ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Ecological Impacts of Bush Encroachment on Rangeland Ecosystem: The Case of Hallona and Medhacho Pastoralist Associations in Borana Lowlands.

Niguse Bekele Dirbaba

Submitted to Science Faculty, Environmental Science Program in partial fulfilment of the requirement for the MSc degree in Environmental Science.

December, 2008

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Acronyms

AAS: Atomic Absorption Spectrometry

Asl: Above Sea Level

Ava.K: Available Potasium

Ava.P: Available Phosphorus

BA: Basal Area

CEC: Cation Exchange Capacity

DBH: Diameter at Breast Height

DSH: Diameter at Stamp Height

EARI: Ethiopian Agricultural Research Institute

Exch.K: Exchangeable Potasium

GPS: Global Positioning System

IVI: Importance Value Index

LSU: Large Stock Unit

OC: Organic Carbon

OM: Organic Matter

RD: Relative Dominance

RF: Relative Frequency

SORD: Southern Range Development Unit.

SSA: Sub-saharan Africa

TLU: Tropical Livestock Unit

TN: Total Nitrogen

Abstract

The Borana rangeland has been an important area of cattle production in Ethiopia. However recent dominance by woody cover is considered as a threat to range conditions in the area. A multidisciplinary approach was followed to assess impacts of bush encroachment on the biophysical environment and pastoralists' livelihood in the two pastoralist associations and and to document pastoralists' perceptions on bush encroachment. The rangelands were stratified into encroached and non-encroached sites based on visual observation and data on vegetation and soil parameters were collected from both encroached and non encroached sites. Pastoralists' perceptions were collected by informal interview. The data were analyzed using excell speardsheet, PC-ORD, version 4.20 and SPSS (SPSS, 1989 – 96) version 14, computer programs. Higher species diversity and herbaceous cover was observed in non-encroached site. Increase in woody plant density might have limited survival rate and percent cover of some light loving herbaceous species in encroached site. In both encroached and non-encroached lands a total of 94 plant species were identified, which included 26 woody and 68 herbaceous species. The density of woody plant was greater than 2500 tree equivalent in encroached sites showing high threat of bush encroachment.Highly significant difference ($p<0.05$) was observed in organic carbon, organic matter and exchangeable potassium contents between encroached and non-encroached sites. Litter fall and decomposition in encroached site might have contributed to the differences. No clear relationships were observed between woody plant density and soil parameters. According to the pastoralists bush encroachment is one of the major constraints to livestock production and cause of feed shortage. Pastoralists were suggested fire, bush clearing and herd diversification as the major solutions for bush encroachment. It was concluded that alteration of local rangeland habitat by bush encroachment might have caused local lose of some herbaceous species. The value of most soil nutrients was higher in encroached site. Implementation of holistic approach that involves the whole community and experts to control expansion of bush encroachment and improving livestock productivity and marketing system to decrease the contribution of over grazing to bush encroachment was recommend as possible solution.

1. Introduction

1.1. Background and Justification

Rangelands are lands on which the indigenous vegetation is predominantly grasses, grass-like plants, forbs or shrubs and is managed as a natural ecosystem (Society for Range Management, 1991). It consists of native and/ or naturalized species, on which management is usually limited to grazing, burning and control of woody species (Mannetje and Jones, 2000). Purdon and Anderson (1980) indicate that in the developing countries of Africa, rangelands comprise over half the land area and support a large human population dependent on grazing livestock. The majority of rangeland ecosystems are located in vegetation biomes such as grasslands, shrub lands, savannas and deserts (Friedel, 1991), and these areas are often characterized by an inherent arid climate that experience large daily and seasonal temperature extremes (Williams *et al*., 1968; Vetter *et al*., 2006). Rangeland covers about 62% of total land area of Ethiopia (Alemayehu Mengistu, 1998). The rangelands of Ethiopia are estimated to cover area of 78 million hectare (Dawit Abebe, 2000). The rangeland of southern Ethiopia, which accounts for 7.6-12.3% of the country, is an important area of cattle production (Oba *et al.,* 2000). The portion of the southern Ethiopian rangelands referred to as the Borana plateau comprises about 95,000 km^2 over all (Coppock, 1994). The Borana are the dominant pastoralist group, and they have been living in the region before the 13th century (Oba, 1996).

Rangelands are extremely important to society for the goods as well as the ecological services they provide. In China, rangelands form the largest terrestrial ecosystem and one of the three most important food producers (Li, 1997). To pastoralists in the Horn of Africa, livestock serves the purpose of wealth accumulation, social prestige, social security, drought bridging mechanism, for marriage gifts and debt payment (Coppock, 1994). Rangelands also play an important role in sequestering atmospheric carbon especially through the large size of these rangelands (Allen-Diaz, 1996).

Rangeland degradation implies a reduction in rank or status, which includes a loss of topsoil, a change to a simple floral/ fauna composition or a transition from one organic

form to a lower organic form, and continuous reduction of productivity (biomass) of the ecosystem (Barrow, 1991). Overgrazing, bush encroachment and subsequent land degradation is a problem in large areas of the east African (Perkins and Thomas, 1993). The demand in livestock products should double near the year 2020 with the increasing demography in developing countries (Delgado *et al.* 1998). Consequently, increased productivities, environmental preservation and natural resources management are needed.

Increase in woody cover in savanna and grass land ecosystem has been called woody plant profiration, vegetation thickening, bush encroachment, shrub encroachment, woody weed invasion or regrowth and is widespread in arid or semiarid savanna and grasslands in North and South America, Africa, South East Asia and Australia (Houghton *et al.,* 2000). Bush encroachment can be defined as "the invasion and/or thickening of aggressive undesired woody species resulting in an imbalance of the grass - bush ratio, a decrease in biodiversity, and a decrease in carrying capacity"(Lechmere-Oertel *et al*., 2005). Changes in natural vegetation dominated by the grass layer leading to dominance by woody cover, and increase in unpalatable forbs are considered as a threat to range conditions in Borana rangeland (Coppock, 1994).

Ayoub (1998) suggests that when these processes of resources mismanagement coincided with the recent recurrent drought, collapse of the economic bases of fragile areas take place. Ecological change can also manifested by progressive growth in bush encroachment, which is a common cause of herbaceous vegetation loss in dry savanna (Oba *et al.*, 2000). Bush encroachment becomes a problem when trees, shrubs and bush cover exceed 30% and includes decline in range condition (White, 1980). Overall woody vegetation reduces grass cover through increasing the competition for available water and nutrients and reducing reaching of sun light to the grass layer (Thurrow, 2000). Prohibition of bush burning undoubtedly exacerbated the problem of bush encroachment which in tern is indicative of the low range carrying capacity and degradation (University of Arizona AgNIC, 2001). In the southern Ethiopian rangelands, 83% of the rangelands were threatened by a combination of bush encroachment and unpalatable forbs (Ayana Angassa, 2007).

In east Africa, biodiversity of rangeland is poorly described in relation to their overall importance (Blench and Sommer, 1999). Gemedo Dalle *et al*. (2006a) also states that besides quantitative data on the impacts of woody plants encroachment on herbaceous biomass and soil nutrients are lacking. Environmental changes, rangeland degradation and pastoral perceptions of the problem are not fully understood and documented (Gemedo Dalle *et al*., 2006b). The overall objectives of the study are to contribute towards better understanding of the current impacts of bush encroachment on grassland vegetation and physical environment of Borana rangelands. The study will generate to the information needed for the development of effective and sustainable rangeland ecosystem management strategies in the study area.

1.2. Statement of the Problems.

The ecological succession in the Borana rangelands indicates that the potential of the grass land is threatened by bush encroachment in many areas (Alemayehu Mengistu, 2004). In the mid-1980s, about 40% of the Borana rangeland had a woody cover exceeding 40% (Assefa Eshete *et al.,* 1986). Later, Gemedo Dalle *et al.* (2006a) also reported that average bush cover was 52% in Borana range land in 2004. This indicates that the bush cover is increasing from time to time. A rapid increase in woody population and degradation of grazing resources badly affected livestock production. Lack of documented data on the potential vegetation resources (biodiversity) and knowledge on the state of deterioration of the floras and faunas and socio-economic impacts are also observed.

1.3. Research Questions

- Do changes in soil nutrient cycling occur with, and/or bush encroachment?
- What are the pastoralists' perceptions towards bush encroachment?
- What are the relationships between bush encroachment, grass species diversity and total plant diversity?
- What do pastoralists suggest to tackle the problem of bush encroachment?

1.4 Objectives of the Study

1.4.1 General Objective of the Study.

To assess the status of bush encroachment in the rangeland ecosystems and to address the responses of the local communities to the problem of bush encroachment in the two districts of the Borana lowlands.

1.4.2 Specific Objectives.

- To determine impact of bush encroachment on plant species diversity.
- To examine the soil nutrient status in areas encroached by bushes and shrubs and in the open (un-canopied) areas.
- To asses major causes and solutions of bush encroachment in Borana rangelands.
- To generate recent baseline data for further research and the management of the rangelands by government and/or non-governmental bodies working in the area.

1.5 Limitations of the Study

Low and uneven distribution of rain fall in the study area might have impact on annual grasess and forbs especially in Medhacho pastoralist association. The study was limited to one season of the year due to limited time of study. Lack of transport facilities and movement of pastoralists to search for water and pasture also affected access to pastoralis to persue the interview.

2. Literature Review

2.1. Rangeland Condition.

Range condition is the present state of health of the range in relation to what it could be with a given set of environmental and managerial factors (FAO, 2000). Range condition measures range deterioration and improvement. The concepts of condition imply that an optimal or desired vegetation cover (in terms of quantity and composition) exists for each particular land ecosystem (FAO, 1993). Optimum range condition will differ according to the manner in which the rangeland is used (e.g. Cattle, Sheep, Wildlife); the comparison used should be clearly stated as well as whether this is based on actual measurements or whether it is assumed (Alemayehu Mengistu, 2005).

For whatever cause, range condition is down when desirable species are replaced by poor species; when reduced soil cover exposes excessive bare surfaces; when erosion accelerates; when production of forage and animals drops; or when any combination of these effects occurs (FAO, 2000). Range condition guide describes the kinds of plants, the kinds of soil and soil erosion assessment and other characteristics of a particular range site and each kind of site has its individual guide developed through research (FAO, 1993).

2.2. The View on Rangeland Degradation

Rangeland degradation is the most extensive among the major types of current land use and few countries have less than 50 percent of their pastoral lands degraded (World Bank, 1992). de Queiroz (1993) suggested that the reference point for rangeland degradation when measured in terms of beef that it can sustain is the potential natural community that provides the highest grazing value for beef cattle production. This indicates that one major aspect of rangeland degradation is reduction in the capacity of the ecosystem to support livestock production and productivity. Change in the pattern and state of vegetation or structure, as defined by patchiness and biodiversity in semi-arid regions, are the main indicators of the state of land degradation (Saco *et al*., 2006).

Oba and Kotile (2001) reported that the major threats in the Borana rangeland were due to loss of perennial grass cover and increase in annuals, unpalatable forbs and bush cover. Blaxter (1994) in Alemayehu Mengistu (2004), also stated that continuous expansion of the settler in the better pasture lands and their takeover of permanent water sources has pushed pastoralists more and more into arid zones depriving them of their dry season fall back areas and thereby greatly increasing their vulnerability to climatic uncertainties and leading over utilization and degradation of their resources. Leopold (1989) also verified the growth of less palatable grasses, shrubs and weeds and the emergence of unstable equilibrium in a region in the United States, after it has been grazed by livestock. This is because of the suppression of palatable grasses due to woody species encroachment that are unpalatable to domestic livestock (Ward, 2005). Concerns in Africa's rangelands due to overstocking have persisted since long period of time (Mack, 1996). Thus, in the absence of proper management measures the rangelands are suspected to eventually become irreversibly degraded.

During the 30 year period after 1974 environmental and rangeland degradation resulted in substantial changes in eastern Ethiopia (Amaha Kassahun, 2006) due to encroaching weeds and woody plants, deforestation due to human population pressure, recurrent droughts and overgrazing resulting in a decline of the grazing and browsing capacities of the rangelands. The grasslands have shrunken and the encroachment by woody plants increased, resulting in changes in the original species composition of livestock in favour of camels and small ruminants (Mortimore, 2005). Subsequently, the roles of dairy cattle and donkeys have now been taken by camels, which are drought tolerant, a good dairy animal for milk production as well as a good pack animal for transportation (Amaha Kassahun, 2006).

The problem is often better understood by the pastoralists than policy makers, development planners and researchers of the countries in the Horn of Africa (Amaha Kassahun, 2003). The lack of understanding of the relationship between the environment and pastoralists and ignorance regarding the perception of the pastoralists may also

contribute to the misunderstanding of the pastoral production system and the priority needs of the pastoralists (Gemedo Dalle *et al*., 2006a).

2.3. Bush Encroachment

Bush encroachment is the suppression of palatable grasses and herbs by encroaching woody species often unpalatable to domestic livestock (Ward, 2005).The ecological succession in the Borana rangelands indicates that the potential of the grass land is threatened by bush encroachment in many areas (Alemayehu Mengistu, 2004). Overall woody vegetation reduces grass cover through increasing the competition for available water and nutrients and reducing the reaching the grass layer (Thurrow, 2000). In addition to competing with grasses,most of the woody plants that are encroaching to the rangelands are commonly thorny and thicket- forming so that grasses produced grazing capacity of the rangeland is extremely reduced (Alemayehu, 2004).This type of vegetation degradation occurs where indigenous shrubs and trees encroach onto former grassland areas changing them to various forms of shrubbed grasslands. On the other hand, the density of trees and shrubs may increase into shrubbed thickets or various wooded types and reduce the relative amount of grass and therefore livestock production (Raj, 2005).

Increase in domestic livestock (grazers) and a decrease in game animal numbers (browsers), increase the pressure on the grass layer and the competitive advantage of a vigorous perennial cover is declined, and a more favorable environment for the woody component is created (Joing, 2004). In some instances woody encroachment is speculated to be due to a lack of foraging by livestock and lack of fire (Herlocker, 1999) thus both overuse and under use have been implicated in affecting vegetation dynamics. Prohibition of bush burning undoubtedly exacerbated the problem of bush encroachment which in turn is indicative of the low range carrying capacity and degradation (Ayana Angassa, 2007).

Environmental changes linked to growing bush cover are presently associated with episodic climatic events as well as recent and historical land alienation in Borana

rangelands (Bassi, 1997) and water development (SORDU, 1990). National policies against fire in the rangelands have, unintentionally, facilitated woody encroachment to detriment of rangeland productivity and pastoral carrying capacities in Ethiopia (Alemayehu Mengistu, 1998). Oba *et al.* (2000) and Gemedo Dalle *et al.* (2006b) also reported that bush encroachment in the Borana rangelands reduces livestock productivity and survival particularly during drought years, when forage scarcity is the greatest.

2.4 Causes for Bush Encroachment

It is difficult to generalize about causes of change in range condition because of site-specific interactions among ecological features and human use (Homewood and Rogers, 1991). Controversy has focused on whether climate or consumers are primarily responsible for vegetation dynamics observed in arid and semi-arid Africa (Ellis and Swift, 1988; Behnke and Scoones, 1993). Prolonged heavy grazing undoubtedly contributes to the disappearance of palatable species and the subsequent dominance by other, less palatable, herbaceous plants or bushes (Haan *et al*., 1997; Steinfeld *et al*., 1997). Ayoub (1998) also suggests that heavy grazing causes change in pasture composition, invasion of woody weeds, a reduction of total vegetative cover and increase in soil erosion. On the other hand, total absence of grazing also reduces biodiversity because a thick canopy of shrubs and trees develops which intercepts light and moisture and results in over-protected plant communities, which are susceptible to natural disasters (Mulugeta Lemenih, 2006).

A regional pattern of bush encroachment was probably associated with restricted mobility of pastoralists over the past one hundred years due to a slowly growing population that encouraged sedentarization (Coppock, 1994). The other environmental changes linked to growing bush cover are presently associated with episodic climatic events as well as recent and historical land alienation (Oba, 1996; Bassi, 1997) and water development (SORDU, 1990).

The accumulated organic matter and soil seed banks imported by livestock from the grazing lands, which after abandonment, regenerate into woodlands, create patchy

environments (Reids and Ellis, 1995). If the grass layer is overutilised, it loses its competitive advantage and can no longer use water and nutrients effectively (Felegeselam Yohannes, 2006). These results in a higher water and nutrient infiltration rate into the subsoil. Such a scenario will benefit trees and bushes and allow them to dominate. Prolonged denudation of soils caused by droughts and grazing, followed by above-average rainfall years with frequent rainfall events, favor mass tree recruitment (Ayoub, 1989). The exclusion of occasional hot veld fires, the replacement of most of the indigenous browsers and grazers by livestock, injudicious stocking rates, poor rangeland management practices, weakening of traditional rangeland and water management strategies, frequent drought and artificial water points are also regarded as the major causes of bush encroachment (Bassi, 1997; Gemedo Dalle *et al.,* 2006a).

In the Borana rangelands of southern Ethiopia, a progressive increase in bush encroachment and loss of grass cover (Coppock, 1994) is associated with changes in patterns of livestock grazing (Bille *et al.,* 1983). Heavy livestock grazing in turn has reduced the herbaceous vegetation cover (Coppock, 1993). The ban on fire in the 1970s might also have facilitated the expansion of bush encroachment (Coppock, 1993; Ayana Angassa, 2007; Gemedo Dalle *et al.,* 2006a), due to a reduced fuel load and fire frequency (Scholes and Archer, 1997).

The Borana pastoralists traditionally practiced strategic grazing management to avoid local overstocking around the scarce dry season water sources. This management regime in combination with episodic climatic events and the planned use of fire maintained a relatively stable tree-grass balance (Ayana Angassa, 2002). However in the last few decades, the high grazing pressure, the official bans on the use of fire and pond development (pond-construction program) promoted bush encroachment and a decline in range condition (Coppock, 1994; Gemedo Dalle *et al.,* 2006a). The shift from grassland (<10% bush cover) to bush climax (*i.e.*, >30% bush cover) is influenced by interactions of episodic rainfall, fire and heavy grazing (Harris, 1980). Once established, bush encroachment accelerates the decline in grass cover, while the intensification of grazing pressure reduces the fuel load required for fire to burn the bush cover (Scholes and Archer, 1997).

2.4.1. Misconception on Use of Fire by Local Government Officials.

Pastoral development in the East African rangelands has been influenced by a widely perceived impression of environmental change such as decline in vegetation resources linked to overstocking of dry lands (Ayana Angassa, 2007). The perception of pastoral development in the African rangelands lies in the essence of the tragedy of the commons (Hiernaux, 1996) following the introduction of the concept of range management into East Africa in the early 1960. Rather, recent debates on pastoral development emphasize that East African rangelands are heterogeneous in space and time (Oba and Kotile, 2001). Therefore, traditional land use systems are the best way to make efficient use of the available forage resources. Any barrier to pastoralist ways of managing resources and loss of the communal rangelands to range enclosures, crop farming and ranching were found to be more likely to cause environmental change (Ayana Angassa, 2007).

In Ethiopia, rangeland policies were designed on the basis of the ranch model as an alternative to the communal rangelands without understanding the consequences of changing land use on the environment (Oba *et al.,* 2000). The Borana rangelands in southern Ethiopia have been substantially altered with the advancement of bush encroachment (Ayana, 2005). Expansion of bush encroachment has been attributed to the official banning of fire due to the policy of forest land conservation in the form of enclosures to foster the regeneration of naturally occurring plant species (Oba, 2000). As a result, the density of bush encroachment has been increased to the extent that the capacity of grazing is reduced. The official banning of fire had previously assumed that the use of fire would be damaging to the rangeland ecosystems (Alemayehu Mengistu, 2004).

2.4.2. Climatic Change

Causes of environmental changes linked to growing bush cover are presently associated with episodic climatic events as well as recent and historical land alienation (Oba, 1996) and water development (SORDU, 1990). Human activity has dramatically altered the composition of the atmospheric layer surrounding Earth. The use of fossil fuels and land

clearing has increased the level of carbon dioxide (~270 ppm in 1850 vs ~370 ppm) in the atmosphere (Jackson *et al.,* 1995). Methane has increased from 750 to 1700 ppb over the same period due to increases in ruminant livestock, burning natural gas and emissions from landfills (Allen-Diaz, 1996). These show that the evidence for global climate change in atmospheric chemistry is increasingly strong. While the vast majority of attention to changes in atmospheric chemistry has been on how greenhouse gases affect climate, there is a more subtle and potentially greater impact on nutrient cycling and effects on soil (Barrow, 1991). Poor rainy seasons or droughts followed by years with above-average rainfall with frequent rainfall events have probably made a substantial contribution to the problem of bush thickening (Raj, 2005).

2.5. Impact of Bush Encroachment

Changes in natural vegetation dominated by the grass layer leading to dominance by woody cover, and increase in unpalatable forbs are considered as a threat to range conditions (Oba *et al.,* 2000). Borana elders ranked bush encroachment third, next to drought and overgrazing, as a cause of range deterioration (Alemayehu Mengistu, 1998).

2.5.1. Impacts on Rangeland Vegetation

Leopold (1989) verified the growth of less palatable grasses, shrubs and weeds and the emergence of unstable equilibrium in a region in the United States, after it has been grazed by livestock. This is because of the suppression of palatable grasses due to woody species encroachment that are unpalatable to domestic livestock (Ward, 2005). In some cases, competition from woody plants here decreases productivity of the herbaceous layer, thus rendering an environment less suitable for grazers such as cattle and possibly more suitable for browsers such as goats or camels (Coppock, 1994).

Overall woody vegetation reduces grass cover through increasing the competition for available water and nutrients and reducing the reaching the grass layer (Thurrow, 2000).Increase in woody plant encroachment and herbaceous biomass production are negatively correlated (Gemedo Dalle, 2004; Oba and Kotile, 2001).

2.5.2. Impacts on Soil Environment

Trees and shrubs have been found to improve the nutrient status of their close surroundings in semi-arid shrub communities, arid grass lands tropical and sub-tropical savanna, eastern saheilian, savanna, east African savanna and South African savanna (Belysky *et al.,* 1990). All the studies which measured carbon, nitrogen, phosphorus revealed consistent horizontal pattern in the top soil. The content of these elements declines gradually as a function of a distance from the trunks and significantly lower in open ground than sub-canopy soil (Georgiadis, 1989). The reason for this complex but action of the interaction trees, under story plants and symbiotic micro-organisms evidently contribute. Nutrients found in low concentrations throughout the soil profile may be taken up by the root system of the matured trees and shrubs. By leaf abscission these nutrients will be concentrated in sub-canopy due to litter and decomposition. This has been suggested as a principal explanation by Vetaas (1992) and Belysky *et al.,* (1990). If nutrients are absorbed by tap roots of woody species, a total nutrient supply to the field-layer is altered. The combination relocation and surface root turnover and shedding of the leaves will act together as nutrient pump (Mc Naughton, 1985). Trees litter will unquestionably lead accumulation of organic matter under and near the trees (Frost *et al*,. 1986)**.**

2.6. Approaches to Control Bush Encroachment.

2.6.1. Using Fire as a Management Tool.

Bush fires have proven to affect ecosystems dynamics (Meurer *et al,*. 1994), are used as tool for building and managing grazed ecosystems (Ansley and Castellano, 2006) controlling grasslands invasiveness and improving fodder quality. However, the use of bush fires should be convenient with pasture types and specific phytogeographical sites. Bush control methods are disturbance methods that reduce the threat of bush encroachment. Ayana Angassa (2007) recommended that re-introduction of fire combined with grazing would probably sustain the savanna ecosystems of southern Ethiopia, rather than fire suppression.

According to the traditional land use practices, the health of landscapes may be improved by periodic burning. In the absence of fire, bushes reduce grass production, creating feed deficits for livestock. The early fire increased soil covering as the late fire increasing naked beaches while the out of season fire provides tender, palatable straw in dry season, but does not ensure an optimal soil covering (Teka *et al.,* 2007).

2.6.2. Bush Clearing

Ayana Angassa (2004) suggested that the use of bush or shrub clearing may be important in the management and improvement of the rangelands with the practice of prescribed burning. The grass component reacted positively to the tree thinning in terms of total dry matter (DM) yield, but forbs were negatively influenced (Smit, 2005). Plants in sub-canopy soil dried faster than plants in open soil (Georgiadis, 1989). Grass production by removing the woody canopy (Dye and Spear, 1982) cannot be solely attributed to increases in irradiance at the grass layer. Increases in soil fertility must also be considered (Georgiadis, 1989).

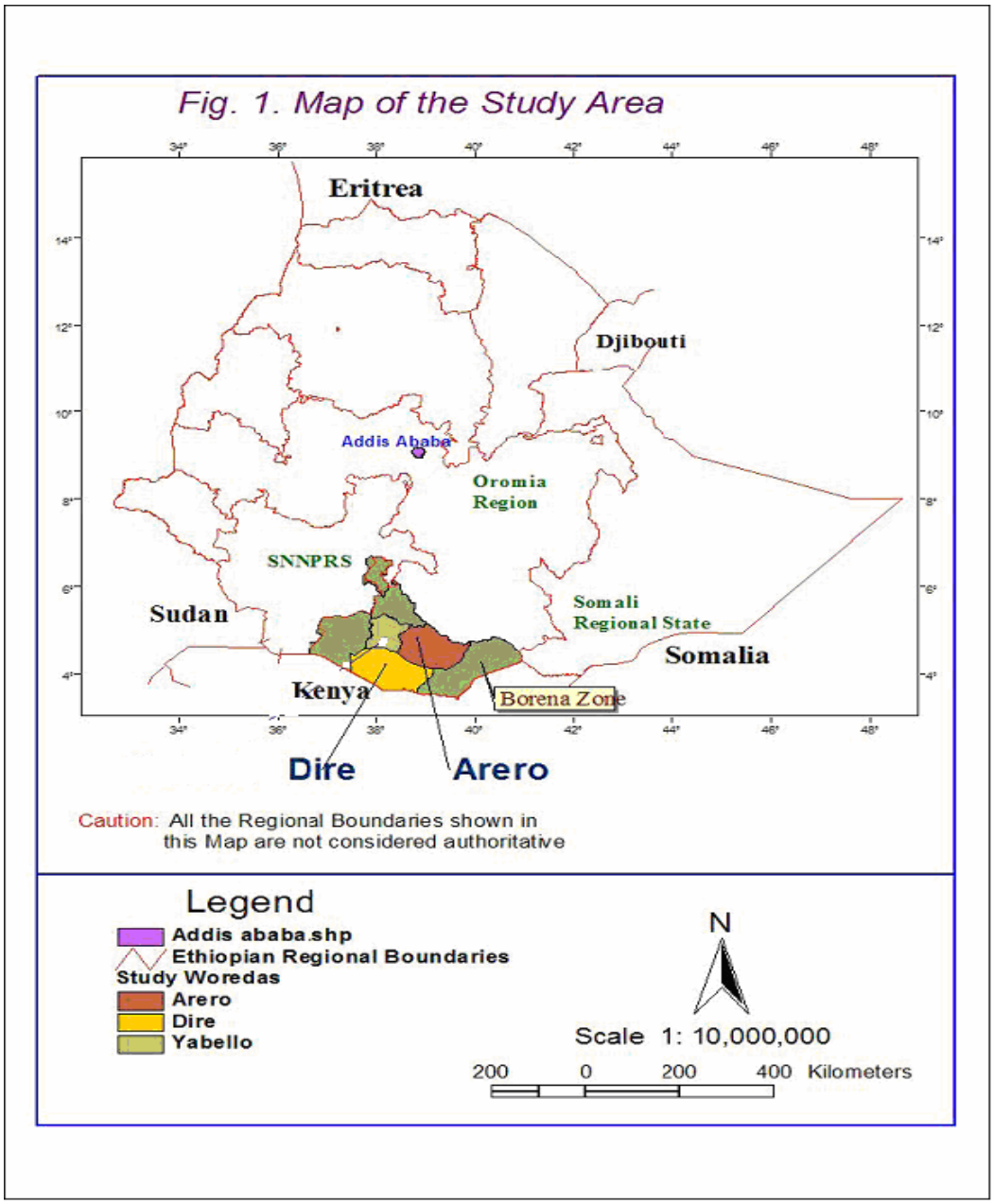
3. Materials and Methods.

3.1. The Study Area

3.1.1. Location and Description

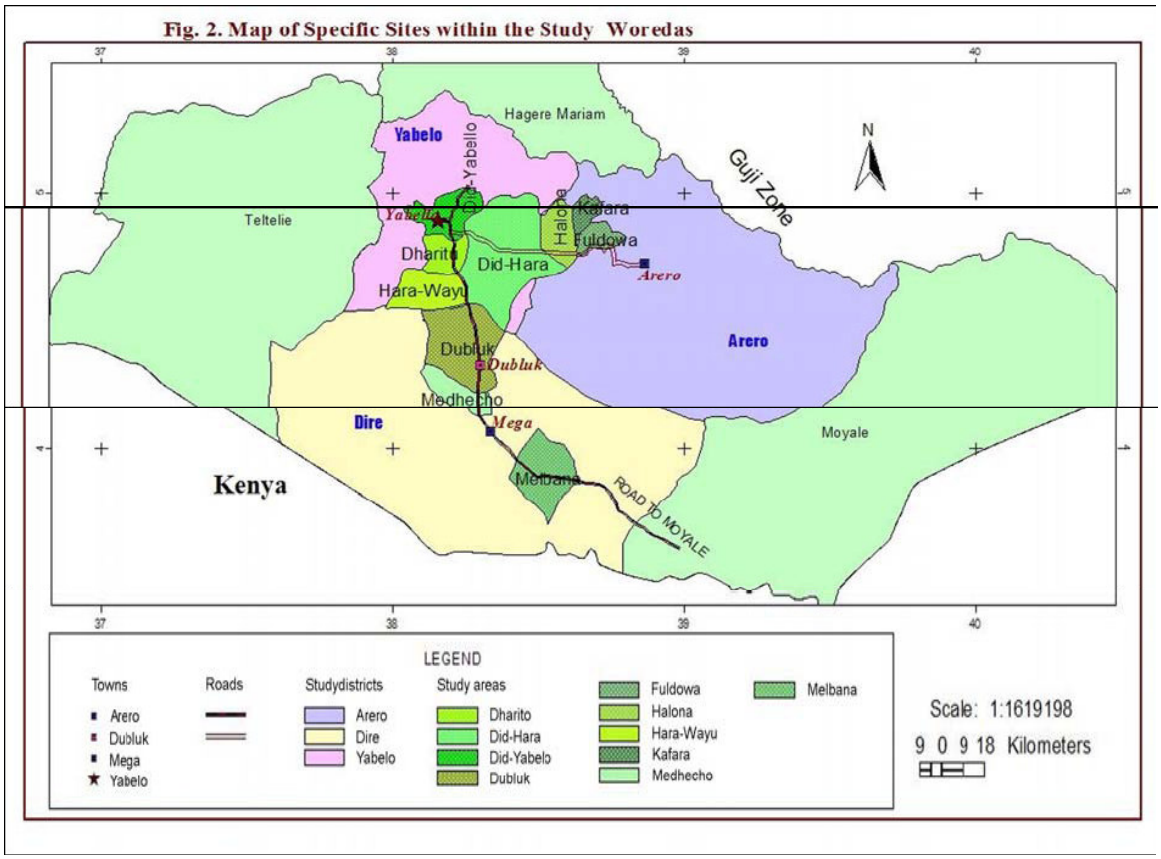
The Borana lowlands, in which, the study was conducted is located in Southern Oromia and at about 570 km (Yabalo town) from Addis Ababa. The total area of Borana zone is estimated to be 4,859,489 hectares. Of this, about 2.5% is cultivated land, about 22.3% is cultivable land, about 7% is forest, about 38.5% is grazing land and about 29.7% is inaccessible land (Borana Zone Pastoralist development Bureau, 2006). The Borana grazing lands in southern Ethiopia traditionally comprised of the Liiban, the Dirre and the Golbo production systems in correspondence with the geographical divisions of Borana land (Oba, 1998). This study was conducted in two pastoralists' associations selected from two woredas. One of these is Hallona which is located at around 47 Km from Yabelo town on the road to Arero town in Arero Woreda. The second one is Medecho pastoralists' association on the main road to Moyale in Dirre woreda 85 km from Yabello and 15 km from Mega.

Fig.1. Map of woredas of the study areas



Source: Ayana Angassa, 2007

Fig.2. Map of the specific sites within the study woredas



Source: Ayana Angassa, 2007

3.1.2. Climate

Rainfall is bimodal with the long (Gana) rains expected between March and May followed by short cool dry season (Adoolessa) which covers June to August and the short rains (Hagaya) between October and November (Upton, 1986).The short rains of Hagaya are followed by long dry season (Bona Hagaya).The mean annual rainfall ranges between 400mm-600mm (Gemedo Dalle *et al*., 2005).

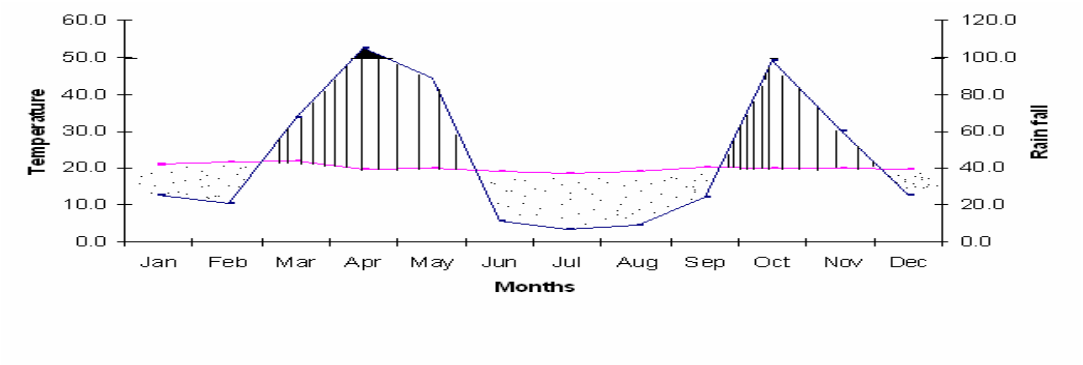


Fig. 3. Monthly temperature and rainfall distribution at Yabello station (1992-2006).
Source: National Meteorological Services Agency, Addis Ababa.

Long term variability in the quantity and distribution of rainfall was observed in Borana lowlands.

Fig. 4. Average annual rainfall at Yabello station (1992-2006)
Source: National Meteorological Services Agency, Addis Ababa.

3.1.3. Soil

The soil types in the study area are granitic and volcanic soils and their mixture (Coppock, 1993 in Gemedo *et al.,* 2006a). Whereas the bottom lands of the Borana range lands are dominated by vertisols (Gemedo Dalle, 2004).

3.1.4. Vegetation

Combretum-terminalia and *Acacia-commiphora* woodlands are the most widely spread vegetation types that characterize the lowlands of Borana zone (Gemedo Dalle, 2004).

Bush land sand thickets, which cover major parts of Borana low land, are dominated by *Acacia and Commiphora* species.

3.1.5. Human and Livestock Population

Human population of the Borana zone is estimated to be 941,595 with 50.2% male and female 49.8% and annual growth rate is 2.32% in rural and 4.11% in urban areas. Livestock population after drought of 2006 is 1,496,652 cattle, 452,174 goats, 173,021 sheep, 106,366 camels, 13945 mules, 61,699 donkeys and 1658 horses (Borana Zone Pastoralist development Bearou, 2006). The calculated population density for the zone is 6.2 persons and 47.4 heads of livestock per km^2, respectively. The latter is equivalent to 18 Tropical Livestock Units (TLU), where 1 TLU is equivalent to a live weight of 250 kg or 13 Large Stock Units (LSU) (1 LSU equals 450 kg live weight).

Table1: Livestock population of the Borana zone.

Type of livestock	Total Number	Percentage Proportion
Cattle	1,496,652	65.31
Goats	452,174	19.73
Sheep	173,021	7.55
Camels	106,366	4.64
Donkeys	61,699	2.69
Horses	1658	0.08
Total	2291570	100

Source: Borana zone pastoralist development bureau, 2006.

3.2. Methods

3.2.1. Selection of the Study Sites

A reconnaissance survey was conducted by forming a multi-disciplinary team, involving traditional range scouts and knowledgeable rangeland expert to select the study site. Further assistance was obtained from the indigenous knowledge of the pastoralists,

scientific publications, primary and secondary data, physical observations and field group discussions to select representative sites.

Transects were selected in such a way as to cover: encroached and non encroached range land sites of the communal grazing areas; totally seven transects, which ranges from 1.5 – 2km in length each, were used to collect vegetation and soil samples. Of these seven transects, three of them were found at Hallona site whereas the rest were located at Medhacho site. To differentiate encroached and non-encroached sites, visual estimation of woody vegetation cover was used. Areas where the shrub, bush and tree canopy was estimated visually as more than 40% were designated as encroached (Ayana Angassa, 2007).

3.3 Study Design

3.3.1. Vegetation Survey

The vegetation sampling was conducted in the late wet season at a time when most plants (grasses) are in full flowering stage which is important for their identification and cover estimation. Transect method was employed by stratifying the study site to compare difference between encroached and non encroached areas. Samples were collected from 20m x 20m plots.

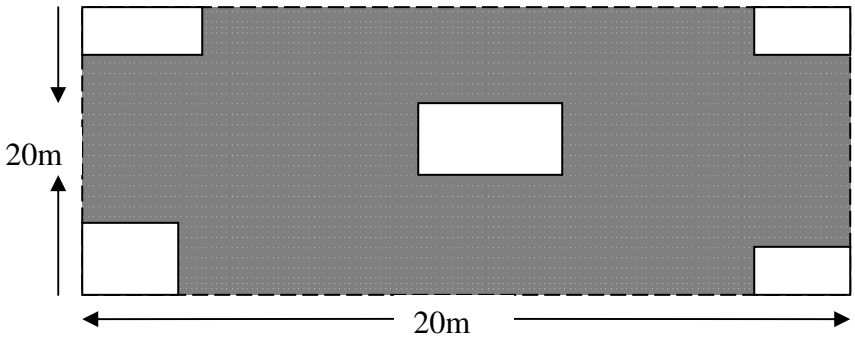


Fig. 5. Vegetation and soil sampling layout.

In establishing the sampling plots, a combination of stratification and systematic sampling were used to take samples from different land categories (encroached and non-encroached). The first sample plot was established randomly for measurement and subsequent plots were established at a fixed interval (200m) on linear transects. The transects are parallel and 500m away from each other. In each major plot, five subplots of 50cm x 50cm were established (four at each corners and one at the center) for herbaceous and bare land cover estimation and species composition assessment. For field trips a Geographic Positioning System (GPS), Compass, Altimeter and a Map of Ethiopia (1:250 000 scales) were also used.

Plant samples were prepared according to the guidelines of the National Herbarium for Floras of Ethiopia and identified in National Herbarium of Ethiopia (Addis Ababa University Science faculty) consulting experts and referring to the published volumes of Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989 and1995; Edwards *et al.*, 1995, 1997 and 2000; Hedberg *et al.,* 2003, 2006; Mesfin, 2004). The assessment of herbaceous plants included species richness, botanical composition, and canopy cover. Species richness was quantified as the number of annual forbs, annual grasses, perennial forbs and perennial grasses species within 50cm × 50cm quadrants placed at the center and four corners of the major quadrant.Two subplots with size of 1m x 5m were at the two opposite sites of the starting line were used to count seedlings. Species richness, density and percentage of adult woody plants and saplings were collected from the major plot ($400m^2$ size plots). All trees and shrubs rooted in within the plot were considered and diameter at breast height (dbh) for trees and diameter at stamp height (dsh) for shrubs were measured using Tree Caliper. Height of trees and shrubs with dbh/dsh greater than 2.5 cm was estimated visually. Number of stems above ground was also counted and registered for trees and shrubs with dbh/dsh greater than 2.5cm. In addition, percentage cover, frequency and woody species richness were measured.

3.3.2. Soil Survey and Laboratory Analysis

Across the seven transect lines total of 60 soil samples, about 31 from encroached and about 29 from non-encroached area were collected. To take the representative sample,

Pits with 15cm depth were dug at the four corners and in the centre of the square plots and composites were made from the soil samples that were taken from four corners and the center of each plot from where the vegetation samples were taken.

Each representative samples were put in a labeled plastic bag and stored in sack at moisture free area and transported to laboratory for analysis. The laboratory analysis was done at Ethiopian Agricultural Research Institute (EARI) Holeta research center. The parameters considered during analysis are organic carbon, total nitrogen, available phosphorus available potasium exchangeable bases (K, Ca and Mg) level, pH water, organic matter and cation exchange capacity (CEC).

Soil parameters were analyzed at Ethiopian Agricultural Research Institute (EARI) Holeta research center. Accordingly, Soil P^H in a 1:2.5 soil-water suspension and read using P^H meter , organic carbon anayzed by oxidation with potassium dichromate ($K_2Cr_2O_7$) in a sulfuric acid medium (Walkley and Black, 1934) whereas organic matter content was calculated by multiplying the value of organic carbon reading with a constant (K=1.724), total nitrogen by Kjeldahl method, Available phosphorus (Bray method for the soil samples with pH- value > 7 and Olsen procedures for samples with pH <7), cation exchange capacity (CEC) was measured by the ammonium acetate(1 N NH_4OAc) extraction and, exchangeable ions by ammonium acetate extraction and measured by the atomic absorption spectrometry (AAS) method (Page *et al.,* 1982).

3.3.3. Pastoralists' Perceptions Survey.

The survey was done through face-to-face interview of pastoralists by the researcher and development agents. Moreover a discussion was made with the chair man of each peasant association to introduce the purpose of the study and to get permission to conduct the interview with the pastoralists in the respective peasant association. The interview was mostly made during the morning and sunset at the time when the pastoralist are available at home. A total of 50 individual pastoralists from the two peasant associations (Hallona and Medhacho) were involved in individual interview.

Group interview was also employed to assess perception of the pastoralist to wards the bush encroachment. Interviews were conducted in an open-ended fashion with sufficient time to gather details from respondents. In all cases questions were asked regarding perceptions of long-term vegetation change (bush encroachment), its causes, and its impact on livestock production and possible solutions.The checklist prepared for the interview was attached in attached in appendix 15.

3.4. Data Analysis

3.4.1. Plant Diversity Analysis

PC-ORD, version 4.20 computer program was applied to determine the plant diversity indices. The percentage cover/ abundance of each species were used for numerical analysis. The average cover/abundance value of each cluster (Land type) identified was computed and then characteristic species of the cluster were recognised. Shannon and Wiener (1949) index of species diversity was applied to quantify species diversity and richness.

The relative Equitability (evenness) of the species in each cluster was also calculated

- Diversity: 'H' = $-\Sigma$ (Pi ln Pi), Where 'H' = the Shannon and Wiener diversity index, 'Pi' = the proportions of individuals abundance of the ith species, and ' ln' = the natural logarism to base e ($\log_e$)
- Equitability(evenness): $J = \frac{H}{Hmax}$

Where "J" is the species evenness "H" Shannon and Wiener diversity index and "Hmax" is lnS, where S is the number of species.

3.4.2. Woody Plants Structure Data Analysis

The vegetation data of tree and shrub with DBH/DSH >2.5cm were calculated and summarized on an Excelspeared sheet using the following formulas.

Density: Density is defined as the number of plants of a certain species per unit area. It is calculated as:

- Density = $\frac{\text{Total number of individuals}}{\text{Sample size in hectare}}$
- Relative density = $\frac{\text{Number of individuals of a species}}{\text{Total number of individuals}} * 100$
- Frequency(F) is calculated with this formula:

$$F = \frac{\text{Number of plot in which a species occur}}{\text{Total number of plots}} * 100$$

- Relative frequency(R.F.) = $\frac{\text{Frequency of a species}}{\text{Sum frequency of all species}} * 100$
- Basal area(BA) = $3.14\ (D/2)^2$ where D is diameter at breast or stump height
- Dominance = Mean basal area of a species * Total number of species.
- Relative dominance = $\frac{\text{Dominance* of a species}}{\text{Dominance of all species}} * 100$

Importance Value Index (IVI): = Relative density + Relative frequency + Relative dominance

3.4.3. Soil Data Analysis

A t-test was used to compare soil parameters (available P, total N, OC, OM, exchangeable bases (Ca^{+2}, Mg^{+2} and K^{+1}), available K^{+1}, pH, and ECE) between encroached and non-encroached sites. The computer program used for this comparison was SPSS (SPSS, 1989 – 96) version 14.

3.4.4. Pastoralists Perception Data Analysis

Pastoralist perceptions was converted to numerical values and analysed by excel spread sheet using simple descriptive statistical tools like mean, percentage and ranking it based on the result from the measured values.

4. Results and Discussion

4.1. Plant Species Diversity

Table 2 below shows vegetation diversity of encroached and non-encroached sites. The non-encroached site was more diversified than the encroached site attaining a higher diversity index. This site attained a species evenness index (J) of 0.7 and 89 species showing the higher even distribution of species and species richness compared to the encroached site. Scholes and Archer (1997) also reported that it has been experienced similar in South Africa and Sahelian region. The increase in woody plant cover is a major concern for conservation and savanna rangeland management, due to its adverse effect on livestock carrying capacity and biodiversity (Van-Wijngaarden, 1985).

Table 2: Vegetation Diversity indices of the encroached and non-encroached sites of the study areas.

Sites	Land type	S	J	H
Total study area	Non-encroached	89	0.704	3.16
	Encroached	73	0.621	2.67
Medhacho	Non-encroached	59	1.258	2.82
	Encroached	49	0.554	2.16
Hallona	Non-encroached	71	0.741	3.16
	Encroached	56	0.635	2.56

Where, S = Species richness, H = Shannon –Wiener's diversity index and J = Evenness

At the specific sites, better species richness, diversity and equitability was observed in non-encroached sites. Hallona site has higher species richness, diversity and evenness than Medhacho site. Increase in woody plant density beyond a critical density limit is normally accompanied by a decrease in herbaceous production and undesirable shift in composition (Gemedo Dalle *et al.,* 2006b). Change in cover of a particular species and decrease in total species richness may lead to decrease in diversity index in encroached site.

4.2. Species Composition

In the study area, a total of 94 plant species were identified, which included 26 woody and 68 herbaceous species (appendix 1 shows the list of each species). Of the 68 herbaceous species, 14 were grasses whereas 54 were non-grass forbs. The proportion of the frequency of grasses, non-grasses forbs and woody species was 14.89 %, 57.45 % and 27.66 % respectively. The detail result was mentioned in appendix 2, 3 and 4. Mc Naughton (1983) also reported similar result which shows changes in grass layer composition were found beneath woody species (e.g. *Acacia tortillis* and *Balanites aegyptica*) in the Serengeti ecosystem of northern Tanzania. Therefore, the effects of the shrub canopy on soils and on the herb layer documented under one species do not necessarily apply to trees, or even to other shrub species.

Of the 26 woody plant species, 17 (65.4%) were found in both encroached and non-encroached sites, 4 (15.4%) were found only in encroached sites while 5 (19.2%) were found only in non-encroached site. These woody species were grouped in to 13 families and 14 genera. Of these, about 9 genera (64.3%) had one species each, while 2 genera (14.3%) comprised of two species each, and 1 genus (7.15%) consisted of 4 species whereas the rest 1genus (7.15%) consisted of 8 species (the details in appendix 2).

Table 3: Woody plants species composition in the encroached site.

No.	Family	Genera	% Proportion	Species within genera
1	Fabaceae	Acacia	38.10	*A. bussei, A. drepanolobium A. etabaica, A. mellifera, A.nilotica, A. oerfata, A. seyal, A. tortilis*
2	Balanitaceae	Balanites	9.52	*B. aegyptiaca, B. rotundifolia*
	Cappararidaceae	Capparis	4.76	*C. tomentosa*
3		Maerua	4.76	*M. triphylla*
4	Commelinacea	Commiphora	9.52	*C. Africana, Commiphora sp.*
5	Amaranthaceae	Chionotrix	4.76	*C. latifolia*
6	Tiliaceea	Grewia	4.76	*G. villosa*
7	Acanthaceae	Justicia	4.76	*J. odora*
8	Anacardiaceae	Rhus	4.76	*R. ruspolii*
9	Solanaceae	Solanum	14.29	*S. capsicoides*, *S. giganteum, S. schimperianum*
	Total	11	100.00	21

The genus with highest number of species was Acacia while Solanum, Commiphora and Balanites were ranked 2nd to 4th.

Table 4: Woody plants species composition of the non-encroached site

No.	Family	Genera	% Proportion	Species within genera
1	Fabaceae	Acacia	31.82	*A. bussei, A. drepanolobium, A. mellifera, A.nilotica, A. oerfata, A.seyal, A. tortilis*
2	Balanitaceae	Balanites	9.09	*B. aegyptiaca, B. rotundifolia*
	Burseraceae	Boswellia	4.55	*B. neglecta*
3		Commiphora	4.55	*C. terebinthina*
4	Cappararidaceae	Capparis	4.55	*C. tomentosa*
5	Commelinacea	Commiphora	9.09	*C. Africana, Commiphora sp.*
6	Amaranthaceae	Chionotrix	4.55	*C. latifolia*
7	Boraginaceae	Heliotropium	4.55	*H. longiflorum*
8	Convolvulaceae	Ipomoea	4.55	*I. kituiensis*
9	Acanthaceae	Justicia	4.55	*J. odora*
10	Solanaceae	Solanum	18.18	*S. capsicoides*, *S. giganteum, S. Incanum, S. schimperianum*
	Total	11	100.00	22

The grass family was consisted of 12 genera in which 10 genera (71.43%) were represented by one species each while 2 genera (28.57%) consisted of two species each (details in appendix 3). Of the total 12 genera one genus was found only in the non encroached site while the rest were found both in encroached and non-encroached sites. Of the total grass species, about 9 species (64.29%) were perennials while 5 species (35.71%) were annuals in their life form. All 14 species were observed in Hallona site while only 12 species were found in Medhacho. 5 annual and 7 perennial species were found in encroached site while all 14 species were found in non encroached site in Hallona. In Medhacho, the grass species that were found in non-encroached site were 3 annuals and 4 perennial while 5 annuals and 6 perennials were found in the encroached site. Decrease in number of perennial species was observed in Hallona encroached site.

Table 5: Grass species composition of the study area.

Sites	**Annuals**	**Perennials**	**Total**
Total study areas	5	9	14
Non-encroached	5	9	14
Encroached	5	8	13
Medhacho non-encroached	3	4	7
Medhacho encroached	5	6	11
Hallona encroached	5	7	12
Hallona non-encroached	5	9	14

Higer grass species richness was observed in between Hallona than Medhacho site (table 5). This might have been because of difference in rain fall distribution between the two sites. According to elders the rainfall distribution was better in Hallona than in Medhacho this year and most of the pastoralists moved from Medhacho to Hallona site to search for better pasture and water this year. Better grass species richness was also observed in encroached site in Medhacho site than the non-encroached one. This also might have been be related to the moisture stress observed in medhacho site. Alemayhu (2004) also listed moisture stress as one of the causes for variation in pasture growth and herbaceous plant composition. Area with high woody plant cover may have lower evapo-transpiration and hold better moisture content during germination period which may give better chance of survival to the annual grasses that are found in encroached area. In addition to bush encroachment, overgrazing by domestic livestock changes vegetation structure and composition as a result of which some species increase in abundance and others decrease (Yates *et al*., 2000).

Perennial grass species distribution difference was observed between the encroached and non encroached sites of the two sites whereas annuals showed consistency in both encroached and non encroached site. Higher variation in species distribution between encroached and non-encroached site was observed in perennial species than the annuals in both study sites. But there is still higher number of perennial species in both sites. The better number of perennial grasses may indicate that the herbaceous layer is in good condition to servive and used as source of feed during dry season.

The forbs were consisted of 19 families which were composed of 40 genera and 54 species. Family Asteraceae with 9 genera (9 species), Acanthaceae with 5 genera (7 species) and Amaranthaceae with 4 genera (5 species) are the top three families consisted of large number of genera and species of forbs (details in appendix 4). About 27 genera (69.23%) were consisted one species with in genera each, 9 genera (23.08%) consisted of two species each while 3 genera (7.69%) consisted of three species each. About 38 species (70.37%) were found in encroached and non- encroached areas, 15 species (27.78%) were found only in non encroached site while one species was found only in encroached site

Table 6: Forb species composition of the study area.

Sites	**Annuals**	**Perennials**	**Total**
Total study areas	15	39	54
Non-encroached	15	38	53
Encroached	11	28	39
Medhacho non-encroached	6	24	30
Medhacho encroached	3	21	24
Hallona non-encroachment	12	18	30
Hallona encroached	9	18	27

The proportions of annual and perennial forbs were 27.8 % and 72.2 %, respectively in the study site. Though the variation was observed in species richness between encroached and non encroached sites the proportion of annual and perennial forbs remained almost similar (28.3% annuals and 71.7 % perennials in non-encroached and 28.2% annuals and 71.8% in encroached site). Higher proportion of annual forbs was observed in non encroached sites while the percent contribution of perennials was high in encroached sites than non encroached sites in both study areas. Variation in species richness between encroached and non-encroached may lead to variation in the total composition in the area. Variation plant species composition will have an effect on forage quality, animal grazing behaviour (in terms of intake rates, number of bites, bite volume and time of bites), abundance and distribution of the species in the rangelands (Reagain, 1996).

4.3 Ground Cover

The mean canopy cover of woody, grasses and forb plants and bare land were 48.88%, 52.45%, 18.65% and 35.82 % respectively in the study site (detail in appendixes 10,11 and 12).Grass and forb cover decrease with increase in woody cover while high percentage of bare ground cover was observed in area with high woody plants canopy cover. Thurrow (2000) also mentioned that overall woody vegetation reduces grass cover through increasing the competition for available water and nutrients and reducing the light reaching the grass layer.Woody plants encroachment reduced herbaceous cover of the rangelands this may reduce the ability of the rangeland to produce adequate forage for livestock feeding and simultaneously increased the threat to the pastoral production system in place. This may further lead from a total failure of the rangelands to produce enough forage for livestock, especially in the absence of adequate measures to control the encroachment. So it demands due attention on integrated management for controlling the woody plants, which also require the support of appropriate rangeland vegetation monitoring and evaluation systems based on the participation of the pastoral communities. Van-Wijngaarden (1985) also reported that in East African savanna ecosystems increases in bush cover by 10% reduce grazing by 7%, while grazing is eliminated completely when bush cover reaches 90%.

Table 7: Average percentage cover of trees/shrubs, forbs, grasses and bareland.

Land type	Mean cover (%)			
	Trees/Shrubs	Forbs	Grasses	Bareland
Encroached site	90.92	16.76	37.68	51.26
Non-encroached site	6.83	20.54	67.21	20.38
Medhacho Encroached site	86.76	13.23	28.92	62.64
Medhacho non-encroached site	7.48	11.90	40.88	29.20
Hallona encroached site	94.8	17.25	45.92	40.56
Hallona non-encroached site	6.14	23.35	80.13	10.93

The woody cover ranges from 6.83 % in non encroached site to 90.92% in encroached site(Detail in appendix 10). Alemayehu (2004) reported that increase in bush encroachment was indicative of the low range carrying capacity and degradation. Bare land cover is high in Medhacho while the vegetation cover is better at Hallona site. As it was understood from pastoralists' interview and visual observations, the woody plants

which cover Hallona site are younger and encroached to the site lately compared to the Medhacho site. The woody plants were expanding to the non-encroached grass land at higher rate in Hallona site than in Medhacho. Many seedlings and saplings were observed at the peripheries of the already encroached land in Hallona site.

In both sites some woody plant species were noted to have higher mean percent canopy cover (detail in Appendix 10). The species with highest canopy cover in the encroached site were *Acacia drepanolobium* (40.3%), *Acacia mellifera (*23.1%) and *Acacia bussei* (16.4%). *Acacia drepanolobium* (71.56%), *Acacia mellifera* (14.3%) *and Justicia odora* (4%) were woody species with highest percentage cover in Hallona whereas *Acacia bussei* (33.8%) *Acacia mellifera* (32.5%) and *Acacia drepanolobium* (6.9%) were the three species with the highest mean canopy cover in Medhacho encroached site. In non-encroached sites *Acacia drepanolobium* (1.55%), *Acacia nilotica* (0.83%), *Justicia odora* (0.83%) and *Acacia tortilis* (0.76%) were the woody plants with highest canopy cover. *Justicia odora* (1.53%) *Acacia nilotica* (1.4%) and *Acacia tortilis* (1.2%) were with the highest canopy cover in Medhacho whereas *Acacia drepanolobium* (3.14%) and *Commiphora africana* (0.79) were with highest canopy cover in Hallona. *Acacia drepanolobium* was reported by the pastoralists as the woody plant which is currently categorized as an aggressive encroacher of the rangelands in Hallona area while *Acacia bussei* was the most aggressive encroacher in Medhacho area. Coppock (1994) also reported that *Acacia drepanolobium* and *Acacia bussei* were dominant encroachers in Borana rangelands.

4.4. Structure of Woody Vegetation

4.4.1 Density

The mean density of trees/shrubs in encroached site was 2794 per hectare whereas the density of saplings and seedlings was 4065 and 4084 per hectare respectively (detail in appendix 5 and 8). The study by Gemedo Dalle (2004) indicated that 3,149 total woody plant per hectare in Borana lowland. A 2,400 woody plant per hectare was considered as a border line between non-encroached and encroached condition (Roques *et al.,* 2001)

and 2,500 trees equivalent per-hectare is considered as the highly encroached site (Richter *et al.,* 2001). Therefore it can be concluded that density of woody plants in encroached study area has entered to highly encroached condition. Woody plant density beyond critical limit decrease herbaceous production and grazing capacity mainly due to severe competition for available soil water (Smit and Rethmann, 1998).This is particularly pertinent in *Acacia mellifera* encroached system, as the lateral roots of this species are known to extend with the grass rooting zone (Adams, 1966) and it is noted for its high water use.

Table 8: Mean density (no./ha) of woody plants sampled in the encroached and non-encroached sites.

Site	Trees/shrubs	Saplings	Seedlings	Total
Encroached Hallona	2589	3063	4500	10152
Encroached Medhacho	2998	5067	3667	11732
Mean	2794	4065	4083	10942
SD	289	1417	589	1117
Non-encroached Hallona	207	429	1286	1921
Non-encroached Medhacho	258	1200	1067	2525
Mean	233	814	1176	2223
SD	36	545	155	427

As it was shown in table 8, Medhacho had higher density of woody plant in both encroached and non-encroached site. For the comparison of the density of each species only trees/shrubs with DBH/DSH greater than 2.5cm were considered. Accordingly *Acacia drepanolobium* (73.15%), *Acacia mellifera* (17.56%) *and Balanites rotundifolia* (4.28%) were ranked first, second and third in their density in Hallona while *Acacia mellifera* (47.53%), *Acacia bussei* (36.7%) and *Acacia drepanolobium* (6.12%) were the species with highest density in Medhacho. In general, Acacia *drepanolobium* (37.17%), *Acacia mellifera* (33.64%) and *Acacia bussei* (19.56) were the three highly encroacher and with highest density per hectare in the study area. These species are spiny, small leaved and have very little feed potential compared to other acacia species like *Acacia tortilis* and *Acacia nilotica* which are valuable feed resource as a browse component. The density of species in different areas show variation and the species that have high density in one area may have lower density in the other area. For example, Gemedo Dalle (2004) reported that *Commiphora africana* contributed about 40% of the total of the total density

of trees/shrubs in Dida Hara which is close to Hallona whereas the contribution of *Commiphora africana* in Hallona and Medhacho is less than less than 1%. This variation in density and distribution the species of might be associated with the impacts of abiotic like soil type which affect the distribution of a particular species. For example the highest density of *Acacia drepanolobium* was observed in the areas that were dominated by black vertisol and water logging areas than sloppy sandy and red soil.

Table 9: Mean density per hectare (no./ha) of the adult tree/shrubs species in encroached sites.

Species name	Hallona	Medhacho	Mean
Acacia bussei	0	1093	546.5
Acacia drepanolobium	1894	183	1038.5
Acacia etabaica	0	5	2.5
Acacia mellifera	455	1425	940
Acacia nilotica	2	52	27
Acacia oerfota	0	168	84
Acacia seyal	0	2	1
Acacia tortilis	0	7	3.5
Balanites aegyptiaca	59	42	50.5
Balanites rotundifolia	111	0	55.5
Commiphora Africana	0	8	4
Commiphora sp.	0	3	1.5
Maerua triphylla	3	10	6.5
Rhus ruspolii	66	0	33

4.4.2 Frequency

The frequency of the tree species in all the 60 plots was computed. Table 10 summarizes the frequency of the ten most frequent woody species in the specified study sites. The most frequent species in Hallona were *Acacia drepanolobium (*23.5%*), Justicia odora* (20.6%) *and Acacia mellifera (*16.2%) while *Acacia bussei (*14.5 %) and *Acacia mellifera* (12%) were the two most frequent species in Medhacho. On average *Acacia drepanolobium* was the top followed by *Justicia odora and Acacia mellifera* in the study site. Dereje Denu (2006) reported the higher the frequency, the more important the plant is in the community. A high frequency value shows that the plant is widely distributed through the study area. Therefore *Acacia drepanolobium* in Hallona and *Acacia bussei* is

in Medhacho were the two most widely distributed woody plant species and they have encroached larger area of the rangeland.

Table 10: Frequency (%) distribution of the ten most frequent woody species in encroached sites.

Scientific name	Medhacho	Hallona
Acacia bussei	14.5	0.0
Acacia drepanolobium	8.4	23.5
Acacia mellifera	12	16.2
Acacia nilotica	9.6	1.5
Acacia oerfota	4.8	0.0
Balanites aegyptiaca	0	14.7
Balanites rotundifolia	0	14.7
Capparis tomentosa	6	0.0
Commiphora africana.	3.6	0.0
Chionothrix latifolia	9.6	0.0
Justicia odora	8.4	20.6
Solanum schimperianum	6	0.0

4.4.3 Basal Area and Relative Dominance

The basal area of all tree/shrub species in the encroached areas as calculated from DBH data was found to be 13 m^2/ha in Medhacho and 8.6m^2/ha in Hallona encroached site (Appendix 9 for details). *Acacia drepanolobium* took the biggest share in the percentage contribution of basal area (52.9%) followed by *Acacia mellifera* (22.5%) in Hallona while *Acacia mellifera* (55.4%) and *Acacia bussei* (31.3%) were the two species with highest contribution to the total basal area per hectare in medhacho encroached site relative to the other species.

4.4.4 Importance Value Index (IVI)

Importance value index combines data for three parameters (relative frequency, relative density and relative abundance). It is useful to compare the ecological significance of species (Lamprecht, 1989). The importance value index for tree/shrubs species was shown in appendix 6. *Acacia drepanolobium, Acacia mellifera* and *Balanites rotundifolia* were the three most important species in Hallona encroached site with IVI (86.28), (46.95) and (26.86), respectively. *Acacia mellifera (*121.93)*, Acacia bussei (*90.74)

Acacia drepanolobium (22.21) ranked from one to three in Medhacho encroached site. High IVI value indicates that the species sociological structure in the community or habitat is high (Dereje Denu, 2006). Therefore the IVI value of the woody plant species in the study site indicated that woody species that were very important in Medhacho were not equaly important in Hallona and vis-versa. The most dominant encroacher in Hallona was *Acacia drepanolobium* while *Acacia mellifera* was the most important in Medhacho. This might have been associated with variation in environmental factors like topography and soil type between the two sites.

4.4.5 Height Distribution

The trees/shrubs in the study area were divided into five height classes. The highest number of individual trees/shrubs was found to be 1555.5/ha representing the height class II. Trees/shrubs in height class I and II, together make 80.9% whereas tree/shrubs in the height classes III, IV and V together are found to be 19.1%. Height has important habitat connotation, for instance only trees and shrubs bellow a certain height can be browsed by various livestock and wildlife species (Alemayehu, 2005).Tree/shrubs with height greater than two meter have less browse value especially for smaller browsers.Smaller browsers will only have access to these leaves when they dry and fall to the ground. Camel can browse trees/shrubs with height up to 3.5m (Abule *et al.,* 2007). So most of the tree/shrubs that were found in the study were within the range of camels that browse on average at 3.5m. This indicates us that increase in population of camels may contribute to control of the woody plant density because of the accesability of the plants.

Table11: The class distribution for trees/shrubs higher than 1m in the study area.

Height	Class	Density per hectare
1m _ 2m	I	893.8
2m_3m	II	1555.5
3m_4m	III	405.0
4m_5m	IV	153.9
>5m	I	18.8

4.5 Regeneration Status of Trees/Shrubs

The species composition and density of seedlings and saplings of tree/shrub species in both Medhacho and Hallona site were considered in this study. The number and type of seedlings and saplings in any vegetation shows the regeneration status of that vegetation (Dereje, 2006).

From this study, 4083 seedlings/ha and 4065 saplings/ha were recorded from 11 tree/shrub species in encroached site whereas 1176 seedlings/ha and 814 saplings/ha were observed from 9 tree/shrub species in non-encroached site on average (Appendix 8). Three species contributed to 84.8% and 91.8 % of the total seedling and sapling count respectively in encroached site. These are *Acacia mellifera*, *Acacia drepanolobium* and *Acacia bussei.* In non-encroached site, *Acacia drepanolobium, Acacia tortilis, Acacia mellifera* and *Acacia nilotica* were species with highest density of the total regeneration. These species contributed 83% and 62.9% of the total density of seedlings and saplings respectively. A total of six species were represented in both seedling and sapling classes, four species were represented only in seedling class, one species was represented only sapling class and three species were absent in regeneration strata and represented by adult plants in encroached site. On the other hands, seven species were represented in seedling and sapling classes, two species were represented only in seedling classes, five species were represented only sapling class whereas five species were absent in regeneration strata in non-encroached site. The ratio of parent plant to seedling was 1:1.46 and 1:5 and that of sapling was 1:1.45 and 1:3.5 in encroached and non-encroached sites respectively.The composition, distribution and density of seedlings and saplings indicate the future status of the vegetation. Higher proportion of young plant (saplings and seedlings) was observed in both encroached and non-encroached areas and this indicates that the encroachment by woody plants may expand to the grass lands and continue as a threat to the productivity and sustainability of the grassland in the study area and need an integrated effort to control the expansion and to minimize the problem, through the participation of the pastoral communities.

For easy of discussion all the species considered in the study area were classified into three groups based upon the density of total regeneration. Accordingly, species that had no seedlings and saplings were grouped under class A, those species whose total density of saplings and seedlings were greater than one and less than one hundred were classified under class B and the species with density greater than hundred were grouped under class C.

Table 12: The regeneration status of different tree species in encroached site.

Regeneration status		
Class A	Class B	Class C
Acacia etabaica	*Acacia seyal*	*Acacia bussei*
Acacia oerfota	*Acacia tortilis*	*Acacia drepanolobium*
Commiphora Africana	*Balanites rotundifolia*	*Acacia mellifera*
	Commiphora sp.	*Acacia nilotica*
	Rhus ruspolii	*Balanites aegyptiaca*
		Maerua triphylla

Table 13: The regeneration status of different tree species in non-encroached site.

Regeneration status		
Class A	**Class B**	**Class C**
Acacia oerfota	*Acacia seyal*	*Acacia bussei*
Balanites rotundifolia	*Commiphora Africana*	*Acacia drepanolobium*
Boswellia neglecta		*Acacia mellifera*
commiphora terebinthina		*Acacia nilotica*
Solanum incanum		*Acacia tortilis*
		Balanites aegyptiaca
		Commiphora sp.

The regeneration status shows that most the woody species that were dominant in encroached site possessed high number of seedlings and saplings in non-encroached (under 'C' category). This high number of seedlings and saplings may indicate that woody plant species that dominated the encroached site were continued to expand and dominate the new sites through seed germination. High number of seedlings and saplings in the already encroached sites also shows that density of the woody plant will increase in the future and bush thickening will continue as a major problem unless an appropriate solution is taken.

4.6 Soil Qaulity

Soil analysis revealed that the mean value of soil pH value was significantly high in non-encroached site (p = 0.05) while the total nitrogen was significantly high in encroached site (p < 0.05). Opposite to this study's result, Gemedo Dalle (2004) reported that pH was positively correlated with woody plant. Highly significant differece (P<=0.001) was observed in organic carbon, organic matter, and exchangeable potassium. The study by Georgiadis (1989) also shows that there was high amount of carbon and nitrogen under the trees and shrubs and a gradual fall as a function of the distance from the trunk, and significantly lower values in the open ground than in sub-canopy soil. No significant difference was observed in available phosphorus, available potassium, calcium and magnesium ions and cation exchange capacity between the encroached and non-encroached sites (p>0.005).

Table 14: Result of soil quality analysis (mean ±SE) in the study area.

Soil parameters	Land type		
	Encroached Mean ± SE	Non-encroached Mean ± SE	P-value
Ava. P(ppm)	3.33 ± 0.25	4.19 ± 0.28	0.28
Total N (%)	0.23 ± 0.03	0.14 ± 0.01	0.02*
OC (%)	2.38 ± 0.17	1.51 ± 0.08	0.00**
Ava. K^+(ppm)	398.41 ± 31.29	337.57 ± 39.19	0.23
Exch. K^+(ppm)	1479.00 ± 113.39	996.80 ± 135.50	0.01**
Ca^{++}(ppm)	10674.50 ± 1234.37	9839.31 ± 1056.63	0.61
Mg^{++} (ppm)	1041.08 ± 78.12	996.19 ± 76.33	0.68
CEC (meq/100g)	45.96±2.77	38.43 ± 3.68	0.11
pH-H2O	7.72 ± 0.08	7.8 ± 0.11	0.05*
OM (%)	4.11 ± 0.29	2.61 ± 0.14	0.00**

* = significant ** highly significant

As was mentioned in table 14, most of the soil nutrients were high in the encroached site. This was more likely, because of the capacity of woody plants to enrich sub-canopy soils through litter fall and decomposition in encroached site. Mack (1977) reported that woody plants act as agents of soil conservation and retaining fertile topsoil beneath the canopy that has been eroded from open areas. This capacity of woody plants to conserve soil might also contribute to better soil nutrients in the encroached site.

Removal of considerable amount herbaceous biomass as the livestock feed might have contributed to less organic matter and other nutrients in the non encroached sites. Scholes and Archer (1997) also repoted that less biomass return causes the reduction of soil organic matter, total nitrogen and available phosphorus in free grazing lands.

4.7 Relationship between Trees/Shrubs, Forbs, Grasses and Bare Land Cover

Tree/shrub canopy cover was strongly negatively correlated with grasses and forbs ground cover (r = -1.00) and positively correlated with bare land ground cover (r= 1.00) in both encroached and non-encroached sites ($P<0.05$). Scholes and Archer (1997) showed that there is strong, negative correlation between tree and grass cover. Accordingly a linear increase in bare land was observed from non-encroached to the encroached sites. The work by Oba *et al*. (2000) also showed that there exist a strong positive correlation between woody plant cover and bare soil. Yates *et al*., (2000) also reported that higher proportion of the bare soil was associated with the density of trees/shrubs. On the contrary, Gemado Dalle (2004) reported that there was a weak negative correlation between bare soil woody plant cover.

4.8 Correlation between Environmental Factors and Species Diversity and Richness

The correlation analysis revealed that tree/shrub density was slightly negatively correlated with pH, Phosphorus, total nitrogen, organic carbon and organic matter, for both the non-encroached and encroached sites whereas magnesium (Mg^{++}) and cation exchange capacity were showed negative correlation with tree/shrub density in non-encroached site and positive correlation in encroached site but only pH value and in encroached site were significantly correlated with tree/shrub density. This shows that tree/shrub density had no significant positive or negative relationship with soil parameters considered in both encroached non-encroached sites the study except pH and magnesium (Mg^{++}) in encroached site. In short no clear relation ship was observed. Andy *et al.,* (1998) also suggested that change in soil characteristics are not required to explain changes in vegetation. On contrary, Gemedo Dalle (2004) reported that in Borana

lowlands soil N, Mg^{++}, CEC, Ca, pH, and P were strongly and positively correlated with the density of woody plants

Table 15: Pearson's correlation coefficient for soil parameters and tree/shrub density in non-encroached and encroached site.

		PH	P(ppm)	%N	%OC	%OM	K^{+}av (ppm)
NE	T/S density	-0.202	-0.153	-0.045	-0.076	-0.076	0.249
E	T/S density	-0.446(*)	0.159	-0.224	-0.130	-0.130	0.297

continued

K^{+}ex(ppm)	Ca^{++} (ppm)	Mg^{++} (ppm)	CEC(meq/100g	T/S density
0.146	0.022	-0.116	-0.108	1.000
0.302	-0.339	0.383(*)	0.055	1.000

* Correlation is significant at the 0.05 level . ** Correlation is significant at the 0.01 level. (2-tailed).

4.9. Pastoralists' Perceptions on Bush Encroachment

4.9.1. Major Constraints of the Livestock Production

The interviewed pastoralists classified the major constraints of the pastoral production system into six groups and explained the negative impacts on the overall livelihood of the pastoral communities (Table 16). About 95% of the respondents in Hallona and 90 % of the respondents in Medhacho metioned that frequent drought as the first obstacle to livestock production. 70% of the respondents at Hallona site and 65% of the respondents at Medhacho site mentioned overgrazing as a major problem. At the same time 65% of the respondents at Hallona site and 55% of the respondents in Medhacho perceived bush encroachment as a major problem. This indicates that majority of the pastoralists have understood bush encroachment as one of the major factors affecting livestock production in the study area.

Table 16: Major constraints to livestock production in the study area

Major constraints	Description of the problem	Impact of the problem
Drought	Became more recurrent Formerly drought was expected with an interval of 7-9 years but now it is impossible to predict and it occurs in two or three years	High livestock mortality Lower prices for livestock More dependency on food aid Increased poverty and destitution Traditional coping mechanisms weakened
Overgrazing	The over all livestock population is increasing Crop farming is introduced to the pastoral production Bush cover is increasing and size of grazing land is decreasing	Decrease feed availability in a dry season Inhibits establishment of grasses Grass cover decreasing and woody cover is increasing
Bush encroachment	Lands that are known as pure grasses land are covered by trees, shrubs and bushes	Decreases grass biomass yield and cause feed shortage. Increases migration for feed Reduces animal productivity It hosts predators
Water shortages	Becoming scarcer, ponds cannot hold water for long period of time	Human and livestock move long distance to get water, increases loss of body weight and death young and weak animals. It also increase the conflict on water resource
Lack of market facilities	Lack of information systems Lack of market infrastructures Lack of Track to transport	Difficulty to access markets Cheaper price for livestock Unplanned livestock sales at loss Loss of producer benefits
Animal disease	Lack of veterinary drug and vaccine supply No early warning systems	Cause more Livestock mortality and risk Total failure in producing productive animals

4.9.2 Major Causes of Feed Shortage

Borana pastoralists who were participated in interview agreed that bush encroachment is among the major factors that causes reduction in grass biomass yield and feed shortage. Over grazing, frequent drought and increase in households number (Olla) were also mention as the major causes.

Table 17: Borana pastoralists' perception on major causes for feed shortage.

Constriants	Percent respondents		
	Hallona	Medhacho	Mean
Drought	70	65	67.5
Bush encroachment	40	45	42.5
Over grazing	30	30	30
Increase in number of house holds	20	15	17.5
Conflicts	10	5	7.5

According to the interviewed pastoralists, formerly some parts of the rangelands were not occupied by human settlements and only used for grazing. But now every corner was occupied by human settlement and no place is reserve to move to during feed shortage. These shows that increase in human and livestock population is aggravating the feed shortage and overgrazing. Bush encroachment was perceived as the second major cause for feed shortage. Richer et al., (2001) found that bush encroachment had an adverse influence on grass biomass production and decrease potential grazing capacity and this is supported by pastoralists' perception. Alemayehu Mengistu (2004) also reported that bush encroachemnt was the fourth major factor contributing to feed shortage in Borana rangelands.

4.9.3 Pastoralists Perceptions on Possible Causes of Bush Encroachments

The interviewed pastoralists mentioned that livestock number per household was decreasing comparing the current situation with the situation befor two decades. But the total livestock population is increasing from time to time due to increase in number of house holds. They also mentioned that the grazing lands that were not visited by livestock during wet season and reserved for dry season are now grazed at a rainy season.Some of the pastoralists says that traditional rangeland management by moving from areas that were used in the rainy season to unused one during dry season is also disturbed now. The pastoralists' ideas indicate the problem of over stocking in the study areas. High stocking density might have caused overgrazing and damaged some grass species that are sensitve to overgrazing and fovoured growth of woody plants. Oba and Kotile (2001) also reported that over stocking aggravates overgrazing and replacement of perennial grasses

with bushes. The contribution of marketing for controlling the livestock pressure is also minimal in the study area.

Pastoralists mentioned that the Borana people, that are the dominant pastoralist group in borana low lands focus on cattle production than browsers. On top of this different species of livestock are kept separately for their own acceptable reasons and grasses and browse are not equally utilized at a particular time. So, imbalance between browsers and grazers also contributed for the expansion of trees and shrubs to the grass land in the study area. Similarly, Joing (2004) stated that increase in domestic livestock (grazers) and a decrease in browsers numbers increases the pressure on the grass layer, the competitive advantage of a vigorous perennial cover declines, and a more creates favorable environment for the woody component.

The pastoralists mentioned they were forced not to burn the rangeland by local government officials starting from the bigning of the derge regium up to 2005. They belive that prohibition of bush burning was exacerbated the problem of bush encroachment. Alemayehu (1998) also reported that prohibition fire in the rangelands have unintentionally facilitated woody encroachment to detriment of rangeland productivity and pastoral carrying capacities in Ethiopia.

Pastoralists also pointed out that ethnic conflicts displaced the Borana pastoralists from their traditional grazing lands as the cause for overstocking and bush encroachment.The displaced population was compressed into a fraction of the former grazing territory where land use became more intensive as opposed to the traditional system. Similarly, SORDU, (1990) reported that water-development and the alienation of a total of 54,000 ha of grazing lands for demonstration ranches in the Liiban and the Dirre production systems of Borana rangelands also caused pressure on the rangelands.According to the key informantes, voluntary sale of livestock is very much limited and rate of off take is low as a result high livestock population is observed in Borana low lands. The pastoralists also mentioned that the Borana rangelands are periodically perturbed by drought and its frequency is increasing from time to time. Raj (2005) also reported that drought followed

by years above-average rainfall event have contribution to the problem of bush thickening.

4.9.4 Impacts of Bush Encroachment

About 50% of the total interviewed pastoralists mentioned bush encroachment as a major cause for reduction in grass biomass yield. Assessment of pastoralists' perceptions confirmed with the research findings.Thurrow (2000) reported that overall woody vegetation reduces grass cover through increasing the competition for available water and nutrients and reducing reaching the grass layer. Often impenetrable bush thickets that result from encroachment monopolize light, water, and nutrients, limiting the amount of grass that can grow underneath (Belsky *et al.,* 1999).

Table18: Major causes for decrease in grass biomass yield mentioned by pastoralist.

Constriants	Percentage of respondents		
	Hallona Site	Medhacho Site	Mean value
Over grazing	50	40	45
Drought	70	70	70
Bush encroachment	50	50	50

In addition to competing with grasses and reduction in biomass yield, noxious woody plants are commonly thorny and thicket- forming so that grasses produced grazing capacity of the rangeland is extremely reduced (Alemayehu, 2004).This idea was also confirmed by pastoralists. Pastoralist also mentioned that trees/shrubs are home for predators which attack their livestock and external parasites like ticks.

4.9.5 Suggested Solutions for Bush Encroachments

4.9.5.1 Bush clearing

47.5% of the interviewed pastoralists recommended bush clearing as a solution for woody plant encroachment. 35% in Hallona and 60% in Medhacho suggested bush clearing. Smit (2005) also indicated that trees and shrubs are known to concentrate nutrients in soil beneath the canopy as a result of litter decomposition.This increases soil fertility, and provides an additional mechanism whereby grass production may be stimulated after woody vegetation is cleared.

Table 19: Solutions suggested by pastoralists to control bush encroachment.

Solutions	Percentage of respondents		
	Hallona	Medhacho	Average
Bush clearings	35	60	47.5
Fire	40	45	42.5
Herd diversification	20	30	25
Government and NGOs Support	0	25	12.5
Area closer	5	15	10
God	5	10	7.5

The pastoralists who did not recommend bush clearing justified that manual bush clearing is insignificant compared to the severity and size of the problem. On top of that the stumps re-sprout and recover after a short period of time. Bush clearing is labor intensive to cover large sized encroached areas. Knoop (1982) also mentioned that on a site dominated by Acacia species, a large number of seedlings germinated and survived in an area cleared of vegetation, but that of few were found in an uncleared area. Clearing has been found to result in marked changes in grass species composition (Ayana, 2002). It is significant that not all changes in species composition with clearing are favourable (Walker 1979 in Ayana, 2002). There was a marked decrease in certain desirable species, and also an increase in certain unpalatable species (Ayana, 2002). On the other hand, bush clearing improved range condition by increasing basal cover of perennial grasses and improving soil condition (Ayana, 2002; Barrow, 1991).

4.9.5.2 Burning

According to elders, fire was used to control the expansion of bush cover and ticks, to remove predator habitats, to improve pasture quality and to facilitate livestock movements in Borana low lands. But it was banned for a long time. 42.5 % of the respondents recommended fire as one of the possible option to control bush encroachment where as the rest are in doubt about the practicality of this option. The role of fire was shown to limit tree recruitment, allowing adult mortality to remain low (Ward, 2005). Fires are known to keep woody seedlings in check, while grasses can survive by virtue of having sensitive tissues safe below ground (Coppock, 1994). Bush fires have proven to affect ecosystems dynamics (Meurer *et al.,* 1994), are used as tool for building and managing grazed ecosystems (Ansley and Castellano, 2006), controlling grasslands invasiveness (Ward, 2005), and improving fodder quality. Those pastoralists who did not recommended fire as a solution put lack of fuel load as a major problem to burn the bushes. Formerly when pastoralists plan to burn a given land, they keep the land to be burnt free of livestock for one growing season and grass is used as a fuel to burn trees and shrubs. But now due high livestock population and lack of feed, every corners of the rangeland are grazed and there is no sufficient grass to burn bushes. Scholes & Archer (1996) also reported that once established, bush encroachment accelerates the decline in grass cover, while the intensification of grazing pressure reduces the fuel load required for fire to burn the bush cover.

4.9.5.3 Herd Diversification

Herd diversification is also pointed out as one of the solution for bush encroachment by some respondents because browsers and grazers depends on different feeds resources and this reduces computation for specific feed type and improve utilization of the available resources. 25 % of the respondents mentioned herd diversification as a possible solution to reduce impacts of bush encroachment. Alemayehu Mengistu (2004) also mentioned the advantage of species diversification that the more different animal species that exploit vegetation, the more plant species colonize the region and biodiversity is correspondingly high. Result from survey works done in 1996/7 shows that cattle represent 73%, goats

15%, sheep 6.5% camel 4%(15,000) and equine 1.5% of the total population (Solomon Desta, 2000). According to report from Borana zone pastoralist development bearou (2006), the numbers of camels and goats have increased from 4% (15,000) to 4.46% (106,366) and 15% to 19.73% respectively while the percentage of cattle population decreased from 73% to 65.31% with in one decade. This shift is likely in response to bush encroachment that benefit browsing camels and goats over and their ability to tolerate drought.

5. Conclusions and Recommendations

5.1 Conclusions

The encroached sites of Hallo and Medhacho rangelands are under sever threat of bush thickening. Alteration of rangeland habitat by Bush encroachment might have caused lose of some herbaceous species in encroached sites. Bush encroachment adversely affected the over plant diversty in the study area. Bush encroachment affects the species richness of the herbaceous plants that are not grass more than the grasses family.Both annual and perennial herbaceous plants species richness decreases with bush encroachment. Herbaceous plant cover decreases while percentage of bare land increases with bush encroachment.

Acacia *drepanolobium, Acacia mellifera* and *Acacia bussei* were the most important encroaching woody plants in the study area. *Acacia mellifera and Acacia drepanolobium* are multiplying themselves and expanding to new areas at a faster rate than other species.The woody plants will encroache to the new areas and dominate the rangelands unless quick and approperiate major is taken. The amount of most soil nutrients increase as the rangeland is encroached by woody plants. Bush encroachment was recognized by pastoralists as one of the major threats to livestock production. Prohibition of fire by local officials, disturbance of tradition rangeland management and frequent drought were the major causes of bush encroachment in the study area.

5.2 Recommendations

- Grasslands that are encroached by woody plant may not easily be restored by implementing a single controlling method. But implementation of different activities like burning, mechanical bush clearing and responding to drought by setting up efficient monitoring system that allows timely feedback of information to decision makers must be used simultaneously
- Reducing livestock number by providing market facilities and improving productivity per head decrease the contribution of overgrazing to expansion of bush encroachment. On the other hand part of rangelands can be kept free of grazing and disturbance for one rainy season to use grass as a fuel to burn the rangelands.
- Awareness should be raised among the pastoralists to avoid the social attachments of livestock.
- Property rights and collective action are important for technological innovation and adoption and thus for sustainable grassland management due to the incentives they provide.
- A primary attention should be given to protecting open grasslands not to be encroached with bushes. Use of the indigenous knowledge supported by scientific methods and communities participation is crucial to control expansion of bush encroachment to open grass land.
- According to elder pastoralists, bush encroachment was not a major problem before two to three decades and it was controlled traditionally. Hence it is appropriate to revisit traditional knowledge of rangeland management and incorporate into rangeland management plan of the governmental and non-governmental organization.
- The pastoralist should be conscious to diversify their livestock species more so that browsers can utilize the available woody plants as a feed source and also contribute to the efforts to control expansion of bush encroachment.
- Since bush clearing is labor intensive, government should provide socio-economic incentives like food for work program that would encourage pastoralists' participation in restoring the land.

- Potential for charcoal production and other wood industries of the tree/shrubs that are encroaching to the rangeland should be assessed so that it can be cleared selectively and used for charcoal and other industrial production.

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Appendices

Appendix 1. Botanical and local names of plant species studied in Medhacho and Hallona pastoralist associations.

S. no.	Species name	Vernacular name	Family name
1	*Abutilon figarianum* Webb	Darguu	Malvaceae
2	*Abutilon hirtum* (Lam.) Sweet	Gurbii	Malvaceae
3	*Acacia bussei* Harms ex sjostedt	Halloo	Fabaceae
4	*Acacia drepanolobium* Harms ex sjostedt	Fulleensa	Fabaceae
5	*Acacia etabaica* Schweinf.	Hallaqabeessa	Fabaceae
6	*Acacia mellifera* (Vahl) Benth	Saphansa	Fabaceae
7	*Acacia nilotica* (L) Willd. ex. Del	Burquqqee	Fabaceae
8	*Acacia oerfota* (Forssk) Schweinf.	Waangaa	Fabaceae
9	*Acacia seyal* Var. fistula (Schweinf) Oliv.	Waaccuu	Fabaceae
10	*Acacia tortilis* (Forssk.) Hayne	Dhaddacha	Fabaceae
11	*Achyranthes aspera* L.		Amaranthaceae
12	*Aerva lanata* (L.) Juss. Ex Schultes	Ababa	Amaranthaceae
13	*Albuca abyssinica* Jacq.	Qorsa bofaa	Hyacinthaceae
14	*Amaranthus thunbergii* Moq.	Raafuu	Amaranthaceae
15	*Aristida adoensis* Hochst.	Saamphillee	Poaceae
16	*Asystasia mysorensis* (Roth) T. Anders.	Qilxiphee Harree	Acanthaceae
17	*Balanites aegyptiaca* (L.) Del.	Baddan Lu'oo	Balanitaceae
18	*Balanites rotundifolia* (Var.rotundifolia)	Baddan Okolee	Balanitaceae
19	*Barleria argentea* Balf. f.	Gurbii	Acanthaceae
20	*Barleria quadrispina* Lindau	Qilxiphee	Acanthaceae
21	*Barleria sp*. (Mooney 5618)		Anthericaceae
22	*Bidens hildebrandtii* O. Haffm.	Abunee	Asteraceae
23	*Blepharis ciliaris (*L.) Burm.f		Acanthaceae
24	*Boswellia neglecta* S. Moore	Dakkara	Burseraceae
25	*Capparis tomentosa* Lam.	Ogoraa-Gaalaa	Cappararidaceae
26	*Cenchrus ciliaris* L.	Mataguddeessa Adii	Poaceae
27	*Chenopodium opulifolium* Schrader ex Koch and Ziz.	Ononnoo	Chenopodiaceae
28	*Chenopidium schraderianum* Schult	Darguu	Chenopodiaceae
29	*Chionothrix latifolia* Rendle	Garbicha	Amaranthaceae
30	*Chloris roxburghiana* Schult.	Iddoo	Poaceae
31	*Chlorophytum gallabatense* Schweinf. ex Baker	Miirtuu	Anthericaceae
32	*Chrysopogon aucheri* (Boiss) Stapf	Alaloo	Poaceae
33	*Commelina Africana* L.	Qaayyoo	Commelinacea
34	*Commelina stephaniniana* Chiov.		Commelinaceae
35	*Commicarpus peduduncu*losus (A. Rich.) Cufod.	Araddoo	Nyctaginaceae
36	*Commiphora africana* (A. Rich.) Engl.	Hammessa Dhiroo	Burseraceae
37	*Commiphora sp.*(Friis *et al.*3160)	Hammeessa Hoomachoo	Burseraceae
38	*commiphora terebinthina* Vollesen	Sanga Igguu	Burseraceae
39	*Crepis foetida* L.	Qanxalaa	Asteraceae
40	*Crossandra spinosa Beck*	Unknpwn-3	Acanthaceae
41	*Cynodon dactylon* (L.) Peris.	Qarcaa/ Sardoo	Poaceae

S. no.	Species name	Vernacular name	Family name
42	*Cyperus amauropus* Steud.	Saattuu	Cyperaceae
43	*cyperus bulbosus* Vahl	Saattuu Arbaa	Cyperaceae
44	*Cyperus sp.*	Saattuu Gororrii	Cyperaceae
45	*Cyphostemma cyphopetalum* (Fresen.) Descoings ex Wild and Drummond	Cophii-Badheessoo	Vitaceae
46	*Eragrostis aspera* (Jacq.) Nees	Saamphillee	Poaceae
47	*Eragrostis papposa* (Roem and Schult.) Steud.	Saamphillee	Poaceae
48	*Euphorbia nubica* N.E.Br.	Aannoo	Euphorbiaceae
49	*Euphorbia polycnemoides* Boiss	Qorsa Haxxiisoo	Euphorbiaceae
50	*Euphorbia tirucalli* L.	Qorsa Diidaa	Euphorbiaceae
51	*Grewia villosa* Wild.	Ogondii	tiliaceae
52	*Gutenbergia somalensis* (O. Hoffm.) M.G. Gilbert	Qaaxxee	Asteraceae
53	*Heliotropium longiflorum* (A. DC. In DC.) Jaub. and Spach.	Darguu	Boraginaceae
54	*Heteropogon contortus* (L.) Roem. And Schult.	Sheericha	Poaceae
55	*Hibiscus flavifolius* Ulbr.	Bungala Dhalaa	Malvaceae
56	*Hibiscus micranthus* L.	Bugaala Korma	Malvaceae
57	*Hypoestes forskoalii* (Vahl) R.Br		Acanthaceae
58	*Indigofera spiniflora* Boiss	Iccinnii	Fabaceae
59	*Indigofera volkensii*. Taub.	Hiddii Hurrii	Fabaceae
60	*Ipomoea kituiensis* (Vatke)	Osilee	Convolvulaceae
61	*Ipomoea marmorata* Britt. and Rendle	Obbee	Convolvulaceae
62	*Ipomoea sp.*(Fiirs *et al.* 8465)	Dambiisuu Allattii	Convolvulaceae
63	*Justicia odora (*Forssk) Lam.	Agaggaroo Harree	Acanthaceae
64	*Kleinia picticaulis* (Bally) C. Jeffrey.	Garroo	Asteraceae
65	*Klenia picticaulis* (Bally) C. Jeffery	Gurroo	Asteraceae
66	*Klenia squarrosa* cufod.	Xixxiixuu	Asteraceae
67	*Lantana rhodesiensis* Moldenke	Midhaan Dubraa	Verbenaceae
68	*Leucas abyssinica* (Benth.) Briq.	Gungumaa Korbeessaa	Lamiaceae
69	*Lintonia nutans* Stapf.	Luucolee	Poaceae
70	*Loudetia arundinaceae* (Hochst ex. A. Rich.) Steud.	Alaloo	Poaceae
71	*Maerua triphylla* A. Rich.	Dhumasoo	Cappararidaceae
72	*Medicago minima* (L.) Bartal.	Anqarree	Fabaceae
73	*Ocimum forskolei Benth.*	Urgoo Dhadhaa	Lamiaceae
74	*Ocimum lamiifolium Hochst. Ex Benth.*	Urgoo Haree	Lamiaceae
75	*Osteoapermum vailliantii* (Decne) T. Norl.	Hadaa	Asteraceae
76	*Oxygonum sinuatum* (Meisn.*)* Dammer	Mogorree	Polygonaceae
77	*Panicum maximum* Jacq.	Mataguddeessa Diimaa	Poaceae
78	*Pennisetum polystachion* (L.) Schult.	Ogonhoo Diimaa	Poaceae
79	*Pennisetum thunbergii* Kunth.	Ogondhoo Adii	Poaceae
80	*Pentarrihum somaliense(N.E.Br.) Liede*	Goorrisa	Asteraceae
81	*Phagnalon abyssinicum* Sch. Bip.ex.A.Rich	Maaracaa	Asteraceae
82	*Plectranthus igniarius* (Schweinf.) Agnew	Barbarreessa	Lamiaceae
83	*Pupalia lappaceae* (L.) A. Juss	Qilxiphee	Amaranthaceae

S. no.	Species name	Vernacular name	Family name
84	*Rhus ruspolii* Engl.	Daboobessaa	Anacardiaceae
85	*Seddra peduncutata* (Balf.f.)Verdc.		Convolvulaceae
86	*Setaria verticillata* (L.) P. Beauv.	Raaphuphaa	Poaceae
87	*Solanum capsicoides* Allioni	Hiddii	Solanaceae
88	*Solanum giganteum* Jacq.	Hiddii Loonii	Solanaceae
89	*Solanum glabratum* Dunal		Solanaceae
90	*Solanum incanum* L.	Hiddii Waatoo	Solanaceae
91	*Solanum schimperianum* Hochst ex. A. Rich.	Hiddii Re'ee	Solanaceae
92	*Tagetes minuta* L.	Suunkii	Asteraceae
93	*Vernonia turbinata* Oliv. and Hiern		Asteraceae
94	*Xerophyta humilis* (Baker) Th. Dur. and Schinz	Areedoo	velloziaceae

Appendix 2: Woody plants species composition of the study sites.

Table 2a: Woody plants species composition of Hallona non-encroached site.

No.	Family	Genera	% Proportion	Species within genera
1	Fabaceae	Acacia	38.46	*A. bussei, A. drepanolobium , A.nilotica, A.seyal, A. tortilis*
2	Balanitaceae	Balanites	15.38	*B. aegyptiaca, B. rotundifolia*
3	Commelinacea	Commiphora	15.38	*C. Africana, Commiphora sp.*
4	Acanthaceae	Justicia	7.69	*J. odora*
5	Solanaceae	Solanum	23.1	*S. capsicoides*, *S. giganteum, S. Incanum,*
	Total	5	100.00	13

Table 2b: Woody plants speies composition of Hallona non-encroached site.

No.	Family	Genera	% Proportion	Species within genera
1	Fabaceae	Acacia	33.33	*A. drepanolobium A. mellifera, A.nilotica,*
2	Balanitaceae	Balanites	22.22	*B. aegyptiaca, B. rotundifolia*
3	Cappararidaceae	Capparis	11.11	*C. tomentosa*
4	Acanthaceae	Justicia	11.11	*J. odora*
5	Anacardiaceae	Rhus	11.11	*R. ruspolii*
6	Solanaceae	Solanum	11.11	*S. giganteum,*
	Total		100.00	9

Table 2c: Woody plants species composition of Medhacho encroached site

No.	Family name	Genera	% Proportion	Species within genera
1	Fabaceae	Acacia	44.4	*A. bussei, A. drepanolobium A. etabaica, A. mellifera, A.nilotica, A. oerfata, A. .seyal, A. tortilis*
2	Balanitaceae	Balanites	5.6	*B. aegyptiaca,*
	Cappararidaceae	Capparis	5.6	*C. tomentosa*
3		Maerua	5.6	*M. triphylla*
4	Commelinacea	Commiphora	11.1	*C. Africana, Commiphora sp.*
5	Amaranthaceae	Chionotrix	5.6	*C. latifolia*
6	Tiliaceea	Grewia	5.6	*G. villosa*
7	Acanthaceae	Justicia	5.6	*J. odora*
8	Solanaceae	Solanum	11.1	*S. capsicoides*, *S. schimperianum*
	Total	9	100.0	18

Table 2d: Woody plants species composition of Medhacho encroached site

No.	Family name	Genera	% Proportion	Species within genera
1	Fabaceae	Acacia	33.33	*A. bussei, A. drepanolobium, A. mellifera, A. nilotica, A. oerfata, A. seyal, A. tortilis*
2	Balanitaceae	Balanites	9.52	*B. aegyptiaca, B. rotundifolia*
	Burseraceae	Boswellia	4.76	*B. neglecta*
3		commiphora	4.76	*C. terebinthina*
4	Cappararidaceae	Capparis	4.76	*C. tomentosa*
5	Commelinacea	Commiphora	9.52	*C. Africana, Commiphora sp.*
7	Amaranthaceae	Chionotrix	4.76	*C. latifolia*
8	Boraginaceae	Heliotropium	4.76	*H. longiflorum*
9	Convolvulaceae	Ipomoea	4.76	*I. kituiensis*
10	Acanthaceae	Justicia	4.76	*J. odora*
11	Solanaceae	Solanum	14.29	*S. capsicoides*, *S. Incanum, S. schimperianum*
	Total	10	100.00	21

Appendix 3: Grass Species Composition of the Study Area.

Table 3a: Grass species composition of the encroached site.

Family name	Genera	% Proportion	Species within genera
Poaceae	Aristida	7.69	*A. adoensis,*
	Cenchrus	7.69	*C. ciliaris*
	Chloris	7.69	*C. roxburghiana*
	Chrysopogon	7.69	*C. aucheri*
	Cynodon	7.69	*C. dactylon*
	Eragrostis	15.38	*E. aspera, E. papposa*
	Lintonia	7.69	*L. nutans*
	Panicum	7.69	*P. maximum*
	Pennisetum	15.38	*P. polystachion*, *P. thunbergii*
	Loudetia	7.69	*L. arundinaceae*
	Setaria	7.69	*S. verticillata*
Total	11	100.00	13

Table 3b: Grass species composition of the non-encroached site.

Family	Genera	% Proportion	Species within genera
Poaceae	Aristida	7.14	*A. adoensis,*
	Cenchrus	7.14	*C. ciliaris*
	Chloris	7.14	*C. roxburghiana*
	Chrysopogon	7.14	*C. aucheri*
	Cynodon	7.14	*C. dactylon*
	Eragrostis	14.29	*E. aspera, E. papposa*
	Heteropogon	7.14	*H. contortus*
	Lintonia	7.14	*L. nutans*
	Panicum	7.14	*P. maximum*
	Pennisetum	14.29	*P. polystachion*, *P. thunbergii*
	Loudetia	7.14	*L. arundinaceae*
	Setaria	7.14	*S. verticillata*
Total	12	100.00	14

Table 3c: Grass species composition of the Hallona non-encroached site.

Family	Genera	% Proportion	Species within genera
Poaceae	Aristida	7.14	*A. adoensis,*
	Cenchrus	7.14	*C. ciliaris*
	Chloris	7.14	*C. roxburghiana*
	Chrysopogon	7.14	*C. aucheri*
	Cynodon	7.14	*C. dactylon*
	Eragrostis	14.29	*E. aspera, E. papposa*
	Heteropogon	7.14	*H. contortus*
	Lintonia	7.14	*L. nutans*
	Panicum	7.14	*P. maximum*
	Pennisetum	14.29	*P. polystachion*, *P. thunbergii*
	Loudetia	7.14	*L. arundinaceae*
	Setaria	7.14	*S. verticillata*
Total	12	100.00	14

Table 3d: Grass species composition of the Hallona encroached site.

Family	Genera	% Proportion	Species within genera
Poaceae	Aristida	9.09	*A. adoensis,*
	Cenchrus	9.09	*C. ciliaris*
	Chloris	9.09	*C. roxburghiana*
	Eragrostis	18.18	*E. aspera, E. papposa*
	Lintonia	9.09	*L. nutans*
	Panicum	9.09	*P. maximum*
	Pennisetum	18.18	*P. polystachion*, *P. thunbergii*
	Loudetia	9.09	*L. arundinaceae*
	Setaria	9.09	*S. verticillata*
Total	13	100.00	12

Table 3e: Grass species composition of the Medhacho encroached site.

Family	Genera	% Proportion	Species within genera
Poaceae	Aristida	14.29	*A. adoensis,*
	Cenchrus	14.29	*C. ciliaris*
	Chrysopogon	14.29	*C. aucheri*
	Cynodon	14.29	*C. dactylon*
	Eragrostis	28.57	*E. aspera, E. papposa*
	Heteropogon	14.29	*H. contortus*
Total	6	100.00	7

Table 3f: Grass species composition of the Medhacho non-encroached site.

Family name	Genera	% Proportion	Species within genera
Poaceae	Aristida	9.09	*A. adoensis,*
	Cenchrus	9.09	*C. ciliaris*
	Chloris	9.09	*C. roxburghiana*
	Chrysopogon	9.09	*C. aucheri*
	Cynodon	9.09	*C. dactylon*
	Eragrostis	18.18	*E. aspera, E. papposa*
	Panicum	9.09	*P. maximum*
	Pennisetum	18.18	*P. polystachion, P. thunbergii*
	Setaria	9.09	*S. verticillata*
Total	9	100.00	11

Appendix 4: Forbs Species Composition of the Study Site.

Table 4a: Forbs species composition of the non-encroached site.

No.	Family name	Genera	% Proportion	Species within genera
1	Acanthaceae	Asystasia	1.89	*A. mysorensis*
		Barleria	3.77	*B. argentea, B. quadrispina*
		Blepharis	1.89	*B. ciliaris*
		Crossandra	1.89	*C. spinosa*
		Hypoestes	1.89	*H. forskoalii*
2	Amaranthaceae	Achyranthes	1.89	*A.. aspera*
		Aerva	1.89	*A. lanata ,*
		Amaranthus	1.89	*A. thunbergii*
		Pupalia	1.89	*P. lappaceae*
3	Anthericaceae	Barleria	1.89	*Barleria sp.*
		Chlorophytum	1.89	*C. gallabatense*
4	Asteraceae	Bidens	1.89	*B. hildebrandtii*
		Crepis	1.89	*C. foetida*
		Gutenbergia	1.89	*G. somalensis*
		Kleinia	1.89	*K. picticaulis,*
		Osteospermum	1.89	*O. vailliantii*
		Pentarrihum	1.89	*P. somaliense*
		Phagnalon	1.89	*P. abyssinicum*
		Tagetes	1.89	*T. minuta*
		Vernonia	1.89	*V. turbinata*
5	Chenopodiaceae	Chenopodium	3.77	*C. opulifolium, C. schraderianum*

No.	Family name	Genera	% Proportion	Species within genera
6	Commelinaceae	Commelina	3.77	*C. Africana, C. stephaniniana*
7	Convolvulaceae	Ipomoea	3.77	*I. marmorata , Ipomoea sp.*
		Seddra	1.89	*S. peduncutata*
8	Cyperaceae	Cyperus	5.66	*C. amauropus , C. bulbosus , Cyperus sp.*
9	Euphorbiaceae	Euphorbia	5.66	*E. nubica , E. polycnemoides, E. tirucalli*
10	Fabaceae	Indigofera	3.77	*I. spiniflora, I. volkensii*
		Medicago	1.89	*M. minima*
11	Hyacinthaceae	Albuca	1.89	*A. abyssinica*
12	Lamiaceae	Leucas	1.89	*L. abyssinica,*
		Ocimum	3.77	*O. forskolei, O. lamiifolium*
		Plectranthus	1.89	*P. igniarius*
13	Malvaceae	Abutilon	3.77	*A. figarianum*, *A. hirtum*
		Hibiscus	3.77	*H. flavifolius, H. micranthus*
14	Nyctaginaceae	Commicarpus	3.77	*C. peduduncolosus, C. plumbagineus*
15	Polygonaceae	Oxygonum	1.89	*O. sinuatum*
16	Solanaceae	Solanum	1.89	*S. glabratum*
17	Velloziaceae	Xerophyta	1.89	*X. humilis*
18	Verbenaceae	Lantana	1.89	*L. rhodesiensis*
19	Vitaceae	Cyphostemma	1.89	*C. cyphopetalum*
	Total	40	100.00	53

Table 4b: Forbs species composition of the encroached site.

No.	Family	Genera	% Proportion	Species within genera
1	Acanthaceae	Asystasia	2.56	*A. mysorensis*
		Barleria	5.13	*B. argentea, B. quadrispina ,*
		Blepharis	2.56	*B. ciliaris*
		Crossandra	2.56	*C. spinosa*
		Hypoestes	2.56	*H. forskoalii*
2	Amaranthaceae	Achyranthes	2.56	*A.. aspera*
		Aerva	2.56	*A. lanata ,*
		Amaranthus	2.56	*A. thunbergii*
		Pupalia	2.56	*P. lappaceae*
3	Anthericaceae	Barleria	2.56	*Barleria sp.*
4		Bidens	2.56	*B. hildebrandtii*
		Crepis	2.56	*C. foetida*
		Gutenbergia	2.56	*G. somalensis*
	Asteraceae	Kleinia	2.56	*K. squarrosa*
		Osteospermum	2.56	*O. vailliantii*
		Pentarrihum	2.56	*P. somaliense*
		Phagnalon	2.56	*P. abyssinicum*
		Tagetes	2.56	*T. minuta*
5	Chenopodiaceae	Chenopodium	2.56	*C. opulifolium*
6	Commelinacea	Commelina	5.13	*C. Africana, C. stephaniniana*
7	Convolvulaceae	Ipomoea	2.56	*Ipomoea sp.*
		Seddra	2.56	*S. peduncutata*

No.	Family	Genera	% Proportion	Species within genera
8	Cyperaceae	Cyperus	5.13	*C. bulbosus , Cyperus sp.*
9	Euphorbiaceae	Euphorbia	5.13	*E. polycnemoides, E. tirucalli*
10	Fabaceae	Indigofera	2.56	*I. spiniflora ,*
11	Lamiaceae	Leucas	2.56	*L. abyssinica,*
		Ocimum	2.56	*O. lamiifolium*
		Plectranthus	2.56	*P. igniarius*
12	Malvaceae	Abutilon	5.13	*A. figarianum, A. hirtum*
		Hibiscus	5.13	*H. flavifolius, H. micranthus*
13	Nyctaginaceae	Commicarpus	2.56	*C. peduduncolosus,*
14	Polygonaceae	Oxygonum	2.56	*O. sinuatum*
15	Verbenaceae	Lantana	2.56	*L. rhodesiensis*
	Total	33	100.00	39

Table 4c: Forbs species composition of Hallona encroached site.

N0.	Family	Genera	% Proportion	Species within genera
1	Acanthaceae	Asystasia	3.57	*A. mysorensis*
		Blepharis	3.57	*B. ciliaris*
		Crossandra	3.57	*C. spinosa*
		Hypoestes	3.57	*H. forskoalii*
2	Amaranthaceae	Achyranthes	3.57	*A.. aspera*
		Pupalia	3.57	*P. lappaceae*
		Aerva	3.57	*A. lanata ,*
		Amaranthus	3.57	*A. thunbergii*
3	Anthericaceae	Barleria	3.57	*Barleria sp.*
4	Asteraceae	Crepis	3.57	*C. foetida*
		Gutenbergia	3.57	*G. somalensis*
		Osteospermum	3.57	*O. vailliantii*
		Pentarrihum	3.57	*P. somaliense*
		Phagnalon	3.57	*P. abyssinicum*
		Tagetes	3.57	*Tagetes minuta*
5	Chenopodiaceae	Chenopodium	3.57	*C. opulifolium*
6	Commelinacea	Commelina	7.14	*C. Africana, C. stephaniniana*
7	Convolvulaceae	Ipomoea	3.57	*Ipomoea sp.*
8	Cyperaceae	Cyperus	3.57	*Cyperus sp.*
9	Euphorbiaceae	Euphorbia	3.57	*E. polycnemoides,*
10	Fabaceae	Indigofera	3.57	*I. spiniflora ,*
11	Lamiaceae	Leucas	3.57	*L. abyssinica,*
12	Malvaceae	Abutilon	3.57	*A. hirtum*
		Hibiscus	3.57	*H. flavifolius,*
13	Nyctaginaceae	Commicarpus	3.57	*C. peduduncolosus*
14	Polygonaceae	Oxygonum	3.57	*O. sinuatum*
15	Verbenaceae	Lantana	3.57	*L. rhodesiensis*
	Total	27	100	28

Table 4d: Forbs species composition of Hallona non-encroached site.

No.	Family	Genera	% Proportion	Species within genera
1	Acanthaceae	Asystasia	3.23	*A. mysorensis*
		Blepharis	6.45	*B. ciliaris, B. quadrispina*
		Crossandra	3.23	*C. spinosa*
2	Amaranthaceae	Achyranthes	3.23	*A.. aspera*
		Aerva	3.23	*A. lanata ,*
		Pupalia	3.23	*P. lappaceae*
3	Anthericaceae	Barleria	3.23	*Barleria sp.*
		Chlorophytum	3.23	*C. gallabatense*
4	Asteraceae	Crepis	3.23	*C. foetida*
		Osteospermum	3.23	*O. vailliantii*
		Pentarrihum	3.23	*P. somaliense*
		Phagnalon	3.23	*P. abyssinicum*
		Vernonia	3.23	*V. turbinata*
5	Commelinacea	Commelina	6.45	*C. Africana, C. stephaniniana*
6	Convolvulaceae	Ipomoea	3.23	*Ipomoea sp.*
7	Cyperaceae	Cyperus	6.45	*C. bulbosus , Cyperus. sp.*
8	Euphorbiaceae	Euphorbia	6.45	*E. nubica , E. polycnemoides,*
9	Fabaceae	Indigofera	3.23	*I. spiniflora ,*
		Medicago	3.23	*M. minima*
10	Lamiaceae	Ocimum	6.45	*O. forskolei, O. lamiifolium*
11	Malvaceae	Abutilon	6.45	*A. figarianum, A. hirtum*
		Hibiscus	3.23	*H. flavifolius,*
12	Nyctaginaceae	Commicarpus	3.23	*C. peduduncolosus,*
13	Polygonaceae	Oxygonum	3.23	*O. sinuatum*
14	Verbenaceae	Lantana	3.23	*L. rhodesiensis*
	Total	25	100.00	31

Table 4e: Forbs species composition of Medhacho encroached site.

No.	Family	Genera	% Proportion	Species within genera
1	Acanthaceae	Barleria	7.41	*B. argentea, B. quadrispina ,*
		Blepharis	3.70	*B. ciliaris*
		Crossandra	3.70	*C. spinosa*
		Hypoestes	3.70	*H. forskoalii*
2	Amaranthaceae	Achyranthes	3.70	*A.. aspera*
		Amaranthus	3.70	*A. thunbergii*
		Pupalia	3.70	*P. lappaceae*
3	Anthericaceae	Barleria	3.70	*Barleria sp.*
4		Bidens	3.70	*B. hildebrandtii*
		Gutenbergia	3.70	*G. somalensis*
	Asteraceae	Kleinia	3.70	*K. squarrosa*
		Pentarrihum	3.70	*P. somaliense*
		Phagnalon	3.70	*P. abyssinicum*
5	Chenopodiaceae	Chenopodium	3.70	*C. opulifolium*
6	Commelinacea	Commelina	3.70	*C. Africana*
7	Convolvulaceae	Seddra	3.70	*S. peduncutata*

No.	Family	Genera	% Proportion	Species within genera
8	Cyperaceae	Cyperus	3.70	*C. bulbosus*
9	Euphorbiaceae	Euphorbia	3.70	*E. tirucalli*
10	Fabaceae	Indigofera	3.70	*I. spiniflora*
11	Lamiaceae	Leucas	3.70	*L. abyssinica*
		Plectranthus	3.70	*P. igniarius*
12	Malvaceae	Abutilon	7.41	*A. figarianum*, *A. hirtum*
		Hibiscus	7.41	*H. flavifolius, H. micranthus*
13	Verbenaceae	Lantana	3.70	*L. rhodesiensis*
	Total	24	100.00	27

Table 4f: Forbs species composition of Medhacho encroached site.

No.	Family name	Genera	% Proportion	Species within genera
1	Acanthaceae	*Barleria*	6.06	*B. argentea, B. quadrispina ,*
		Blepharis	3.03	*B. ciliaris*
		Crossandra	3.03	*C. spinosa*
		Hypoestes	3.03	*H. forskoalii*
2	Amaranthaceae	*Achyranthes*	3.03	*A.. aspera*
		Aerva	3.03	*A. lanata ,*
		Amaranthus	3.03	*A. thunbergii*
3	Anthericaceae	*Barleria*	3.03	*Barleria sp.*
4	Asteraceae	*Bidens*	3.03	*B. hildebrandtii*
		Gutenbergia	3.03	*G. somalensis*
		Pentarrihum	3.03	*P. somaliense*
		Kleinia	3.03	*K. picticaulis,*
5	Chenopodiaceae	*Chenopodium*	3.03	*C. opulifolium*
6	Commelinacea	*Commelina*	6.06	*C. Africana, C. stephaniniana*
7	Convolvulaceae	*Ipomoea*	3.03	*I. marmorata ,*
		Seddra	3.03	*S. peduncutata*
8	Cyperaceae	*Cyperus*	9.09	*C. amauropus , C. bulbosus , Cyperus sp.*
9	Euphorbiaceae	*Euphorbia*	6.06	*E. nubica , E. tirucalli*
10	Fabaceae	*Indigofera*	6.06	*I. spiniflora , I. volkensii*
11	Hyacinthaceae	*Albuca*	3.03	*A. abyssinica*
12	Lamiaceae	*Leucas*	3.03	*L. abyssinica,*
13	Malvaceae	*Abutilon*	6.06	*A. figarianum, A. hirtum*
		Hibiscus	6.06	*H. flavifolius, H. micranthus*
14	Nyctaginaceae	*Commicarpus*	3.03	*C. peduduncolosus,*
15	Vitaceae	*Cyphostemma*	3.03	*C. cyphopetalum*
	Total	26	100	33

Appendix 5: Density per Hectare of Each Adult Trees/Shrubs.

Table 5a. Density per hectare of each adult trees/shrubs species in encroached site.

Species name	Vernacular name	Hallona	Medhacho	Mean
Acacia bussei	Halloo	0.0	1093.0	546.5
Acacia drepanolobium	Fulleensa	1894.0	183.0	1038.5
Acacia etabaica	Hallaqabeessa	0.0	5.0	2.5
Acacia mellifera	Saphansa	455.0	1425.0	940.0
Acacia nilotica	Burquqqee	2.0	52.0	27.0
Acacia oerfota	Waangaa	0.0	168.0	84.0
Acacia seyal	Wachuu	0.0	2.0	1.0
Acacia tortilis	Dhaddacha	0.0	7.0	3.5
Balanites aegyptiaca	Baddan lu'oo	59.0	42.0	50.5
Balanites rotundifolia	Baddan Okolee	111.0	0.0	55.5
Commiphora africana	Hammeessa dhiroo	0.0	8.0	4.0
Commiphora sp.	Hammeessa homacho	0.0	3.0	1.5
Maerua triphylla	Dhumasoo	3.0	10.0	6.5
Rhus ruspolii	Daboobessaa	66.0	0.0	33.0
Total		2589.0	2998.0	2793.5

Table 5b: Density per hectare of each adult trees/shrubs species in non-encroached site.

Species name	Vernacular name	Hallona	Medhacho	Mean
Acacia bussei	Halloo	1.8	51.7	26.8
Acacia drepanolobium	Fulleensa	67.9	3.3	35.6
Acacia mellifera	Saphansa	0.0	8.3	4.2
Acacia nilotica	Burquqqee	8.9	38.3	23.6
Acacia oerfota	Waangaa	0.0	25.0	12.5
Acacia seyal	Waaccuu	7.1	15.0	11.1
Acacia tortilis	Dhaddacha	8.9	46.7	27.8
Balanites aegyptiaca	Baddan Lu'oo	35.7	0.0	17.9
Balanites rotundifolia	Baddan Okolee	16.1	0.0	8.1
Boswellia neglecta	Dakkara	5.4	0.0	2.7
Commiphora africana	Hammesa dhiroo	55.4	36.7	46.0
Commiphora sp.	Hammeessa homachoo	0.0	30.0	15.0
Commiphora terebinthina	Sangaa igu	0.0	3.3	1.7
Solanum incanum	Hiddii waatoo	0.0	0.0	0.0
Total		207.2	258.4	232.8

Appendix 6: Importance Value Index (IVI) of Woody Plants.

Table 6a: Importance value index (IVI) of woody plants in encroached site.

Species Name	R. frequency	R. density	R. dominance	IVI
Acacia bussei	11.22	2.53	18.33	32.07
Acacia drepanolobium	21.5	5.10	23.67	50.27
Acacia etabaica	0.94	0.01	0.03	0.97
Acacia mellifera	20.56	4.42	42.57	67.55
Acacia nilotica	8.41	0.12	1.22	9.76
Acacia oerfota	3.74	0.38	3.24	7.37
Acacia seyal	0.94	0.004	0.17	1.11
Acacia tortilis	1.87	0.02	0.4	2.28
Balanites aegyptiaca	13.08	0.24	3.05	16.37
Balanites rotundifolia	8.41	0.27	2.89	11.58
Commiphora africana	2.8	0.02	0.03	2.85
Commiphora sp.	1.87	0.008	0.02	1.89
Maerua triphylla	2.8	0.031	0.04	2.87
Rhus ruspolii	1.87	0.16	4.34	6.38

Table 6b: Importance value index (IVI) of woody plants in non-encroached.

Species Name	R. frequency	R. density	R. dominance	IVI
Acacia bussei	10.35	0.05	11.66	22.05
Acacia drepanolobium	17.24	0.06	5.10	22.34
Acacia mellifera	3.45	0.01	1.52	4.98
Acacia nilotica	15.52	0.04	11.98	27.54
Acacia oerfota	1.72	0.02	2.29	4.04
Acacia seyal	5.17	0.01	5.74	10.92
Acacia tortilis	18.97	0.05	25.68	44.70
Balanites aegyptiaca	6.90	0.03	5.14	12.06
Balanites rotundifolia	3.45	0.01	3.51	6.97
Boswellia neglecta	1.72	0.00	17.96	19.69
Commiphora africana	10.35	0.08	7.07	17.50
Commiphora sp.	1.72	0.03	1.64	3.39
commiphora terebinthina	1.72	0.00	0.09	1.82
Solanum incanum	1.72	0.01	0.62	2.35

Table 6c. Importance value index (IVI) of woody plants Hallona encroached site

Species Name	R. frequency	R. density	Relative dominance	IVI
Acacia bussei	0.00	0.00	0.00	0.00
Acacia drepanolobium	31.40	2.04	52.84	86.28
Acacia etabaica	0.00	0.00	0.00	0.00
Acacia mellifera	21.60	0.94	24.41	46.95
Acacia nilotica	2.00	0.00	0.04	2.04
Acacia oerfota	0.00	0.00	0.00	0.00
Acacia seyal	0.00	0.00	0.00	0.00
Acacia tortilis	0.00	0.00	0.00	0.00
Balanites aegyptiaca	19.60	0.20	5.22	25.02

Species Name	R. frequency	R. density	Relative dominance	IVI
Balanites rotundifolia	19.60	0.27	6.99	26.86
Commiphora africana	0.00	0.00	0.00	0.00
Commiphora sp.	0.00	0.00	0.00	0.00
Maerua triphylla	2.00	0.00	0.02	2.02
Rhus ruspolii	3.90	0.41	10.49	14.80

Appendix 6d. Importance value index (IVI) of woody plants Medhacho site

Species Name	R. frequency	R. density	R. dominance	IVI
Acacia bussei	23.00	36.47	31.27	90.74
Acacia drepanolobium	13.00	6.12	3.09	22.21
Acacia etabaica	4.00	0.17	0.05	4.22
Acacia mellifera	19.00	47.53	55.40	121.93
Acacia nilotica	15.00	1.72	2.06	18.78
Acacia oerfota	8.00	5.61	5.53	19.14
Acacia seyal	2.00	0.06	0.29	2.35
Acacia tortilis	4.00	0.22	0.68	4.90
Balanites aegyptiaca	4.00	1.39	1.51	6.90
Balanites rotundifolia	0.00	0.00	0.00	0.00
Commiphora africana	0.00	0.28	0.00	0.28
Commiphora sp.	4.00	0.11	0.00	4.11
Maerua triphylla	6.00	0.33	0.00	6.33
Rhus ruspolii	0.00	0.00	0.00	0.00

Appendix 7: Soil Parameters

Table 7a: Soil analysis (Mean ± SE) in Medhacho area

	Land type		
	Encroached	Non-encroached	
Soil parameters	Mean ± SE	Mean ± SE	P-value
Ava. P(ppm)	3.72 ± 0.32	2.94 ± 0.408	0.15
Total N (%)	0.21 ± 0.05	0.13 ± 0.006	0.16
OC (%)	1.63 ± 0.16	1.3 ± 0.086	0.05
Ava. K(ppm)	434.80 ± 59.61	278.3 ± 39.397	0.04
Exch. K(ppm)	1593.40 ± 211.75	1003.2 ± 197.453	0.05
Ca (ppm)	5450.70 ± 569.65	7328.6 ± 695.777	0.05
Mg (ppm)	1412.80 ± 74.77	1241.6 ± 90.218	0.16
CEC (meq/100g)	37.80 ± 3.19	30.9 ± 3.557	0.16
pH-H2O	7.71 ± 0.15	8.1 ± 0.12	0.09
OM (%)	2.80 ± 0.27	2.2 ± 0.148	0.05

Table 7b: Soil analysis (Mean ± SE) in Hallona area

	Land type		
	Encroached	Non-encroached	
Soil parameters	Mean ± SE	Mean ± SE	P-value
Ava. P(ppm)	3.30 ± 0.40	4.91 ±0.28	0.003
Total N (%)	0.25 ±0.02	0.15 ±0.01	0.00
OC (%)	3.09 ±0.13	1.78±0.11	0.00
Ava. K(ppm)	364.33 ±22.88	401.09 ±66.78	0.61
Exch. K(ppm)	1371.80 ±99.88	989.94 ± 19	0.091
Ca (ppm)	15571.79 ±1521.00	12529.38 ±1829.30	0.212
Mg (ppm)	692.57 ± 44.98	733.26 ± 79.51	0.661
CEC (meq/100g)	53.64 ±3.56	46.53 ± 6.01	0.32
pH-H2O	7.72 ± 0.07	7.53 ± 0.16	0.288
OM (%)	5.32 ± 0.22	3.07 ±0.18	0.000

Appendix 8: Density per hectare of seedlings and saplings

Table 8a. Density per hectare of seedlings and saplings in encroached site

Scientific name	Seedlings per hectare			Saplings per hectare		
	Hallona	Medhacho	Mean	Hallona	Medhacho	Mean
Acacia bussei Harms	0.0	1600.0	800.0	0.0	1800.0	900.0
Acacia drepanolobium	2125.0	200.0	1162.5	2500.0	266.6	1383.3
Acacia mellifera	2062.5	933.3	1497.9	500.0	2400.0	1450.0
Acacia nilotica	0.0	466.7	233.4	0.0	266.7	133.3
Acacia seyal	0.0	0.0	0.0	0.0	66.7	33.3
Acacia tortilis	0.0	133.3	66.7	0.0	0.0	0.0
Balanites aegyptiaca	125.0	66.7	95.9	0.0	66.7	33.3
Balanites rotundifolia	62.5	0.0	31.3	0.0	0.0	0.0
Commiphora sp.	0.0	133.3	66.7	0.0	0.0	0.0
Maerua triphylla	62.5	133.3	97.9	62.5	200.0	131.3
Rhus ruspolii	62.5	0.0	31.3	0.0	0.0	0.0
Total	4500	3666.6	4083.3	3062.5	5067	4065

Table 8b. Density per hectare of seedlings and saplings in non-encroached site

Scientific name	Seedlings per hectare			Saplings per hectare		
	Hallona	Medhacho	Mean	Hallona	Medhacho	Mean
Acacia bussei	0.0	133.3	66.7	0.0	266.7	133.4
Acacia drepanolobium	928.6	0.0	464.3	285.7	0.0	142.9
Acacia mellifera	285.7	0.0	142.9	71.4	200.0	135.7
Acacia nilotica	71.4	66.7	69.1	0.0	400.0	200.0
Acacia seyal	0.0	66.7	33.4	0.0	133.3	66.7
Acacia tortilis	0.0	600.0	300.0	0.0	66.7	33.4
Balanites aegyptiaca	0.0	0.0	0.0	71.4	0.0	35.7
Commiphora Africana	0.0	0.0	0.0	0.0	66.7	33.4
Commiphora sp.	0.0	200.0	100.0	0.0	66.7	33.4
Total	1285.7	1066.7	1176.2	428.5	1200.1	814.3

Appendix 9. Basal area and relative dominance of woody species.

Table 9a. Basal area and relative dominance of woody species in Hallona site

Species name	Vernacular name	BA/ha.	Mean BA	Dominancy	R.D
Acacia bussei	Halloo	0.000	0.000	0.000	0.000
Acacia drepanolobium	Fulleensa	4.553	0.002	2.910	52.839
Acacia etabaica	Hallaqabeessa	0.000	0.000	0.000	0.000
Acacia mellifera	Saphansa	2.104	0.005	1.350	24.410
Acacia nilotica	Burquqqee	0.003	0.002	0.002	0.040
Acacia oerfota	Waangaa	0.000	0.000	0.000	0.000
Acacia seyal	Wachuu	0.000	0.000	0.000	0.000
Acacia tortilis	Dhaddacha	0.000	0.000	0.000	0.000
Balanites aegyptiaca	Baddan lu'oo	0.450	0.008	0.290	5.220
Balanites rotundifolia	Baddan Okolee	0.602	0.005	0.390	6.990
Commiphora Africana	Hammeessa dhiroo	0.000	0.000	0.000	0.000
Commiphora sp.	Hammeessa homacho	0.000	0.000	0.000	0.000
Maerua triphylla	Dhumasoo	0.002	0.001	0.001	0.020
Rhus ruspolii	Daboobessaa	0.904	0.014	0.580	10.490
Total		8.600		5.520	

Table 9b. Basal area and relative dominance of woody species in Medhacho site

Species name	Vernacular name	BA/ha.	Mean BA	Dominancy	R.D
Acacia bussei	Halloo	4.069	0.004	2.441	31.273
Acacia drepanolobium	Fulleensa	0.402	0.002	0.241	3.086
Acacia etabaica	Hallaqabeessa	0.007	0.001	0.004	0.050
Acacia mellifera	Saphansa	7.208	0.005	4.325	55.398
Acacia nilotica	Burquqqee	0.268	0.005	0.161	2.057
Acacia oerfota	Waangaa	0.720	0.004	0.432	5.531
Acacia seyal	Wachuu	0.038	0.023	0.023	0.290
Acacia tortilis	Dhaddacha	0.089	0.013	0.053	0.681
Balanites aegyptiaca	Baddan lu'oo	0.197	0.005	0.118	1.510
Balanites rotundifolia	Baddan Okolee	0.000	0.000	0.000	0.000
Commiphora africana	Hammeessa dhiroo	0.007	0.001	0.004	0.050
Commiphora sp.	Hammeessa homacho	0.003	0.001	0.002	0.025
Maerua triphylla	Dhumasoo	0.007	0.001	0.004	0.050
Rhus ruspolii	Daboobessaa	0.000	0.000	0.000	0.000
Total		13.000		7.807	

Appendix 10: Woody cover of the study area

Table 10a: Woody cover of the encroached sites.

Code	Scientific name	Family name	% Cover
Acacbuss	*Acacia bussei*	Fabaceae	16.39
Acacdrep	*Acacia drepanolobium*	Fabaceae	40.29
Acacetab	*Acacia etabaica*	Fabaceae	0.07
Acacmell	*Acacia mellifera*	Fabaceae	23.10
Acacnilo	*Acacia nilotica*	Fabaceae	1.29
Acacoerf	*Acacia oerfota*	Fabaceae	2.42
Acacseya	*Acacia seyal*	Fabaceae	0.03
Acactort	*Acacia tortilis*	Fabaceae	0.23
Balaaegy	*Balanites aegyptiaca*	Balanitaceae	0.84
Balarotu	*Balanites rotundifolia*	Balanitaceae	1.00
Capptome	*Capparis tomentosa*	Cappararidaceae	0.13
Chiolati	*Chionotrix latifolia*	Amaranthaceae	0.23
Commafri	*Commiphora africana.*	Commelinacea	0.10
Commipsp	*Commiphora sp.*	Commelinacea	0.07
Grewvill	*Grewia villosa*	Tiliaceea	0.01
Justodor	*Justicia odora*	Acanthaceae	3.49
Maertrip	*Maerua triphylla*	Cappararidaceae	0.10
Rhusrusp	*Rhus ruspolii*	Anacardiaceae	0.81
Solacaps	*Solanum capsicoides*	Solanaceae	0.07
Solagiga	*Solanum giganteum*	Solanaceae	0.01
Solaschi	*Solanum schimperianum*	Solanaceae	0.28
Total			90.92

Table 10b: Woody cover of the non-encroached site

Code	Scientific name	Family name	% cover
Acacbuss	*Acacia bussei*	Fabaceae	0.48
Acacdrep	*Acacia drepanolobium*	Fabaceae	1.55
Acacmell	*Acacia mellifera*	Fabaceae	0.10
Acacnilo	*Acacia nilotica*	Fabaceae	0.83
Acacoerf	*Acacia oerfota*	Fabaceae	0.03
Acacseya	*Acacia seyal*	Fabaceae	0.21
Acactort	*Acacia tortilis*	Fabaceae	0.76
Balaaegy	*Balanites aegyptiaca*	Balanitaceae	0.38
Balarotu	*Balanites rotundifolia*	Balanitaceae	0.17
Boswnegl	*Boswellia neglecta*	Burseraceae	0.03
Capptome	*Capparis tomentosa*	Cappararidaceae	0.04
Chiolati	*Chionotrix latifolia*	Amaranthaceae	0.03
Commafri	*Commiphora africana.*	Commelinacea	0.52
Commipsp	*Commiphora sp.*	Commelinacea	0.17
commtere	*commiphora terebinthina*	Burseraceae	0.03
Helilong	*Heliotropium longiflorum*	Boraginaceae	0.03
Ipomkitu	*Ipomoea kituiensis*	Convolvulaceae	0.14
Justodor	*Justicia odora*	Acanthaceae	0.83
Solacaps	*Solanum capsicoides*	Solanaceae	0.01
Solagiga	*Solanum giganteum*	Solanaceae	0.07
Solainca	*Solanum incanum*	Solanaceae	0.03

Code	Scientific name	Family name	% cover
Solaschi	*Solanum schimperianum*	Solanaceae	0.36
Total			6.83

Appendix 11: Average Percentage Cover of Grasses.

Table 11a: Average percentage cover of grasses in encroached site.

S. no.	code	Scientific name	Family name	% Cover
1	*Arisadoe*	*Aristida adoensis*	Poaceae	2.50
2	*Cenccili*	*Cenchrus ciliaris*	Poaceae	23.81
3	*Chloroxb*	*Chloris roxburghiana*	Poaceae	1.87
4	*Chryauch*	*Chrysopogon aucheri*	Poaceae	2.55
5	*Cynodact*	*Cynodon dactylon*	Poaceae	2.77
6	*Eragaspe*	*Eragrostis aspera*	Poaceae	9.53
7	*Eragpapp*	*Eragrostis papposa*	Poaceae	7.02
8	*Hetecont*	*Heteropogon contortus*	Poaceae	0.32
9	*Lintnuta*	*Lintonia nutans*	Poaceae	2.70
10	*Loudarun*	*Loudetia arundinaceae*	Poaceae	0.41
11	*Panimaxi*	*Panicum maximum*	Poaceae	3.50
12	*Pennpoly*	*Pennisetum polystachion*	Poaceae	1.28
13	*Pennthun*	*Pennisetum thunbergii*	Poaceae	5.90
14	*Setavert*	*Setaria verticillata*	Poaceae	3.04
	Total			67.21

Table 11b: Average percentage cover of grasses in encroached site.

S. no.	Code	Scientific name	Family name	% cover
1	*Arisadoe*	*Aristida adoensis*	Poaceae	0.81
2	*Cenccili*	*Cenchrus ciliaris*	Poaceae	7.90
3	*Chloroxb*	*Chloris roxburghiana*	Poaceae	1.36
4	*Chryauch*	*Chrysopogon aucheri*	Poaceae	1.20
5	*Cynodact*	*Cynodon dactylon*	Poaceae	0.36
6	*Eragaspe*	*Eragrostis aspera*	Poaceae	2.70
7	*Eragpapp*	*Eragrostis papposa*	Poaceae	1.54
8	*Lintnuta*	*Lintonia nutans*	Poaceae	0.19
9	*Panimaxi*	*Panicum maximum*	Poaceae	2.37
10	*Pennpoly*	*Pennisetum polystachion*	Poaceae	5.14
11	*Pennthun*	*Pennisetum thunbergii*	Poaceae	3.25
12	*Setavert*	*Setaria verticillata*	Poaceae	10.85
13	*Loudarun*	*Loudetia arundinaceae*	Poaceae	0.01
	Total			37.68

Appendix 12: Average Percentage Cover of Forbs.

Table 12a: Average percentage cover of forbs in encroached area.

Code	Scientific name	Family name	% Cover
Abutfiga	*Abutilon figarianum*	Malvaceae	0.37
Abuthirt	*Abutilon hirtum*	Malvaceae	0.05
Achyaspe	*Achyranthes aspera*	Amaranthaceae	0.19
Aervlana	*Aerva lanata*	Amaranthaceae	0.11
Amarthun	*Amaranthus thunbergii*	Amaranthaceae	0.14
Asysmyso	*Asystasia mysorensis*	Acanthaceae	0.54
Barlarge	*Barleria argentea*	Acanthaceae	0.01
Barlquad	*Barleria quadrispina*	Acanthaceae	0.11
Barlersp	*Barleria sp.*	Anthericaceae	0.77
Bidehild	*Bidens hildebrandtii*	Asteraceae	0.03
Blepcili	*Blepharis ciliaris*	Acanthaceae	0.54
Chenopul	*Chenopodium opulifolium*	Chenopodiaceae	0.07
Commafri	*Commelina Africana*	Commelinacea	1.77
Commstep	*Commelina stephaniniana*	Commelinaceae	0.19
*Commpedu**	*Commicarpus peduduncu losus*	Nyctaginaceae	0.23
Crepfoet	*Crepis foetida*	Asteraceae	0.07
Crosspin	*Crossandra spinosa*	Acanthaceae	0.01
Cypeamau	*Cyperus amauropus*	Cyperaceae	0.12
cypebulb	*cyperus bulbosus*	Cyperaceae	0.46
Cyperusp	*Cyperus sp.*	Cyperaceae	0.90
Euphpoly	*Euphorbia polycnemoides*	Euphorbiaceae	0.17
Euphtiru	*Euphorbia tirucalli*	Euphorbiaceae	0.12
Gutesoma	*Gutenbergia somalensis*	Asteraceae	1.04
Hibiflav	*Hibiscus flavifolius*	Malvaceae	0.10
Hibimicr	*Hibiscus micranthus*	Malvaceae	0.17
Hypofors	*Hypoestes forskoalii*	Acanthaceae	1.22
Indispin	*Indigofera spiniflora*	Fabaceae	0.61
Ipomoesp	*Ipomoea sp.*	Convolvulaceae	0.62
Klensqua	*Klenia squarrosa*	Asteraceae	0.01
Lantrhod	*Lantana rhodesiensis*	Verbenaceae	0.04
Leucabys	*Leucas abyssinica*	Lamiaceae	0.08
Ocimlami	*Ocimum lamiifolium*	Lamiaceae	0.01
Ostevail	*Osteospermum vailliantii*	Asteraceae	0.07
Oxygsinu	*Oxygonum sinuatum*	Polygonaceae	1.67
Pentsoma	*Pentarrihum somaliense*	Asteraceae	0.18
Phagabys	*Phagnalon abyssinicum*	Asteraceae	0.05
Plecigni	*Plectranthus igniarius*	Lamiaceae	0.01
Pupalapp	*Pupalia lappaceae*	Amaranthaceae	3.78
Seddpedu	*Seddra peduncutata*	Convolvulaceae	0.05

Code	Scientific name	Family name	% cCover
Tageminu	*Tagetes minuta*	Asteraceae	0.01
Total			16.76

Table 12b: Average percentage cover of forbs in non-encroached area**.**

Code	Scientific name	Family name	% Cover
Abutfiga	*Abutilon figarianum*	Malvaceae	0.15
Abuthirt	*Abutilon hirtum*	Malvaceae	0.31
Achyaspe	*Achyranthes aspera*	Amaranthaceae	0.08
Aervlana	*Aerva lanata*	Amaranthaceae	0.03
Albuabys	*Albuca abyssinica*	Hyacinthaceae	0.11
Amarthun	*Amaranthus thunbergii*	Amaranthaceae	0.36
Asysmyso	*Asystasia mysorensis*	Acanthaceae	0.45
Barlarge	*Barleria argentea*	Acanthaceae	0.18
Barlquad	*Barleria quadrispina*	Acanthaceae	0.76
Barlersp	*Barleria sp.*	Anthericaceae	0.26
Bidehild	*Bidens hildebrandtii*	Asteraceae	0.01
Blepcili	*Blepharis ciliaris*	Acanthaceae	0.90
Chenopul	*Chenopodium opulifolium*	Chenopodiaceae	0.29
Chenschr	*Chenopodium schraderianum*	Chenopodiaceae	0.03
Chlogall	*Chlorophytum gallabatense*	Anthericaceae	0.15
Commafri	*Commelina Africana*	Commelinacea	1.85
Commstep	*Commelina stephaniniana*	Commelinaceae	0.50
*Commpedu**	*Commicarpus peduduncul*osus	Nyctaginaceae	0.59
Commpedu	*Commicarpus plumbagineus*	Nyctaginaceae	0.04
Crepfoet	*Crepis foetida*	Asteraceae	0.01
Crosspin	*Crossandra spinosa*	Acanthaceae	0.07
Cypeamau	*Cyperus amauropus*	Cyperaceae	0.12
cypebulb	*cyperus bulbosus*	Cyperaceae	0.46
Cyperusp	*Cyperus sp.*	Cyperaceae	0.90
Cyphcyph	*Cyphostemma cyphopetalum*	Vitaceae	0.01
Euphnubi	*Euphorbia nubica*	Euphorbiaceae	0.12
Euphpoly	*Euphorbia polycnemoides*	Euphorbiaceae	0.33
Euphtiru	*Euphorbia tirucalli*	Euphorbiaceae	0.35
Gutesoma	*Gutenbergia somalensis*	Asteraceae	0.32
Hibiflav	*Hibiscus flavifolius*	Malvaceae	0.37
Hibimicr	*Hibiscus micranthus*	Malvaceae	0.27
Hypofors	*Hypoestes forskoalii*	Acanthaceae	0.50
Indispin	*Indigofera spiniflora*	Fabaceae	2.80
Indivolk	*Indigofera volkensii*	Fabaceae	0.01
Ipommarm	*Ipomoea marmorata*	Convolvulaceae	0.10
Ipomoesp	*Ipomoea sp.*	Convolvulaceae	0.03
Kleipict	*Kleinia picticaulis*	Asteraceae	0.03
Lantrhod	*Lantana rhodesiensis*	Verbenaceae	0.01

Code	Scientific name	Family name	% Cover
Leucabys	*Leucas abyssinica*	Lamiaceae	0.01
Medimini	*Medicago minima*	Fabaceae	0.01
Ocimfors	*Ocimum forskolei*	Lamiaceae	0.28
Ocimlami	*Ocimum lamiifolium*	Lamiaceae	0.01
Ostevail	*Osteospermum vailliantii*	Asteraceae	0.65
Oxygsinu	*Oxygonum sinuatum*	Polygonaceae	0.17
Pentsoma	*Pentarrihum somaliense*	Asteraceae	1.04
Phagabys	*Phagnalon abyssinicum*	Asteraceae	0.15
Plecigni	*Plectranthus igniarius*	Lamiaceae	0.14
Pupalapp	*Pupalia lappaceae*	Amaranthaceae	0.35
Seddpedu	*Seddra peduncutata*	Convolvulaceae	2.66
Solaglab	*Solanum glabratum*	Solanaceae	0.01
Tageminu	*Tagetes minuta*	Asteraceae	0.18
Vernturb	*Vernonia turbinata*	Asteraceae	0.13
Xerohumi	*Xerophyta humilis*	Velloziaceae	0.90
Total			20.54

Appendix 13: Soil Characteristics Laboratory Analysis Result

Table 13a: Soil characteristics laboratory analysis result in encroached site

Field NO.	PH	P(ppm)	%N	%Oc	%OM	Kav (ppm)	Kex(ppm)	Ca(ppm)	Mg(ppm)	CEC(meq/100g)
H1S4	7.9	3.2	0.17	2.88	4.97	386.988	1401.465	23498.5	415.2	45.86
H1S5	8.08	6.2	0.2	2.69	4.64	185.094	918.015	23266.4	471.6	60.14
H1S6	7.57	4.6	0.32	3.66	6.31	377.580	1813.545	16512.5	491.6	68.02
H1S7	7.73	3.6	0.29	3.59	6.19	362.460	1488.965	25098	887.9	57.48
H1S8	7.82	4.6	0.19	2.53	4.36	278.817	1170.740	15644.6	849.3	48.36
H1S9	7.84	4.6	0.25	2.92	5.03	430.658	1096.925	18366.9	600.6	49.82
H2S6	7.23	4.4	0.17	2.85	4.91	481.719	927.305	4306.6	613.4	24.9
H2S7	7.49	6.2	0.2	2.42	4.17	206.598	895.040	8093.5	802	49.24
H2S8	7.74	5.6	0.19	2.34	4.03	277.137	1046.090	13598.6	1093.6	22.26
H2S9	8.08	5.4	0.19	2.46	4.24	343.991	930.725	21010.9	789.3	73.7
H2S10	7.82	4.2	0.28	3.2	5.52	471.975	1711.870	16252.7	567.9	55.02
H3S1	8.18	4.4	0.32	3.51	6.05	321.479	1327.655	20493.7	606.4	55.48
H3S2	7.24	4.6	0.29	3.98	6.86	474.327	1914.245	10409.6	779.5	57.76
H3S3	7.58	4.6	0.32	3.51	6.05	418.562	1770.040	10573.6	834.8	69.7
H3S4	7.48	4.6	0.32	3.43	5.91	441.399	1865.365	10777.9	598.8	53.9
H3S5	7.8	7.8	0.31	3.43	5.91	370.524	1670.810	11244.7	679.2	66.64
M1S11	8.46	3.6	0.14	1.17	2.02	95.403	333.380	7821.1	1049.6	35.46
MS22	7.84	2.4	0.19	2.46	4.24	496.157	1884.425	6017.2	1167.1	44.82
M1S1	7.36	6	0.26	2.81	4.84	802.862	2797.065	5043.3	1552.5	53.24
M1S2	7.92	3	0.23	2.85	4.91	621.789	2465.645	7044	1472.8	60.14
M1S3	8.26	3	0.92	1.1	1.90	402.098	978.140	7649.5	1052.9	20.06
M2S11	6.59	3.4	0.16	1.56	2.69	512.621	2288.200	3113.3	1797.5	48.2
M2S1	6.97	4.2	0.14	1.48	2.55	547.218	1955.795	2644	1464.8	39.42
M2S2	6.89	3.2	0.13	1.52	2.62	486.749	1601.395	2974.5	1539.7	37.48
M3S11	7.25	3.2	0.15	1.6	2.76	330.551	1627.305	7533.4	1585.2	26.22
M3S1	8.25	5	0.11	1.17	2.02	207.260	877.445	7604.1	1412.5	21.82
M3S2	8.15	2.2	0.11	1.013	1.75	96.411	375.420	8530	790.1	20.76

Field NO.	PH	P(ppm)	%N	%Oc	%OM	Kav (ppm)	Kex(ppm)	Ca(ppm)	Mg(ppm)	CEC(meq/100g)
M3S3	8.3	2.4	0.15	1.17	2.02	201.558	609.565	1719	1350.3	44.76
M4S1	7.67	6.2	0.12	1.25	2.16	817.635	2165.990	3955.9	1483.8	42.8
M4S2	7.52	4.4	0.19	1.99	3.43	618.440	2664.595	5419.2	1850.6	44.46
M4S3	8.26	3.6	0.11	1.29	2.22	284.529	1275.840	4692.6	1623	26.9

Table 13b: Soil characteristics laboratory analysis result in non- encroached site

Field No.	PH	P(ppm)	%N	%Oc	%OM	Kav (ppm)	Kex(ppm)	Ca(ppm)	Mg(ppm)	CEC(meq/100gm
H1S10	8.14	2	0.16	1.95	3.36	605.672	715.640	20786.4	582.8	33.3
H1S1	8.25	5	0.11	1.36	2.34	119.921	238.545	15162.8	1406.7	19.36
H1S2	7.85	4	0.17	1.64	2.83	171.318	347.065	3716.3	735.9	14.7
H1S3	7.68	7.6	0.23	1.91	3.29	508.589	1183.450	18366.9	487.6	22.78
H2S5	6.76	3.4	0.19	2.3	3.97	716.520	1445.950	8244.9	625.7	46.98
H2S4	7.74	3.6	0.22	2.61	4.50	638.589	1120.880	3171.3	727.5	74.16
H2S3	6.78	2	0.11	1.17	2.02	772.622	1924.510	14451.3	1214	71.12
H2S2	6.68	2.6	0.13	1.6	2.76	587.528	960.545	17428.3	334.9	32.28
H2S1	8.09	3.2	0.17	1.95	3.36	466.263	2900.210	19683.8	610.1	40.84
H3S10	6.96	2	0.11	1.21	2.09	422.594	753.280	1856.9	607.5	68.96
H3S9	7.67	2.6	0.14	1.68	2.90	329.543	775.280	4034.2	1101.3	60.86
H3S8	6.68	3.2	0.114	1.87	3.22	112.875	564.595	14817.1	593.4	71.4
H3S7	7.96	2.4	0.13	1.79	3.09	61.814	310.895	18944.6	637.3	71.28
H3S6	8.16	2.6	0.14	1.91	3.29	101.451	618.365	14746.5	601	23.38
M1S8	8.29	1.6	0.12	1.013	1.75	137.393	332.890	7589	712.2	17.84
M1S7	8.44	2.4	0.14	1.21	2.09	316.439	643.785	7745.4	884.2	17.86
M1S6	7.94	2.8	0.18	1.48	2.55	268.065	1356.985	5363.7	2033.1	56.06
M2S3	7.36	7.6	0.15	1.79	3.09	432.002	2232.470	3582.6	1343.8	44.96
M2S4	7.33	2.8	0.15	1.56	2.69	396.050	2077.025	3320.2	1205.3	37.96
M2S5	8.32	3.6	0.11	1.25	2.16	164.598	836.870	7664.6	924.2	33.1
M2S6	8.23	1.6	0.12	1.013	1.75	58.454	252.235	6680.7	1213.6	40.48
M3S5	7.35	2	0.11	0.94	1.62	396.050	1448.395	2770.2	1022.4	52.76
M3S6	7.96	4.4	0.18	2.07	3.57	512.285	2537.010	5858.2	1880.1	18.46
M3S7	8.5	2.4	0.12	1.013	1.75	459.207	465.850	9143.1	1068.2	28.5
M3S8	7.45	2	0.11	1.17	2.02	88.011	397.905	9102.7	1077.6	37.5
M4S4	8.25	2.2	0.08	0.97	1.67	146.801	469.765	11638.2	1324.9	16.62
M4S5	8.44	2	0.12	0.97	1.67	135.377	228.770	10104.3	1177.3	27.86
M4S6	8.46	4.6	0.14	1.29	2.22	443.079	1117.945	9380.2	1367.4	20.62
M4S7	8.38	2.2	0.12	1.21	2.09	220.364	650.140	9985.7	1389.6	12.5

Appendix 14: Location of study area.

S.No	Field No.	Altitude	GPS Marks	Slope (%)	Aspects	Bearing
1	H1S10	1456.0m	37N 0446665 UTM 0530573	3	E	270
2	H1S1	1459.0m	37N 0446482 UTM 0530657	2	N	270
3	H1S2	1450.0m	37N 0446259 UTM 0530672	5	W	270
4	H1S3	1437.0m	37N 0446049 UTM 0530668	5	W	270
5	H2S5	1499.0m	37N 0447063 UTM 0530205	4	W	270
6	H2S4	1496.5m	37N 0446806 UTM 0530154	2	S	270
7	H2S3	1498.0m	37N 0446582 UTM 0530154	3	S	270
8	H2S2	1498.5m	37N 0446380 UTM 0530154	3	W	270
9	H2S1	1492.0m	37N 0446179 UTM 0530154	3	W	270
10	H3S10	1515.0m	37N 0448756 UTM 0530997	2	N	270
11	H3S9	1513.0m	37N 0448524 UTM 0530975	3	NE	270
12	H3S8	1511.0m	37N 0448341 UTM 0530966	1	W	270
13	H3S7	1511.0m	37N 0448142 UTM 0530983	1	N	270
14	H3S6	1506.0m	37N 0447620 UTM 0530965	3	NW	270
15	H1S4	1431.5m	37N 0445954 UTM 0530662	3	W	270
16	H1S5	1429.0m	37N 0445719 UTM 0530666	2	W	270
17	H1S6	1426.5m	37N 0445512 UTM 0530668	1	N	270
18	H1S7	1426.5m	37N 0445361 UTM 0530671	1	NE	270
19	H1S8	1429.0m	37N 0445209 UTM 0530672	2	E	270
20	H1S9	1431.5m	37N 0445038 UTM 0530675	2	NW	270
21	H2S6	1450.0m	37N 0446066 UTM 0530153	3	W	270
22	H2S7	1443.5m	37N 0445862 UTM 0530153	1	N	270
23	H2S8	1441.0m	37N 0445637 UTM 0530161	1	E	270
24	H2S9	1435.0m	37N 0445395 UTM 0530175	1	NE	270
25	H2S10	1435.5m	37N 0445130 UTM 0530189	1	NE	270
26	H3S1	1432.0m	37N 0446330 UTM 0531257	4	N	270
27	H3S2	1433.0m	37N 0446021 UTM 0531395	2	N	270
28	H3S3	1428.0m	37N 0445668 UTM 0531520	1	N	270
29	H3S4	1424.0m	37N 0445329 UTM 0531647	4	N	270
30	H3S5	1420.0m	37N 0444966 UTM 0531751	4	W	270
31	M1S8	1520.0m	37N 0419651 UTM 0467233	1	S	180
32	M1S7	1518.5m	37N 0419634 UTM 0467030	4	S	180
33	M1S6	1514.5m	37N 0419595 UTM 0466803	4	S	180
34	M2S3	1453.0m	37N 0418906 UTM 0465023	0	S	180
35	M2S4	1455.0m	37N 0418964 UTM 0464707	0	S	180
36	M2S5	1457.5m	37N 0418955 UTM 0464330	0	S	180
37	M2S6	1459.0m	37N 0418981 UTM 0464004	2	NW	180
38	M3S5	1513.0m	37N 0420510 UTM 0468023	3	NE	170
39	M3S6	1515.0m	37N 0420555 UTM 0467750	1	NE	170
40	M3S7	1525.0m	37N 0420637 UTM 0467369	4	N	170
41	M3S8	1530.0m	37N 0420739 UTM 0467090	3	N	170
42	M4S4	1472.0m	37N 0421062 UTM 0467556	4	N	170
43	M4S5	1490.0m	37N 0421058 UTM 0467293	4	N	170
44	M4S6	1480.0m	37N 0421053 UTM 0467085	5	N	170
45	M4S7	1510.0m	37N 0421063 UTM 0466873	4	N	170
46	M1S11	1512.5m	37N 0413573 UTM 0466651	3	S	180
47	MS22	1504.0m	37N 0419515 UTM 0466091	1	S	180
48	M1S1	1474.0m	37N 0419513 UTM 0466247	2	S	180

S.No	Field No.	Altitude	GPS Marks	Slope (%)	Aspects	Bearing
49	M1S2	1466.5m	37N 0419425 UTM 0465810	2	S	180
50	M1S3	1465.5m	37N 0419394 UTM 0465388	1	S	180
51	M2S11	1495.0m	37N 0418843 UTM 0465706	1	S	180
52	M2S1	1451.0m	37N 0418856 UTM 0465440	0	S	180
53	M2S2	1454.0m	37N 0418884 UTM 0465132	0	S	180
54	M3S11	1459.0m	37N 0420423 UTM 0469045	2	N	170
55	M3S1	1469.0m	37N 0420432 UTM 0468725	4	N	170
56	M3S2	1470.0m	37N 0420486 UTM 0468497	4	N	170
57	M3S3	1474.0m	37N 0420487 UTM 0468247	0	E	170
58	M4S1	1439.5m	37N 0420846 UTM 0469286	0	E	170
59	M4S2	1436.5m	37N 0420925 UTM 0469039	3	E	170
60	M4S3	1444.0m	37N 0420943 UTM 0467569	3	E	170

Appendix 15: Questionnaire

Title: Ecological Impacts of Bush Encroachment on Rangeland Ecosystem: The Case of Hallona and Medhacho Pastoralist Associations in Borana Lowlands.

Skeleton of questionnaire prepared to interview pastoralists and understand impacts of bush encroachment on rangeland ecosystem and pastoralists livelihoods .

Name (Optional) _____sex_____Age_____

Zone_____ Woreda_____ Peasant Association_____

1. Do you have cultural methods of rangeland management in this area? Yes_____or No____ If yes, would you explain the mechanisms? _____
2. What do the ownership / grazing system look like in your surrounding? Communal_____ individually owned _____ others mention_____
3. How do you practice grazing in your area? Using rotational system_____ free grazing _____ others mention them _____
4. Do you mix animals of different species mainly grazers and browsers during grazing time? Yes____ No___If no, why? _____
5. Would you tell me advantages or disadvantages of mixing different species of domestic animals?
6. What do call the land grazed by cattle with different age groups?_____

7. What are the major differences between these land categories? _____
8. Would you mention the names of some major trees, bushes and shrubs that are commonly grown in your area? _____ mention those which are palatable for grazers and those consumed by browser and unpalatable ones separately._____
9. Mention those plants that do not dry even during drought season and provide special advantages._____
10. Is there any constraint for grass yield and livestock productivity in you woreda? Yes_____ No_____if yes mention them_____
11. Of these constraints which ones are/is the major constraint? _____
12. Do you have shortage of feed/ grasses and grazing lands? Yes_____no_____ if yes, how do you overcome the problem? _____
13. Is there a problem of bush encroachment to the rangeland in your areas? Yes_____ No _____.if yes, what are its impacts on rangeland condition grass yield? _____ and livestock productivity?
14. What are the names of the bushes and shrubs newly encroaching to the rangeland?
15. Would you mention some of what you may fill as the major causes of bush encroacheemnts?
16. What is the trend observed on livestock population? Would you compare the situations before ten years and the current? Increasing ____ decreasing____ no changes_____
17. Would you tell us the over all impacts of the bush encroachment on the grass yield and productivity?
18. Generall what are the impacts that bush encroachment brought to your livelihoods?
19. Is there any advantage that you are getting from these newly encroaching species?
20. Is there any relationships between production of different species of domestic animals and bush encroachment?
21. Is there any effort done by the society in a group or individually to minimize these problems?
22. What are the possible solutions that can be suggested in the future based on your indigenous knowledge?

23. Generally speaking, is the rangeland condition worsening or getting better in your area? What are the major indicators? If it is getting worse, why?
24. Are the Borana people nomads? Or follow sedentary life?
25. What are advantages and disadvantages of nomadic and sedimentary life respectively?

Declaration

I, Niguse Bekele, hereby to declare that this thesis is the product of my original work and that it has not been submitted to any other university for award of academic degree. Information from various sources has been duly acknowledged.

Signature: …… Date: ……

Advisors

1. Dr. Mekuria Argaw Signiture …… Date.....
2. Dr. Gemedo Dalle Signiture……..Date.....