Species Diversity Index (H') = 1.08

Appendix 2.3 Botanical composition (BC), crown cover (CC), and density (D) of woody species in site II

Species	BC (%)	CC (%)	D (N/ha)
Abutilon anglosomaleae	0.85	0.01	4.17
Acacia etbaica	28.21	32.71	137.50
A. mellifera	11.11	3.83	54.17
A. nilotica	1.71	8.42	8.33
A. nubica	10.26	11.37	50.00
A. senegal	0.85	0.67	4.17
A. tortilis	6.84	10.80	33.33
Cadaba rotundifolia	1.71	0.09	8.33
Cordia gharaf	1.71	0.29	8.33
C. ovalis	1.71	0.47	8.33
Dodonea angustifolia	0.85	0.88	4.17
Grewia erythrea	10.26	0.19	50.00
G. ferruginea	2.56	0.04	12.50
G. villosa	3.42	0.02	16.67
Indigofera articulata	5.98	0.14	29.17
Salvadora persica	3.42	5.83	16.67
Solanum incanum	1.71	0.31	8.33
Zizyphus spina-christi	0.85	0.04	4.17
Adohadi(Commip.)	1.71	0.55	8.33
Kurbita(Commip.)	1.71	0.80	8.33
Numhila	1.71	0.90	8.33
Hurufili	0.85	0.00	4.17
Total	100.00	78.36	487.50

Total No. of species = 22

Species Diversity Index (H') = 1.09

Appendix 2.4 Botanical composition (BC), crown cover (CC), and density (D) of woody species in site III

Species	BC (%)	CC (%)	D (N/ha)
Acacia ethaica	33.09	47.76	191.67
A. mellifera	7.19	3.27	41.67
A. nubica	5.76	1.47	33.33
A. senegal	2.16	0.69	12.50
A. tortilis	1.44	8.04	8.33
Balanites aegyptiaca	3.60	2.00	20.83
Cadia purpurea	4.32	1.47	25.00
Cordia gharaf	2.16	0.18	12.50
C. ovalis	5.04	0.61	29.17
Dodonea angustifolia	0.72	1.44	4.17
Grewia bicolor	0.72	0.03	4.17
G. erythrea	9.35	0.11	54.17
G. ferruginea	2.16	0.44	12.50
Indigofera articulata	0.72	0.00	4.17
Rhus natalensis	3.60	0.48	20.83
Salvadora persica	2.16	5.02	12.50
Solanum incanum	0.72	0.00	4.17
Tarchonanthus camphoratus	5.76	2.58	33.33
Adohadi(Commip.)	3.60	0.28	20.83
Sinkilsie	2.16	0.31	12.50
hurufili	3.60	0.08	20.83
Total	**100.00**	**76.26**	**579.17**

Total No. of species = 21

Species Diversity Index (H') = 1.09

Appendix 2.5 Mean relative density(RD), frequency(RF), cover(RC) and importance value index (IVI) of woody species listed in order of IVI for the study sites

Species	RD (%)	RF (%)	RC (%)	IVI (%)
Site I (Abala):-				
Acacia etbaica[ab]	25.66	17.55	62.27	105.48
A.mellifera[ab]	15.08	9.56	5.17	29.81
A tortilis[ab]	5.85	6.17	12.21	24.23
A nubica[ab]	6.17	7.71	7.41	21.29
Grewia erythrea[ab]	8.41	9.81	0.31	18.52
Lycium shawii	8.56	5.92	0.85	15.33
Acacia senegal[b]	4.08	5.77	2.13	11.98
Grewia ferruginea[a]	4.42	5.70	0.17	10.29
Salvadora persica[ab]	1.82	3.54	4.93	10.29
Balanites aegyptiaca	2.61	4.52	1.56	8.69
Sinkilisie	2.67	3.99	0.38	7.04
Cordia gharaf[b]	2.62	3.80	0.41	6.83
Rhus natalensis	2.57	3.55	0.47	6.59
Cordia ovalis[a]	2.16	4.05	0.31	6.52
Cadia purpurea	2.67	1.96	0.87	5.50
Aseraito	2.01	3.02	0.12	5.15
Grewia villosa	1.41	1.77	0.04	3.22
Adohadi(Commiphora spp.)[a]	0.62	0.82	0.05	1.49
Kurbita(Commiphora spp.)	0.61	0.79	0.04	1.44
Total	**100.00**	**100.00**	**100.00**	**300.00**
Site II (Shugala):-				
Acacia etbaica[ab]	26.87	21.06	43.53	91.46
A.nubica[ab]	10.27	9.46	15.16	34.89
A. mellifera[ab]	11.02	9.62	5.81	26.45
A tortilis[ab]	6.90	6.39	12.03	25.32
Grewia erythrea[ab]	10.35	10.78	0.28	21.41
Salvadora persica[ab]	3.54	5.17	10.67	19.38
Acacia nilotica	3.52	2.22	8.04	13.78
Indigofera articulata	5.81	6.62	0.21	12.64
Grewia villosa	3.61	2.78	0.02	6.41
G.ferruginea[a]	2.61	3.65	0.05	6.31
Kurbita(Commiphora spp.)	1.67	2.78	1.06	5.51
Adohadi(Commiphora spp.)[a]	1.67	2.78	0.80	5.25
Solanum incanum	1.67	2.78	0.49	4.94
Cordia ovalis[a]	1.59	2.50	0.73	4.82

Appendix 2.5 (Cont.)

Species	RD (%)	RF (%)	RC (%)	IVI (%)
Cadaba rotundifolia	1 52	2 22	0 04	3 78
Numhila	1 52	2.09	0.10	3.71
Dodonea angustifolia	0.83	1.39	1.43	3.65
Acacia senegal[a]	0 83	1 39	0.87	3 09
Cordia gharaf[a]	1.55	1.11	0 31	2 97
Zizyphus spina-christi	0.93	1.39	0 05	2.37
Abutilon anglosomalica	0.76	0 98	0 01	1.75
Hurufili	0 76	0.84	0 01	1 61
Total	**100.00**	**100.00**	**100.00**	**300.00**
Site III (Murga):-				
Acacia etbaica[ab]	34 34	26 09	63 46	123 89
Tarchonantus camphoratus	5 45	7 24	4.14	16 83
A.nubica[ab]	6 18	5 09	4 56	15 83
Grewia erythrea[ab]	8 18	6 56	0 21	14 95
A mellifera[ab]	6 33	4 68	3 15	14 16
A.tortilis[ab]	1.75	2 58	8.45	12 78
Salvadora persica[ab]	2 51	3 51	6.71	12.73
Cadia purpurea	4 32	6.07	1.65	12.04
Balanites aegyptiaca	3.76	4 49	2 09	10 34
Balanites aegyptiaca	2 61	4 52	1 56	8 69
Rhus natalensis	3.7	3 53	0.91	8 14
Cordia ovalis[a]	3 54	3.69	0.67	7 90
Adohadi(Commiphora spp.)[a]	3.47	3 92	0 38	7 77
Grewia ferruginea[a]	2 35	3 49	0 84	6 68
Hurufili	3 3	3.15	0.17	6 62
Sinkliliste	2 27	3 35	0 37	5 99
Acacia senegal[a]	2.19	3 09	0.30	5.58
Cordia gharaf[a]	2.77	2 98	0.19	5.94
Dodonea angustifolia	0 62	0 93	0 09	1 64
Grewia bicolor	0 76	0 93	0.09	1 78
Solanum incanum	0 6	1.11	0.01	1.72
Total	**100.00**	**100.00**	**100.00**	**300.00**

[a] = Species common in all the three sites

[b] = species whose IVI > 10% in all the three sites and selected for comparision

Appendix 2.6 Traditional uses of indigenous woody species in a semi-arid area of Abala

Species	Uses
Abutilon anglosomaleae	Live fence
Aereva javanica	Flowers are used for local mattress making
Acacia etbaica	Excellent firewood and charcoal, house construction, fodder, fence, medicine; shade and tanning
A. mellifera	Fodder, firewood, fencing, and medicine
A. nilotica	Shade/shelter, fodder; firewood/charcoal, house construction; fencing, medicine and tanning
A. nubica	Fodder; medicine, fiber and hut frames
A. senegal	Fencing, firewood, farm implements, fodder and medicine
A. tortilis	Shade/shelter, pole for house construction, fodder, medicine, household utensils; farm implements; and ceremonial purposes
Balanites aegyptiaca	Edible fruit, fodder, firewood, shade/shelter, rituals, writing board, medicine, wood for doors, farm implements and household utensils
B. rotundifolia	Edible fruit, shade/shelter, fodder, and medicine
Boscia coriaceae	Fodder, cleaning, fumigation/steam bath for ladies, and medicine
Cadaba rotundifolia	Fodder, firewood, and medicine
Cadia purpurea	Roofing material for local mud house
Calotropis procera	Medicine
Capparis tomentosa	Live fence and medicine
Combretum molle	Shade/shelter, farm implements, wood for house door making.
Commiphora spp	Wood for utensils and house door making, fodder, and fence
Cordia gharaf	Edible fruit, fencing, fodder, house construction, and sticks
C. ovalis	Fencing, edible fruit, and sticks
Delonix elata	Shade
Dobera glabra	Edible fruit; shade/shelter; medicine; household utensils, fodder, and firewood
Dodonea angustifolia	Firewood, fumigation for milk containers, and tool handles
Ficus sycomorus	Edible fruit; shade/shelter, and rituals
Grewia bicolor	Fodder; edible fruit; Afar mat house construction, arrow spears, and walking sticks
G. erythrea	Edible fruit, medicine, and fodder
G. ferruginea	Edible fruit and fodder
G. tenax	Walking sticks; edible fruit, and fodder
G. villosa	Edible fruit, sticks, fodder, and medicine
Indigofera articulata	Fodder
Lycium shawii	Live fence
Maerua angolensis	Live fence
Nicotiana glauca	Medicine
Rhus natalensis	Fodder; edible fruit; firewood, farm implements

Appendix 2.6 (Cont.)

Species	Uses
Salvadora persica	Tooth brush, edible fruit and flowers, and fodder
Solanum incanum	Medicine
Tarchonantus camphoratus	Firewood, fumigation for milk containers, and charcoal making
Zizyphus spina-christi	Edible fruits, fodder, shade/shelter, firewood, tool handles, and medicine
Yucca	Household utensils and fiber
Euphorbia spp.	Medicine
Aloe spp	Edible sap and soil conservation
Hurufili	Roofing
Numhila	Fodder
Havokaito	Fodder and fiber for house construction
Katoita	Shade, fodder, construction
Yeluito	Edible fruit, shade/shelter; and construction
Sinkilisie	Fodder, shade/shelter; and wood for house door making

Appendix 3 Analysis of variance (ANOVA) tables

<u>Note:</u> In all the following ANOVA tables, ns = non significant at (P 0.05), * = significant at (P=0 05) and ** = significant at (P=0 01)

Appendix 3.1 Analysis of variance (ANOVA) table for species botanical composition, cover and density in the three sites

Source of variation	*Sum of squares*	*df*	*Mean Squares*	*F*
Composition (%)				
Site	10.28681	2	5.143406	0.377677^{ns}
Species	1245 856	5	249 1713	18 29647*
Error	136.1855	10	13.61855	
Total	1392 329	17		
Cover (%)				
Site	6 661411	2	3.330706	0 133923^{ns}
Species	3970.576	5	794 1151	31 93017**
Error	248.7037	10	24 87037	
Total	4225 941	17		
Density (N/ha)				
Site	1205 478	2	602 7392	1.14493^{ns}
Species	42053 91	5	8410 783	15.97666**
Error	5264.42	10	526 442	
Total	48523.81	17		

Appendix 3.2 ANOVA table for total crown cover (%) of 6 selected trees and shrubs along a 10km transect in site I, II and III

Source of variation	Sum of Squares	df	Mean Squares	F
Site I				
Distance	312.0769	5	62 41538	0.158241 ^{ns}
Species	11328.99	5	2265 797	5 744467 *
Error	9860 781	25	394 4313	
Total	21501 84	35		
Site II				
Distance	202 9718	5	40 59437	0 12829 ^{ns}
Species	3996.701	5	799.3401	2.526145 ^{ns}
Error	7910.672	25	316 4269	
Total	12110.34	35		
Site III				
Distance	595 9575	5	119 1915	1 277112 ^{ns}
Species	9989 095	5	1997 819	21 40621 **
Error	2333 223	25	93 32893	
Total	12918 28	35		

Appendix 3.3 ANOVA table for density (N/ha) of 6 selected trees and shrubs along a 10km transect within site I, II and III

Source of variation	Sum of Squares	df	Mean Squares	F
Site I				
Distance	33003 47	5	6600 694	0 608788 ^{ns}
Species	91545 14	5	18309 03	1.688657 ^{ns}
Error	271059	25	10842 36	
Total	395607 6	35		
Site II				
Distance	1180 556	5	236 1111	0.048405 ^{ns}
Species	52638 89	5	10527 78	2.158314 ^{ns}
Error	121944 4	25	4877.778	
Total	175763.9	35		
Site III				
Distance	5347 222	5	1069 444	0.208559 ^{ns}
Species	139722 2	5	27944 44	5 449621 *
Error	128194 4	25	5127 778	
Total	273263 9	35		

Appendix 3.4 ANOVA table for diversity index of 6 selected woody species

Source of variation	*Sum of Squares*	*df*	*Mean Squares*	*F*
Site	0.001144	2	0 000572	0 050347^{ns}
Error	0.170483	15	0 011366	
Total	0 171628	35		

Appendix 3.5 ANOVA table for species composition (%) across a 10km transect in site 1

		Acacia etbaica		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	7874 7083	1574.9417	8.3153**
Error	18	3409 2500	4028	
Total	23	11283 9583		

		A.mellifera		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	5706.8333	1141.3667	3 4442*
Error	18	5965 0000	331.3889	
Total	23	11671.8333		

		A.nubica		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	2205.8750	441.1750	2.7614*
Error	18	2875 7500	159.7639	
Total	23	5081.6250		

		A.tortilis		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	2425.2083	485.0417	10.9717**
Error	18	795.7500	44 2083	
Total	23	3220 9583		

		Grewia erythrea		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	979 7083	195 9417	2 0197^{ns}
Error	18	1746 2500	97 0139	
Total	23	2725.9583		

		Salvadora persica		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	161.2083	32.2417	1 6406^{ns}
Error	18	353 7500	19.6528	
Total	23	514.9583		

Appendix 3.6 ANOVA table for species composition (%) across a 10km transect in site II

A.etbaica

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	8668.2083	1733.6417	6.7636**
Error	18	4613.7500	256.3194	
Total	23	13281.9583		

A.mellifera

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	3160.8750	632.1750	3.6745*
Error	18	3096.7500	172.0417	
Total	23	6257.6250		

A.nubica

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	4119.5000	823.9000	6.6310**
Error	18	2236.5000	124.2500	
Total	23	6356.0000		

A.tortilis

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	4651.8750	930.3750	4.7445**
Error	18	3529.7500	196.0972	
Total	23	8181.6250		

G.erythrea

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	1094.7083	218.9417	1.3100^{ns}
Error	18	3008.2500	167.1250	
Total	23	4102.9583		

S.persica

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	505.3333	101.0667	1.0723^{ns}
Error	18	1696.5000	94.2500	
Total	23	2201.8333		

Appendix 3.7 ANOVA table for species composition (%) across a 10km transect in site III

A.etbaica				
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	3723 7083	744 7417	5 3853**
Error	18	2489 2500	138 2917	
Total	23	6212 9583		

A.mellifera				
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	2562 3333	512 4667	10.4172**
Error	18	885 5000	49 1944	
Total	23	3447 8333		

A.nubica				
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	115 2083	23 0417	8026^{ns}
Error	18	516 7500	28.7083	
Total	23	631 9583		

A.tortilis				
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	208.3333	41.6667	8000^{ns}
Error	18	937 5000	52 0833	
Total	23	1145 8333		

G.erythrea				
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	580 2083	116 0417	1 5283^{ns}
Error	18	1366 7500	75.9306	
Total	23	1946 9583		

S.persica				
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	136.8750	27.3750	6033^{ns}
Error	18	816 7500	45 3750	
Total	23	953 6250		

Appendix 3.8 ANOVA table for crown cover of species (%) across a 10km transect in site I

		A ethaica		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	25071 6092	5014 3218	11 3437**
Error	18	7956 6644	442 0369	
Total	23	33028 2736		

		A mellifera		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	91 9179	18 3836	6627^{ns}
Error	18	499 2901	27.7383	
Total	23	591 2080		

		A nubica		
Source	D F	Sum of Squares	Mean Squares	
Distance	5	881 4783	176 2957	5 8384**
Error	18	543 5305	30.1961	
Total	23	1425 0088		

		A tortilis		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	13143 9289	2628 7858	1 0286^{ns}
Error	18	46000 9060	2555 6059	
Total	23	59144		

		G.erythrea		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	4254	0851	1 3087^{ns}
Error	18	1 1702	0650	
Total	23	1.5956		

		S persica		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	1530 6510	306 1302	1 2028^{ns}
Error	18	4581 3889	254 5216	
Total	23	6112 0399		

Appendix 3.9 ANOVA table for cron cover of species (%) across a 10km transect in site II

A.etbaica

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	14309.2674	2861.8535	5.9147**
Error	18	8709.3188	483.8510	
Total	23	23018.5862		

A.mellifera

	D F	Sum of Squares	Mean Squares	F
Distance	5	336.6224	67.3245	1.5582^{ns}
Error	18	777.6997	43.2055	
Total	23	1114.3221		

A.nubica

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	5724.0753	1144.8151	6.5074**
Error	18	3166.6490	175.9249	
Total	23	8890.7243		

A.tortilis

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	10147.8541	2029.5708	5.9078**
Error	18	6183.7523	343.5418	
Total	23	16331.6064		

G.erythrea

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	1.2649	.2530	2.0842^{ns}
Error	18	2.1849	.1214	
Total	23	3.4498		

S.persica

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	1934.9994	386.9999	1.9117^{ns}
Error	18	3643.9203	202.4400	
Total	23	5578.9197		

Appendix 3.10 ANOVA table for crown cover of species (%) across a 10km transect in site III

		A.etbaica		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	6464 3477	1292 8695	2.4249ns
Error	18	9596 9694	533 1650	
Total	23	16061 3172		

		A mellifera		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	853.0797	170 6159	9 2574**
Error	18	331 7439	18 4302	
Total	23	1184 8236		

		A nubica		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	2458	0492	8055[ns]
Error	18	1.0987	0610	
Total	23	1.3446		

		A.tortilis		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	3282.7355	656 5471	8150[ns]
Error	18	14499 9901	805.5550	
Total	23	17782 7256		

		G erythrea		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	.6289	1258	1.3636[ns]
Error	18	1.6603	0922	
Total	23	2 2892		

		S persica		
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	885 7310	177 1462	7129[ns]
Error	18	4472 8268	248 4904	
Total	23	5358 5577		

Appendix 3.11 ANOVA table for density of species (N/ha) across a 10km transect in site I

A. etbaica

Source	D.F.	Sum of Squares	Mean Squares	F
Distance	5	253333.3333	50666.6667	14.0308^{**}
Error	18	65000.0000	3611.1111	
Total	23	318333.3333		

A. mellifera

Source	D.F.	Sum of Squares	Mean Squares	F
Distance	5	700000.0000	140000.0000	3.3826^{*}
Error	18	745000.0000	41388.8889	
Total	23	1445000.000		

A. nubica

Source	D.F.	Sum of Squares	Mean Squares	F
Distance	5	95000.0000	19000.0000	4.0235^{**}
Error	18	85000.0000	4722.2222	
Total	23	180000.0000		

A. tortilis

Source	D.F.	Sum of Squares	Mean Squares	F
Distance	5	103333.3333	20666.6667	3.9158^{**}
Error	18	95000.0000	5277.7778	
Total	23	198333.3333		

G. erythrea

Source	D.F.	Sum of Squares	Mean Squares	F
Distance	5	30000.0000	6000.0000	1.2000^{ns}
Error	18	90000.0000	5000.0000	
Total	23	120000.0000		

S. persica

Source	D.F.	Sum of Squares	Mean Squares	F
Distance	5	8750.0000	1750.0000	1.8000^{ns}
Error	18	17500.0000	972.2222	
Total	23	26250.0000		

Appendix 3.12 ANOVA table for density of species (N/ha) across a 10km transect in site II

A.ethaica				
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	203750.0000	40750.0000	10.1172**
Error	18	72500.0000	4027.7778	
Total	23	276250.0000		

A.mellifera				
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	97083.3333	19416.6667	3.4098*
Error	18	102500.0000	5694.4444	
Total	23	199583.3333		

A.nubica				
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	87083.3333	17416.6667	4.3241**
Error	18	72500.0000	4027.7778	
Total	23	159583.3333		

A.tortilis				
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	58333.3333	11666.6667	3.8182*
Error	18	55000.0000	3055.5556	
Total	23	113333.3333		

G.erythrea				
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	30000.0000	6000.0000	1.2000^{ns}
Error	18	90000.0000	5000.0000	
Total	23	120000.0000		

S.persica				
Source	D F	Sum of Squares	Mean Squares	F
Distance	5	8333.3333	1666.6667	1.2000^{ns}
Error	18	25000.0000	1388.8889	
Total	23	33333.3333		

Appendix 3.13 ANOVA table for density of species (N/ha) across a 10km transect in site III

A.ethaica

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	63333.3333	12666.6667	4.1455**
Error	18	55000.0000	3055.5556	
Total	23	118333.3333		

A.mellifera

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	128333.3333	25666.6667	9.2400**
Error	18	50000.0000	2777.7778	
Total	23	178333.3333		

A.nubica

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	3333.3333	666.6667	8000^{ns}
Error	18	15000.0000	833.3333	
Total	23	18333.3333		

A.tortilis

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	3333.3333	666.6667	8000^{ns}
Error	18	15000.0000	833.3333	
Total	23	18333.3333		

G.erythrea

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	17083.3333	3416.6667	1.4471^{ns}
Error	18	42500.0000	2361.1111	
Total	23	59583.3333		

S.persica

Source	D F	Sum of Squares	Mean Squares	F
Distance	5	3750.0000	750.0000	6000^{ns}
Error	18	22500.0000	1250.0000	
Total	23	26250.0000		