Invasion of *Prosopis juliflora* (SW.) DC and Rural Livelihoods

The Case of Afar Pastoralists at Middle Awash Area of Ethiopia

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Credit

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Title picture: The invasion of *Prosopis juliflora* on Adobtele village and range land (Photo taken by Zeraye, June 2007)

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Declaration

I, Zeraye Mehari Haile, hereby declare that this thesis is my own research work with due acknowledgement of other materials used. I further state that the thesis has not been submitted for a degree award at any other university than UMB.

Zeraye Mehari Haile

Ås, June 2008

Dedication

To those Afar pastoralists who are facing all negative aspects of *Prosopis juliflora,* with compassion!

Acknowledgement

I want my countless thank to go to my advisor Fred Håkon Johnsen (Dr. Scient.) from the bottom of my heart for his invaluable support at any stage of this work. His guidance and comments were crucial.

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My wife Messi with our two kids and my honored parents are the rest to take the endless gratitude. Brothers and sister please receive my appreciation!

Abstract

Prosopis juliflora, an evergreen tree/bush, is one of the most invasive species in arid and semi arid areas. Since its introduction to Middle Awash area of Ethiopia (late 1970s), it has invaded a huge amount of grasslands, rangelands and farmlands. These lands are life supporting for Afar pastoralists through provision of pastures and ecological goods. The invasion of *P. juliflora* made livestock rearing difficult; which ultimatly affects the Afar pastoral livelihoods. Despite this fact, research in the areas is scanty. And hence a study was conducted to investigate the effect of *P. juliflora* invasion on grazing lands, livestock rearing and Afar pastoral livelihoods in Middle Awash area in the year 2007. Group discussion and questionaire survey of totally 142 households in 6 villages were used for data collection. The result showed that 74% of the respondents knew the bush for the past twenty years; and 84% of the total surveyed households rated it as undesirable for the community. However, abundance driven utilization of the bush was found on fuelwood, for fencing homesteads and barn construction. A quarter of the surveyed households used mesquite as means of income. Age of household head and change in livestock asset are significant variables to influence a household to use mesquite as source of income. *P. juliflora* was blamed to inhibit mobility by invading 1/2 to 2/3 of grazing lands, occupying settlement areas and blocking paths. The invasion interferred with pastoral tradition and institutions (84% of respondents) and the thorn was accused for being poisonous both for the people and their livestock. The invasion further undermined multipurpose trees/bushes, grass availability and under canopy growth. *Acacia nilotica*, *A. senegal*, *A. tortilis*, *Andropogon canaliculatus*, *Cadaba rotundifolia*, *Chrysopogon plumulosus*, *Cymbopogon pospischilii*, *Eragrostis cylindriflore*, *Salvadora persica* and *Terapogon cenchriformis* are the most affected plant species by the invasion. All these factors affected the livestock assets and productivity of the basin causing 80% livestock loss as compared to ten years ago and more than 85% perceived milk yield reduction. Each household lost 6.5 small stock and 7 cattle due to health hazards caused by *P. juliflora* pod. As a result households engaged in to crop cultivation, share cropping, formal employment, casual labor and small trade as risk management strategies. Age of household head, level of education, change in livestock asset and perceived size of grazing land invasion are significant variables to affect household decision toward using the strategies. Thus, the invasion has affected the livestock assets of the basin which in turn increases ecological vulnerability of the pastoralists in that fragile ecosystem.

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List of Acronyms and abbreviations

ARPARDB	Afar Region Pastoral, Agricultural and Rural Development Bureau
EARO	Ethiopian Agricultural Research Organization
EIAR	Ethiopian Institute of Agricultural Research (the then EARO)
HADRA	Henry Doubleday Research Association
IAS	Invasive Alien Species
ISSG	Invasive Species Specialist Group
WARC	Werer Agricultural Research Center
WBISPP	Woody Biomass Inventory and Strategic Plan Project

1. Introduction

1.1 Background

Exotic plant species have been introduced deliberately and/or accidentally to countries for various reasons. Some of such species have been proved to be helpful in their new places with regard to their economic importance, biodiversity aspect, ecological merit, or a combination of those factors. On the other hand there are a lot of exotic plant species which are found harmful after their introduction in different ways. For example: (a) by interfering with rural livelihoods activities; (b) impeding land use systems; and (c) incurring extra costs of management to their 'new home' due to the fact that they invade a large amount of land within a short period of time. Such plant species, in most cases, are declared to be invasive alien species (IAS) in their new locality. Ways by which IAS are incorporated into rural livelihoods vary. Shakleton et al. (2006) discussed four pathways.

The first is when the rural community accepts the introduction or they themselves introduce a species because they perceive it as useful. Under this case, initially it is in controlled condition (e.g. within farming land). The species starts affecting non-beneficiaries' livelihoods when it gets out of control and invades much of the landscape. The second possibility[1] is where intentional introduction of IAS into an area takes place and it becomes abundant through time. In this case, the opportunity cost of using scarce resources may invite the rural people to exploit the introduced species. The exploitation is good for controlling the spread of IAS. The third situation is when the IAS is not introduced on purpose, but local people have already accepted the presence of IAS and try to make use of it. The last condition is the existence of IAS which has no obvious uses for the community. At initial stage of invasion, the threat may be little. However, the threat becomes more serious when the scale of invasion increases to the extent of affecting the supply of other ecosystem goods and livelihood activities of the community. Ecosystem goods, according to Scoones (1998), are relevant for the sustainability of most rural livelihoods.

Invasive plant species are causing big challenges to global ecosystems and biodiversity (Manchester and Bullock, 2000; D'Antonio and Kark, 2002). According to D'Antonio and Kark, (2002), such plants are mostly characterized by high ecological adaptability and vigorous growth even in harsh climate to cover huge acreages. These natures of the species will undoubtedly

[1] For example: introduction of plant species for reclaiming eroded lands in a given area, but subsequently the plant invades other land use systems, like arable lands, grazing lands and parks of the area.

affect people's livelihoods by threatening their means of stay like grazing areas, farmlands and fisheries; either by reducing its productivity or completely denying access. This further worsens the living conditions of resource poor rural people of developing countries. According to Pimental et al. (2000), around US$ 1.4 trillion annual global economic damage, which is around 5% of the world economy, is caused by problems associated with bio-invaders. One of the top 100 bio-invaders rated in 2004 by Invasive Species Specialist Group (ISSG) was *Prosopis sp*. (Lowe et al., 2004).

Prosopis juliflora (Swarz) DC (hereafter mesquite) is one of the commonest tree species found in the dry tropics (Pasiecznik et al., 2001; Pasiecznik et al., 2004). It has been extensively planted for its supply of fuel and fodder even in drier climates of the tropics (Pasiecznik et al., 2004). However, the spread has come out of control in many countries. Hence, mesquite was listed as one of the most invading species in the world by ISSG on Global Invasive Species Database (http://www.issg.org/database accessed 10/03/2008). The plant has occupied millions of hectares of land which were under different land use systems in Africa, Asia, South America and Australia (Pasiecznik, 1999). It is still highly expanding in eastern and southern Africa, tropical Asia and Australia (Pasiecznik, 1999; Matthews and Brand, 2004).

In Ethiopia, mesquite was first seen in the eastern part of the country in the late 1970s (EARO and HADRA, 2005). It was introduced to Middle Awash area of Afar National Regional State[2] some 30 years before (personal communication with elders at Worer). The pastoralists were told about the merits of mesquite (additional feed for livestock, fuelwood source, reclaiming salt affected soils, etc.). Expecting the advantages, it was planted over large areas in the region by programs like Food for Work Programme until 1988 (EARO and HADRA, 2005). In addition to this initial momentum that privileged the invader, there are other factors which have contributed to the current invasion status. These are: viable mesquite seeds survive in livestock and warthogs' droppings (Hailu, et al., 2004); its inherent characteristics of fast growth and drought resistance (Pasiecznik et al., 2004); and resistance to browsing. These allow it to propagate largely in semi-arid and arid areas of the country in general and in Afar region[3] in particular. Now, mesquite is the national no. 1 invasive alien plant (EARO and HADRA, 2005).

[2]Afar National Regional State is one of the 11 administrating regional states in Ethiopia.
[3]Throughout the paper Afar region is synonymously used as Afar National Regional State

Dry and wet season grazing lands, agricultural lands, river banks and settlement areas of Afar region are increasingly facing threat of invasion. The problem is more severe in Zone[4]-3 and Zone-1 of the region. The unchecked expansion is not only affecting the pastoral community and their livestock but also other economic activities of the region. Agricultural operation costs of the area are rising due to additional operation costs and other expenditures which are realized after the invasion, such as: clearing cost against road side, irrigation canal and agricultural field invasions, maintenance costs of frequent tire punctures due to its sharp thorn, soon worn out of farm machineries due to strong mesquite's roots in the farms, increased pesticide spray as mesquite acts as host to insect pests and other related problems.

1.2 Statement of the problem

Currently, mesquite is a main regional issue for its thorny, weedy and invasive nature. In the Middle Awash area, more than 30,000 ha of grasslands, rangelands, water points and crop lands are estimated to be occupied by mesquite (personal communication with Care-Awash staff). These invaded resources are the key supporting units for livestock keeping, which in turn are the main stay for Afar people[5] in that fragile ecosystem. The dense, impermeable thickets formed by the invasion reduce grass availability and stocking density. The invasion is also affecting multipurpose indigenous trees in the valley (Ameha, 2006). The invasion leads to shrinkage of the rangelands and grasslands and will therefore threaten sustained existence of the pastoral system in the area (like seasonal herd mobility, herd composition, mutual helping institutions and others).

According to Ameha (2006), mesquite invasion is also affecting plant species diversity in the Middle Awash area. He found that there was less diversity and fewer plant species under the mesquite's canopy than under indigenous *Acacia* species. Besides, the invasion is making paths to water points and grazing areas inaccessible and acts as a shelter to predators near to satellite camps in the area (FARM AFRICA, 2002).

All these factors contribute to increased pressure on the remaining pasture and raise the Afar pastorals' vulnerability to the recurrent moisture stress the area experiences. However, so

[4]In Ethiopia, national regional states are further administratively divided into zones. Accordingly, Afar National Regional State has five zones. Middle Awash is found in Zone-3.

[5]The Afar are one of the largest pastoral clusters in the horn of Africa (Getachew, 2001). Their settlement allocations cover the borders of Ethiopia, Eritrea and Djibouti. Out of the total Afar population, two-thirds live in Ethiopia (Tadesse and Yohanes, 2007).

far, there is no single research regarding mesquite invasion and the pastoral livelihoods in the Afar region.

1.3 Research objectives

The general objective of the study was to investigate effects of mesquite invasion on grazing lands, livestock keeping and household livelihoods in Middle Awash area of Afar region.

The following are specific objectives of the study.

1. To investigate pastoralist perception about the invasive species
2. To assess the extent to which grazing options are impacted by mesquite invasion
3. To assess the effect of mesquite invasion on the pastoral livelihoods

In the process to answer these objectives, the following research questions were addressed:

Objective one

1. What is the perception of the pastoralists about mesquite?

Objective two

1. Does mesquite invasion affect forage availability in grazing areas?
2. How is the access to grazing areas and water points affected by the invasion?

Objective three

1. Are livestock rearing and pastoral households affected by the invasion?
2. What measures have been taken by the pastoralists as a consequence of the invasion?

1.4 Significance of the study

Herders and farmers are facing challenges from invasive species, like mesquite, (e.g. Sudan Update 1997; Gavali et al., 2003; Esther and Brent, 2005; Stefan, 2005; Siges et al., 2005; Shackleton et al., 2006). Assessing the impact of such species on rural livelihoods will have paramount importance for the subsequent relieving programs.

Nevertheless, information with respect to mesquite invasion and the pastoral Afar livelihoods in Ethiopia is scanty. This study will hence generate information regarding the pastorals' perception about the invasion and its impact on their livestock and grazing availability. These have a direct manifestation on the pastoral livelihoods. The generated information will hence provide a good base for developing projects to tackle the problems.

1.5 Scope and limitations

In the study area, almost all of those whose income completely depends on charcoal making and fuel wood collection from mesquite are highlanders[6]. And they may view the invasion differently. However, their view was not assessed in this study due to resource constraints (mainly time and budget). Thus, the outcome merely applies for the Afar pastorals of the area.

The same constraints forced the study to confine to Middle Awash area of the region. Nonetheless, the Afar pastorals found in other parts of the region have also faced problems due to mesquite invasion.

Obtaining exact figures of livestock assets was difficult. Respondents were reluctant in telling the true figure. Such problems have been faced by different researchers (e.g. Ali, 1992; Antenalu, 2006). It was also not possible to have herd inventory due to time and budget limitations. Therefore, in this study, figures related to livestock show the trend rather than the exact situation.

1.6 Organization of the thesis

The thesis has five chapters. After the introduction chapter, literature will be reviewed. The third chapter presents materials and methods used in the study. Results of the study and its discussion are provided in the fourth chapter. The final chapter will conclude and recommend based on the findings.

[6] Highlander- refers to those who do not belong to the ethnic group Afar but came from other parts of the country and live in Afar region.

2. Literature review

2.1 Rural livelihoods and IAS: Conceptual framework for interpreting the impact

The invasion of IAS is causing environmental crises and huge losses on biodiversity (Manchester and Bullock, 2000; D'Antonio and Kark, 2002). According to the Global Invasive Species Database, *Prosopis juliflora* is one of such species. The effect of invasive plant species on rural livelihoods is linked: (a) to extra cost of management due to farm land invasion; (b) to reduced agricultural production as a consequence of farm land invasion; (c) to reduced productivity of grasslands and rangelands because of encroachment; (d) to increased threat to human and/or animal health due to invaders' chemistry; (e) to increased disease incidence associated with micro-climate change due to invasion; and (f) to reduced utilities from indigenous herbs, trees and wild animals.

Conceptual framework which is helpful in interpreting the impact of IAS on rural livelihoods was proposed by Shakleton et al. (2006). The framework and its discussion by the authors are presented here.

According to them, the framework is assumed to be applicable for a variety of IAS and for different situations and scales of measurements**.** It consists of four curves projected over time since the introduction of an IAS in a given area (Figure 1).

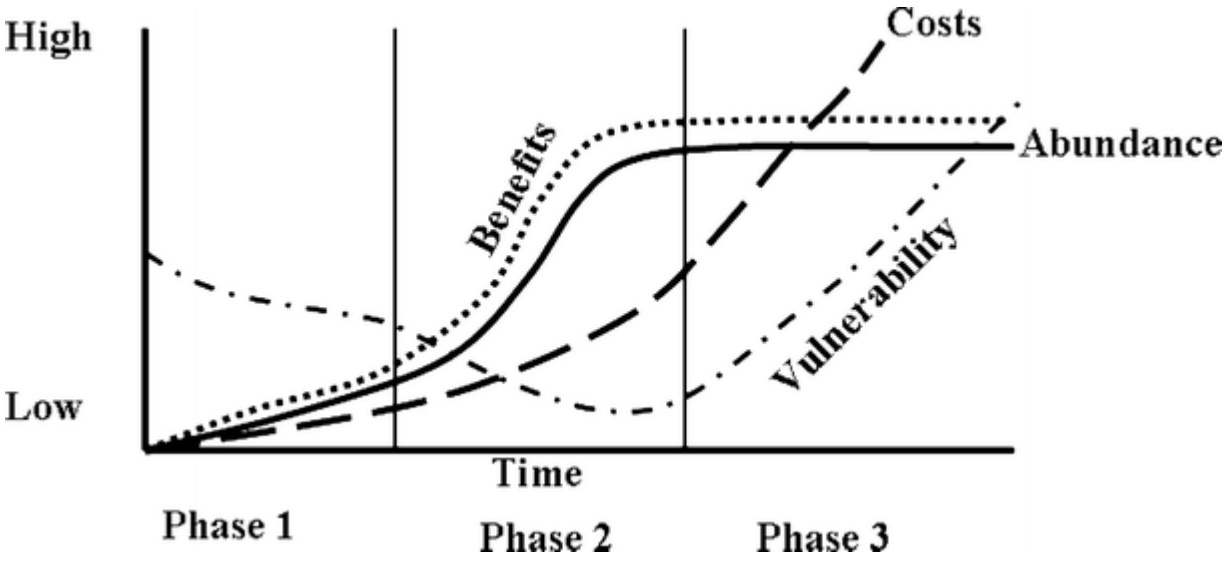


Figure 1: A conceptual framework to interpret impacts of IAS on rural livelihoods
(Source: Shakleton et al., 2006)

Abundance curve: In the absence of any management practice against an IAS, the curve will have sigmoid shape following the density dependant logistical function.

Benefit curve: It shows the benefits from an IAS to local livelihoods, if any. It is assumed that greater potential benefits will be realized from an IAS as its abundance increases.

Cost curve: a curve which considers all sorts of costs associated with an IAS. It is exponential because the associated costs are compounding as the abundance of the IAS increases with time.

Vulnerability curve: It shows local livelihoods vulnerability due to an IAS. The authors assumed that livelihood vulnerability for most of rural livelihoods is naturally high at the beginning. The vulnerability reduces as an IAS provides new openings to make a living. However, as costs increase, the vulnerability rises again. The situation may even make the rural households more vulnerable than at the start depending on cost-benefit ratio.

The time axis shows the temporal dynamics that the rural households are experiencing with an IAS. In Phase 1, livelihood vulnerability is due to other livelihood factors than the IAS. This is because of its low abundance and associated costs. Initially, it is accessed by few and hence benefit realization by the majority of the community is low. Most people start noticing the presence in Phase 2. In this case, if the species is beneficial, the community will start utilizing it. Due to the benefits obtained vulnerability reduces, however, utilization costs and ecological costs increase. Then, a threshold reaches when checking the invasion is needed, at the end of Phase 2. If the invasion is not controlled or other economical solutions are not identified, then cost-benefit ratio becomes large. This is Phase 3. In this phase, the rural community will either have to control the invasion or live with increased vulnerability.

The authors noted that species variability and geographic differences may result in different shapes and steepness of the four curves than presented. Accordingly, a 2*2 matrix was prepared based on aggressiveness and beneficial characteristics. Using the matrix, they produced four variations of the conceptual framework which are helpful for understanding an IAS' impact on rural livelihoods (see Table 1 and Figure 2).

Highly competitive species: In Phase 1 the abundance is low irrespective of its usefulness. In this phase, the benefits from useful ones are rare and opportunistic but there are no obvious uses for undesirable species. In Phase 2 useful species begin to integrate with rural livelihoods as the benefits increase with abundance. However, that of undesirable species starts

affecting local livelihood activities by reducing productivity of agricultural lands, grazing lands and ecological goods. Because of the competitive nature, costs increase for both useful and undesirable species. In Phase3 the benefits from useful species decreases; and for undesirable ones the cost reaches a point calling for control measures. For useful species also, cost continues to increase leading a raised cost-benefit ratio. At this point intervention is needed and due to the intervention taken the benefits may rise.

Table 1: Matrix of species competitiveness and usefulness (Source: Shakleton et al., 2006)

		Competitive ability	
		Weak	**Strong**
Beneficial traits	Low	Undesirable, weakly competitive species	Undesirable, strongly competitive species
		It has negligible or low impact on rural people, because its invasivity is low. Hence, it is easily controlled, although such control does represent a cost. It currently has no known use and hence no benefit curve.	The species has no or limited direct or indirect benefits to people. It invades rapidly, and is often difficult to control. The impacts on rural livelihoods will be most severe in the later phases of invasion. Rural communities are frequently unable to control it without external help.
	High	Useful, weakly competitive species	Useful, strongly competitive species
		Not very invasive, it is easy to manage. Benefits can be extracted from it and hence rural people with limited livelihood options will exploit it to maximum benefit. Such exploitation will be sufficient to keep it in check in most situations.	Such species invade the landscape or streams rapidly and thus are often difficult to control. They are useful to the invaded society and hence there is resistance to its complete removal. However, harvesting by dependent communities is an inadequate control measure and so abundance and concomitant ecological costs increase with time. People would like to be able to limit the species to a farming situation. Landscape invasion usually requires some external agency to assist in control.

Weakly competitive species: Initially, as that of highly competitive species, the abundance is low and the benefits from useful species are rare and opportunistic. In Phase 2 the abundance increases slowly and accordingly the benefits for useful species. Here, useful species are considered as resources and sources of livelihoods. However, those of undesirable ones spread solely to become a minor pest. If such species are let to invade, an invasion status which affects the rural livelihoods will be reached. In this phase, vulnerability of rural households due to useful species is avoided as long as the benefits exceed the costs.

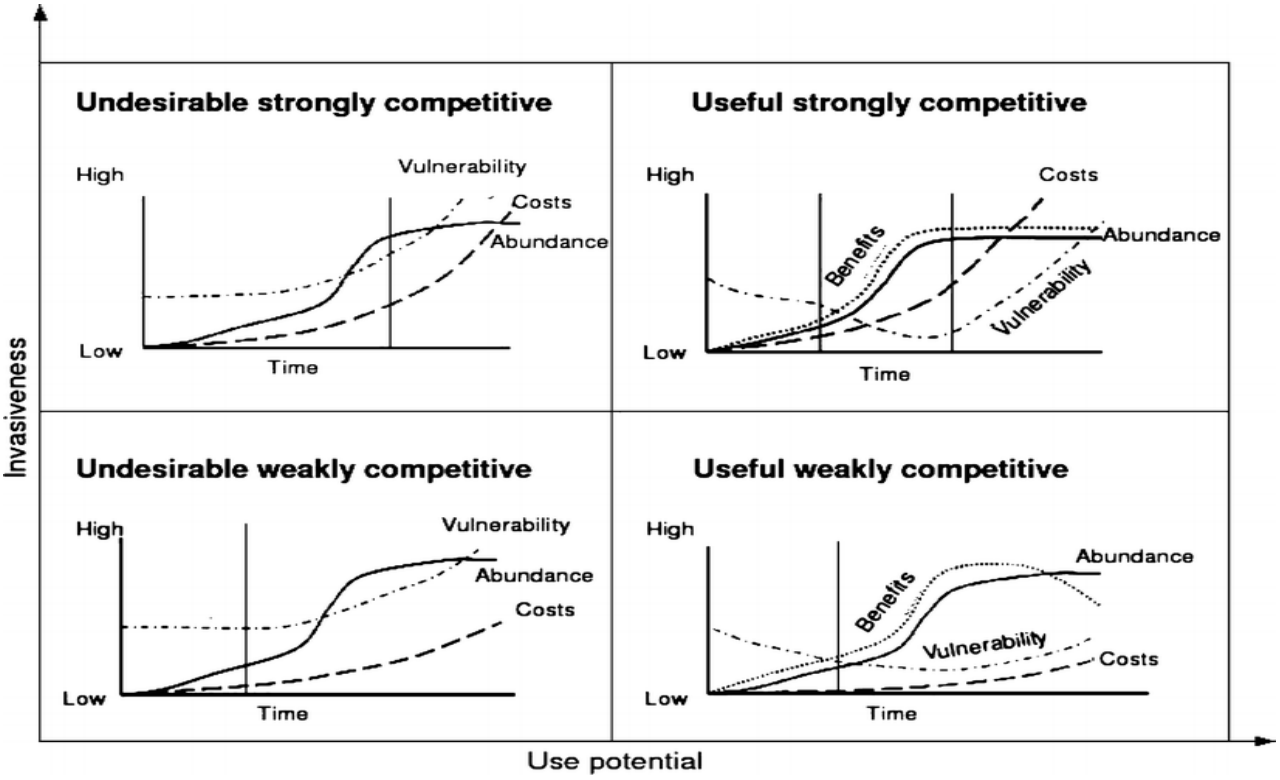


Figure 2: Variations of conceptual framework for different species
(Source: Shakleton et al., 2006)

2.2 Botanical description of *Prosopis juliflora*

Pasiecznik, et al. (2001) mentioned three origins, citing sources, for the name *Prosopis* which all rooted to ancient Greek. These are: 'a kind of prickly fruit', 'bardane' (a type of thorny plant) and the third as 'pros' meaning 'towards' and 'opis', wife of Saturn (the Greek goddess of abundance and agriculture). According to them, the name *juliflora* derived from two words, *julus* (meaning 'whip like') and *flora* (refers to the long inflorescences). Commonly, *Prosopis juliflora* is called mesquite, honey mesquite, Mexican thorn or cashaw (Pasiecznik et al., 2001; Pasiecznik et al., 2004; Zeila et al., 2004). It has at least four vernacular names[7] in Ethiopia, *Yeferenj biskut/Dergi-Hara /Woyane* in Afar region and *Biskut* around Dire-Dawa.

[7] The four vernacular names mentioned have origins related to its relished pods and time reference. *Yeferenj biskut* literally means 'White man's biscuit'; it was given as appreciation to the relished pod referring to the white man who is believed to have introduced the plant to the area. *Dergi-Hara* in Afar language means Derg-Tree, due to its introduction in the Derg regime and *Woyane* (common name for Tigrayan People's Liberation Front, TPLF) owing to noticing mesquite's speedy invasion and relating it to TPLF's success against the then Derg regime at the time. *Biskut* at Dire-Dawa is related to the relished pod and it means 'biscuit'.

Prosopis juliflora (SW.) DC belongs to genus *Prosopis* Linnaeus emend. Burkart, family Leguminosae (Fabaceae) and sub-family Mimosoideae (Pasiecznik et al., 2001). The species shows the largest genetic variability within the genus *Prosopis* causing it to behave differently in different environment (Pasiecznik et al., 2004). This may be due to obligately out-crossing as a result of self incompatibility (Felker and Clark, 1980). Mesquite is evergreen to semi-evergreen, flat-topped crown, thorny with a bushy appearance of spreading branches touching to the ground (Muthana, 1988; Pasiecznik et al., 2001; Pasiecznik et al., 2004). Its height ranges from 3-12 m and rarely reaches around 20 m depending on genetics, population and environment (Pasiecznik et al., 2001). The trunk's diameter reaches up to 1.2 m (Zeila et al., 2004). According to Kassahun et al. (2005), *Prosopis juliflora* in Ethiopia is generally described as short-multistemic (6-8 basal stems) with spreading canopy of twisted branches. In Afar region, it ranges from bush to tree reaching up to 15 m height and an average diameter of 0.2 m (Ameha, 2006).

Figure 3: Leaves and thorn of *P. Juliflora*

The leaves are pinnate (Figure 3) with 1-2 pairs of pinnae having 11-19 dark green leaflets (Kassahun et al., 2005); with high tannin content (Pasiecznik et al., 2001; Esther and Brent, 2005). Greenish-yellow flowers crowded on 5-12 cm long staked spikes give rise to indehiscent pods (Kassahun et al., 2005). On average a pod has 20-30 cm length and consists of up to 30 seeds (Kassahun et al., 2005). Seeds are half siblings and the resulting seedlings/tree will show considerable variation in its physiological, morphological and ecological characters (Felker et al., 1981). Immature pods are green and turn yellow at maturity. The pods contain high levels of protein and sugar and are also palatable to livestock and wild animals (Benedito, 1988; Pasiecznik et al., 2004; Esther and Brent, 2005). The plant carries stout yellowish poisonous

spines (Figure 3) coming up in pairs from the heart wood of its branches reaching up to 8cm (Ameha, 2006; Kassahun et al., 2005). The species has deep tap root system (Pasiecznik et al., 2001).

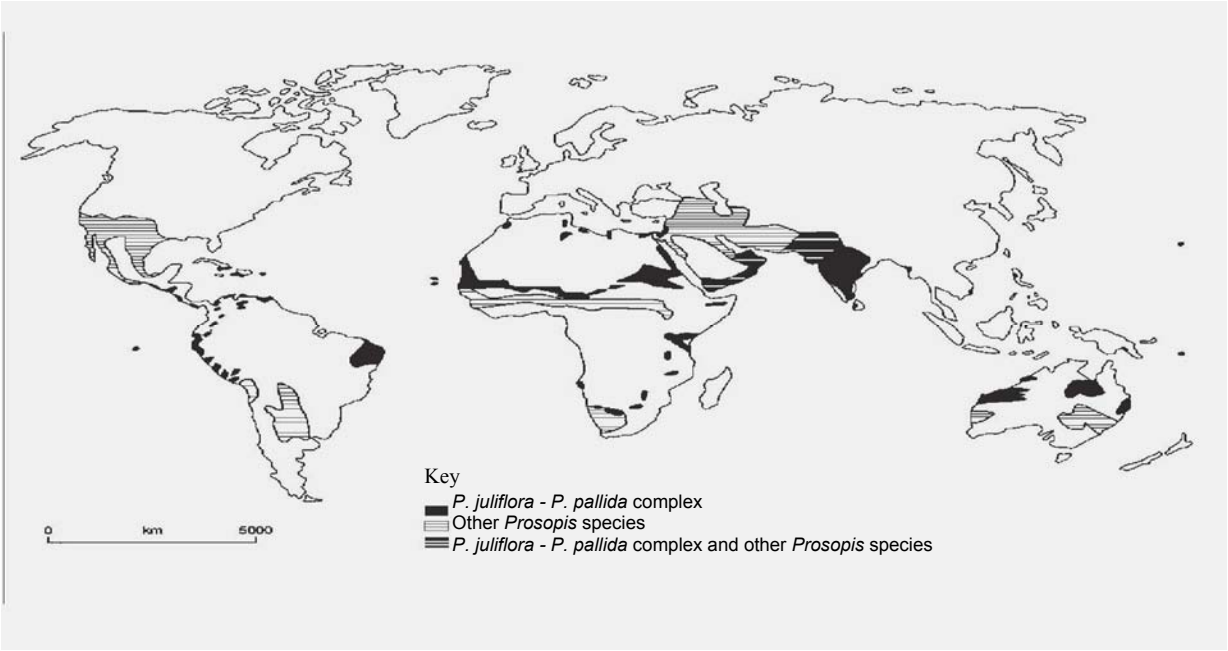


Figure 4: Distribution of *Prosopis* species in the year 2000 (Source: Paseicznik et al, 2001)

2.3 Ecology of *Prosopis juliflora*

Prosopis juliflora is native to the Caribbean, Central America and northern South America (Pasiecznik et al., 2004). Mesquite has a very wide soil and site adaptability: from sand dune to clay soils; from saline to alkaline soil; from < 200 to > 1500 m above seal level altitude; and from 50 to 1500 mm mean annual rain fall (m.a.r.) (Pasiecznik et al., 2004; Zeila et al., 2004). It is one of the most common trees in semi-arid and arid parts of the sub-tropical and tropical zones (Pasiecznik et al., 2001; Pasiecznik et al., 2004). Nowadays, it is very common in Africa, Asia and Australia (Figure 4).

Soil nutrient conditions and physical characteristics are hardly limiting the growth of mesquite (Pasiecznik et al., 2001). But better performance was observed on free draining than water logging soils (Ameha, 2006).

Prosopis juliflora performs well within 150 to 600 mm m.a.r. (Muthana, 1988). In this regard, the xerophytic adaptation of the leaves and the presence of lateral and tap roots play role (Pasiecznik et al., 2001). The lateral roots are useful for utilizing erratic rains whereas the deep tap root can reach ground water (Pasiecznik et al., 2001). The species can survive as high as 50

^{0}C and 70 ^{0}C air temperature and soil temperature, respectively (Pasiecznik et al., 2001). Pasiecznik et al. (2004) summarized the ecological adaptations of *Prosopis juliflora* as it '…can survive on inhospitable sites where little else can grow, tolerating some of the hottest temperatures ever recorded, and on poor, even very saline or alkaline soils.' These remarkable features of mesquite allow it to proliferate in arid to semi arid areas.

2.4 Introduction and invasion of *Prosopis juliflora* in Ethiopia

Documentation is lacking regarding when, from where, how and by whom *Prosopis juliflora* was introduced to Ethiopia, but some speculations exist. The earliest time of notice is believed to be in the late 1970s at Goro nursery of Dire-Dawa, eastern Ethiopia, probably from India (EARO and HADRA, 2005). If this is true, it is unfortunate that the seed sources for India and sub-Saharan Africa were from a non palatable type (Alban et al., 2002). Such haphazard introduction has yielded thorny inferior germplasm of the species in Ethiopia and resulted in little appreciation of the plant (Kassahun et al., 2005).

Mesquite was introduced to Middle Awash area, specifically to Worer, some 30 years before by a British man called William Ulcro (personal communication with elders at Worer). Ulcro, who was in charge of the Middle Awash Irrigation Project, introduced the species unauthorized (Kassahun et al., 2005). His sources are not clear; however, Kenya, Sudan or Dire-Dawa is suspected (EARO and HADRA, 2005). Mesquite was planted as hedge around offices, residential areas and along road sides within the compound of Middle Awash Basin Water Resources Agency based at Worer.

Local elders at Worer were told about the benefits of mesquite in order to get their permissions to plant its seeds and seedlings in Middle Awash area (personal communication with elders at Worer). The scheme continued until 1988 aided by various programs including Food for Work Program (EARO and HADRA, 2005). This gave good opportunity for mesquite to base in the valley. Then, the plant started expanding competing against grasses and indigenous trees. Consequently, starting from the early 1990s, local people began to realize the outweighing negative impacts compared to the expected benefits of the species (personal communication with elders at Worer).

Apart from the initial plantings, those inherent characteristics of mesquite discussed in section 2.3 have contributed to its unrestricted invasion. In addition, a research at Middle Awash area revealed that about half of the seeds which passed through animal digestive tracts have the

ability to germinate (Hailu et al., 2004). According to their findings, the maximum germination percentage was observed on seeds recovered from warthogs (47%) followed by goats (37%). They also observed up to 2833 seeds recovered from a kilogram of cattle dropping. This shows the amount and possibility of mesquite seeds transportation to far distances within livestock digestive tracts. On top of this, the seeds can germinate under wide ranges of temperature (20 - 40 ^{0}C) and moisture stressed environments (Abiyot and Getachew, 2006). Besides, the strong poisonous thorns and bushy growth habit of mesquite in the Middle Awash area act as repellent for human to utilize its benefits (Kassahun et al., 2005). It is due to these reasons that mesquite has unchecked expansion in the area.

So far, there is no survey made to assess the size of mesquite invasion in Ethiopia. But it is estimated to have invaded more than 30,000 hectares of lands in the Middle Awash area only (personal communication with Care-Awash staff). The species has also occupied a number of hectares in the Lower Awash area of the region and is still expanding to other parts. These lands were basically life supporting units for Afar pastorals through providing pastures for their livestock and ecological goods such as traditional medicines, wild fruits and materials for house construction.

In addition to Afar and Dire-Dawa regions, currently the species is spreading in arid and semi-arid parts of Somali, Oromia and Amhara regions (Ameha, 2006) and the species is declared to be the country's no. 1 invasive plant species (EARO and HADRA, 2005).

2.5 Benefits of *Prosopis juliflora*

Prosopis juliflora has documented merits like improving soil fertility, controlling soil erosion, stabilizing sand dunes, providing fuel wood and feed/forage for livestock, life fencing and for construction timber and furniture wood (Zeila et al., 2004; Esther and Brent, 2005; Kassahun et al., 2005; Stefen, 2005). However, there are also research findings which contrast some of the described benefits.

In some studies, the physico-chemical property of soil under mesquite canopy was found to be better than the adjacent open field (e.g. El Fadl, 1997 cited in Esther and Brent, 2005) which may be due to nitrogen fixation, leaf litter addition and change in soil structure due to deep tap root system (Pasiecznik et al., 2001). However, there are also observations where soil texture under mesquite canopy and open field were not significantly different (Ameha, 2006); besides

Zainal et al. (1988) (cited in Pasiecznik et al., 2001) noted that litter of *Prosopis juliflora* reduces soil fertility.

Mesquite is reported to produce good quality firewood and charcoal. Because of its high biomass production even on degraded land, it provides more firewood than other tree species (Ahmed et al, 1994). In India, it is grown on wastelands as a resource to fuel energy for cities and villages (Ahmed et al, 1994). However, there are conflicting reports on the quality of the fuel wood. According to Esther and Brent (2005) the fuel wood is of good quality with high calorific value, whereas local people from Ng'ambo area of Kenya claimed that the fuel wood produced poisonous smoke (Anonymous, 2004). They also complained that the wood is soft and easily attacked by insects which make the tree unfit for fuel wood and house construction (Anonymous, 2004).

Mesquite pods have been said having high nutritional value and being palatable for livestock (Benedito, 1988; Paseicznik et al., 2004; Esther and Brent, 2005). It has around 13% crude protein and is rich in saccharose, calcium, phosphorus, iron and vitamin B (Benedito, 1988). Ellis and Swift (1988) also reported that livestock of arid and semi-arid areas survive on dry pods during drought periods. However, according to Esther and Brent (2005) prolonged consumption of the pod by cattle causes constipation, impacted rumen and jaw and tongue trouble. There are also reports in Kenya that goats which consume mesquite pods have had problems like mouth disorientation, teeth fall off and swollen stomach (Anonymous, 2004). According to the report, these effects may result in death.

These conflicting findings on some important features of mesquite may be due to the high genetic variability within the species.

2.6 Negative effects of *Prosopis juliflora* on rural livelihoods

Mesquite invasion forms impermeable, dense thickets. It reduces grass cover of grazing lands and consequently affects stocking density (Pasiecznik, 1999). The invasion is also a major problem for agricultural lands. Mesquite is accused for diminishing ground water (Pasiecznik, 1999; Pasiecznik et al., 2001; Pasiecznik et al., 2004) with the help of its long tap root system. The leaves have allelopathic effects inhibiting under canopy growth (Al-Humaid and Warrag, 1998; Nakamo et al., 2003); the pollen also causes allergic reactions (Pasiecznik, 1999). The thorns are very poisonous both for humans and animals. It is these elements that enable mesquite to affect the livelihoods of the rural poor.

In Kachchh, India, mesquite has invaded more than half of Bani grassland which has an area of 2500 sq km (Gavali et al., 2003). According to the researchers, it has caused considerable damage on indigenous trees and wildlife and reduced the availability of palatable grasses. As a result, herders' livelihoods have been severely affected which led to migration and change in livestock composition (Gavali et al., 2003). An amount of farmlands in north-eastern Sudan has already been invaded by mesquite (Sudan Update, 1997; Catterson, 2003). Farmers in the area could not afford the management cost which left them in trouble to secure their livelihoods (Sudan Update, 1997). Considering the seriousness of the invasion, Sudan has passed a law to eradicate mesquite (Sudan Update, 1997). Kenya's arid and semi-arid parts are also facing large scale invasion from mesquite (Stefen, 2005). Studies conducted around Lake Baringo of Kenya showed that mesquite invasion of pasturelands, farmlands and fishing areas is affecting the local livelihoods (Esther and Brent, 2005 and Zeila et al., 2004). The studies revealed that the invasion has caused migration of people to un-invaded locations, increased conflict on remaining limited resources, and increased mosquito infestation aggravating malaria incidence. The people are also quoted blaming mesquite as a hideout for predators and cattle rustlers (Zeila et al., 2004).

Mesquite has invaded important habitats such as grazing lands and watering points of pastoralists in the dry and semi-dry parts of Ethiopia (Figure 5). Such encroachment of grazing lands reduces grass fodder availability (e.g. Gemedo et al., 2006; Angassa and Oba, 2008) and thereby affects livestock rearing which is the principal component of pastoral livelihoods. A study by Gemedo et al. (2006) in southern Ethiopia showed that woody plant encroachment is a major threat for the livelihoods of pastoralists and their ecosystem. In Afar, mesquite has encroached thousands of hectares of valuable lands. Grass availability under its canopy was found extremely rare (Ameha, 2006). The bush is expanding from time to time which increasingly puts the Afar pastorals in problem.

Peoples in the dry lands are demanding the eradication of mesquite (Zeila et al., 2004); however, experiences show that mesquite eradication is costly and very difficult once it establishes (Pasiecznik, 1999; Zeila et al., 2004). Ranchers in Argentina and south-western USA spent millions of dollars to check *Prosopis* invasion for the last fifty years but no cost effective management technique ha yet been developed (Pasiecznik, 1999). In Australia and South Africa, biological control (seed eating beetles) were tried along with other control programs; in Sudan children were trained uprooting mesquite seedlings in the eradication program (Pasiecznik,

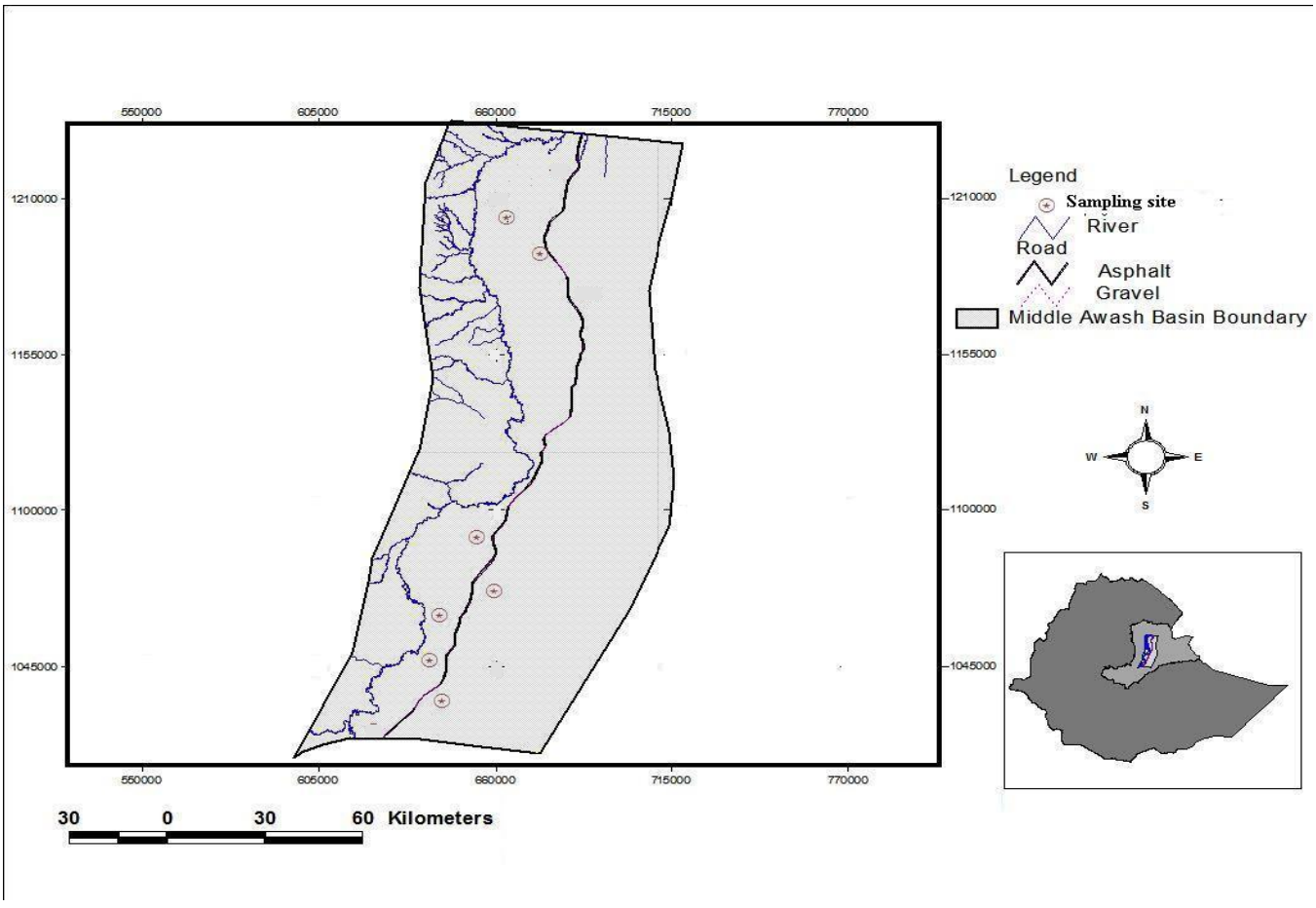
1999). The experiences from these efforts tell that once mesquite is introduced to a place, it will remain there.

Figure 5: Mesquite encroachment at Bedlu -Ale grazing land, Middle Awash Area

3. Materials and Methods

3.1 The study area

The study was conducted in Afar National Regional State which is found in north-eastern part of Ethiopia. The region covers around one-third of pastoral lowlands in the country and about 10% of the total area of Ethiopia (Yirgalem, 2001). Middle Awash area is found in between Upper and Lower Awash River basins (Figure 6). Its altitudes ranges from 500 to 820 meters above sea level and it is located between 9^0 30' and 10^0 20'N and 40^0 30' and 40^0 50'E. The main stays of local people to the region are pastoral and agro-pastoral. Livestock population of the study area is estimated to be 414,568 small stock (sheep and goats), 224,670 cattle and 76,600 camels (ARPARDB, 2007). According to the report, around one hundred thousand people are living in the study area.



+ The sampling sites in the map are sequenced as Awash Arba, Sideha-Faghe, Worer, Halaideghe, Amibara and Gewane ('top' two points) as one move from south to north.

Figure 6: Middle Awash Basin map showing sampling sites

Thirty year meteorological observation data from Werer Agricultural Research Center revealed that Middle Awash area is experiencing bimodal rainfall pattern. As per the observation, July and August are the wettest months with monthly mean rainfall greater than 100 mm. The second rainy season appears in February to April with monthly mean of around 70 mm. The mean annual potential evapo-transpiration (2702 mm) of the area exceeds the mean annual rain fall (562 mm). This implies the area is characterized by moisture deficit. The mean annual temperature is 34.1 ^{0}C. November and June have minimum and maximum mean temperatures of 18.9 and 38 ^{0}C, respectively.

The land use system of the study area includes shrub land (38%), open land (30%), grass land (19%), rock outcrop (6%), wood land and sand dunes (4%), and wet land, riverine forest and water body, 1% each (WBISPP, 2003). *Acacia nilotica* and *Tamarix aphylla* are the dominant species of the riverine forest found along the bank of Awash River. Other tree species like *Salvador persica*, *Dobera globra*, *Cadaba routundifolia* and *Prosopis juliflora* are common in areas with high saline soil (Ameha, 2006).

Development agents working at Pastoral and Agro-pastoral Office of Zone-3, Afar region, were consulted about mesquite invasion status of villages in the study area. Besides, personal experience and researchers report (e.g. Hailu, 2003; Hailu et al, 2004; Abiyot et al, 2006; Amaha, 2006) about the invasion were also taken in to consideration.

3.2 Study Design, Sampling technique and methods of data collection

3.2.1 Study design

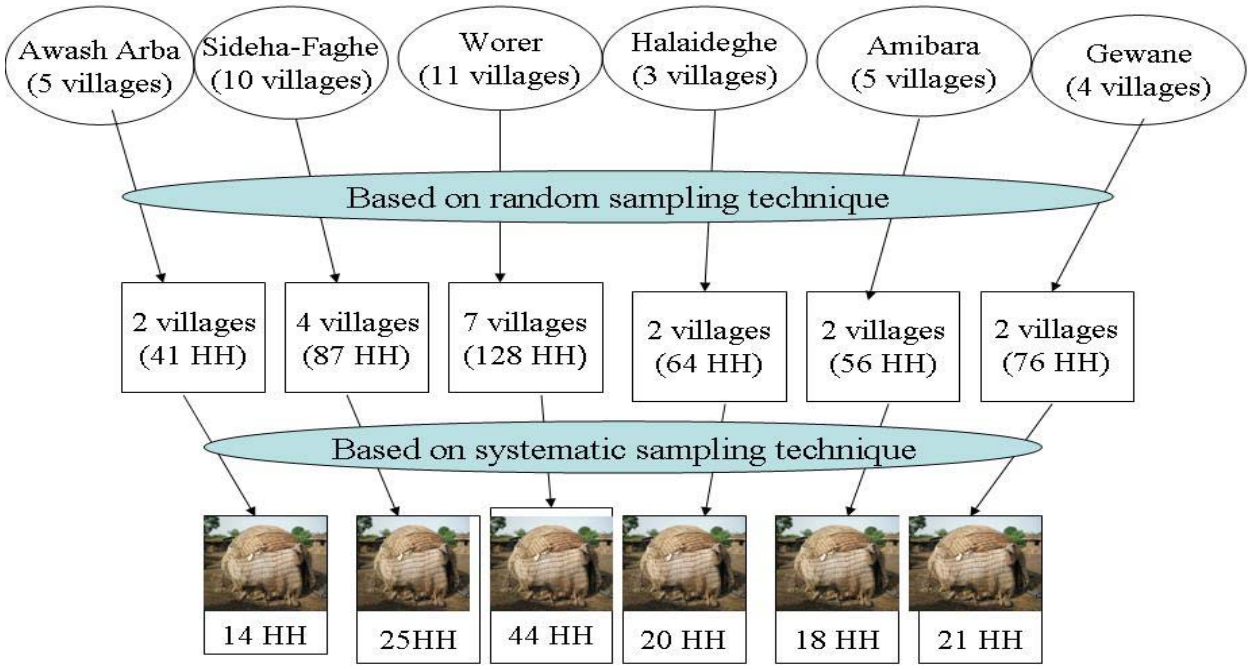
In the attempt to find the consequences of mesquite invasion on pastoral livelihood, survey research was employed. The design was selected because it enables collection of data on multiple cases from a pre defined community in a relatively short period of time (Bryman, 2004). Group discussion[8] with elders was also done.

3.2.2 Sampling technique

Stratified random sampling method using random and systematic sampling[9] was used at village and household levels, respectively. The technique, according to Bryman, 2004, is good at reducing sampling errors that may affect the outcome of the study.

[8] Group discussion helps in identifying important and significant issues related with a given topic (Bryman, 2004).
[9] Systematic sampling technique is a variation of simple random sampling under probability sampling technique where units are selected from the sampling frame with out the help of random numbers (Bryman, 2004).

Lists of pastoral villages of the selected data collecting sites were obtained from Pastoral and Agro-pastoral Office. According to the list 11, 10, 5, 5, 4 and 3 pastoral villages are found in Worer, Sideha-Faghe, Amibara, Awash Arba, Gewane and Halaideghe areas, respectively. Among these, two villages for each of Amibara, Awash Arba, Gewane and Halaideghe areas and 7 and 4 villages for Worer and Sideha-Faghe areas, respectively, were selected using random sampling techniques (see Figure 7) .



HH: Households

Figure 7: Schematic presentation of households selected for the survey

Complete lists of household heads of selected villages were obtained from elders at each village. This is because the information was not available at the Administration Office. Accordingly, 431 households were enumerated in the interest areas. The distribution was 128, 87, 76, 64, 56 and 41 households at the selected villages of Worer, Sideha-Faghe, Gewane, Halaideghe, Amibara and Awash Arba, respectively. From these 44, 25, 21, 20, 18 and 14 households (totally 142 households) were selected from the above villages using systematic sampling technique (see Figure 7). The surveyed households represented 32% of the total number of households in the sample villages.

3.2.3 Data collection methods

The research was implemented from mid of June to end of July 2007. Group discussion with elders was conducted before the survey. Five elders participated for group discussion (one from Sideha-Faghe and two from each of Halaideghe and Worer). The discussion was important for re-designing the prepared structured questionnaire and as a triangulation for the survey result. Structured interview with both open-ended and closed-ended questions was used to collect data from households. The interview method helped reducing errors due to variability in enumerators as it guarantees standardization of the questions (Bryman, 2004). Personal observation was also used to understand the circumstances during both site selection and household survey.

Two enumerators and three translators assisted in data collection. A thorough discussion was made with the enumerators about the questionnaire. Translators were trained for a day about understanding the questions, interpretation and translation of concepts. The researcher along with the enumerators undertook pre-test on six respondents. The respondents were randomly selected from Serkamo area. After the pre-test a minor change on questions and question sequence was done.

In this study, the household was used as unit of analysis. Because of cultural norm it is the household head who is expected to speak on behalf of the household. Most households were male headed and even for the few widows, the matured son acted as head. As a result quite few respondents were females. However, housewives of most interviewed households were also involved in answering open ended questions along with their heads.

During the survey, a card was used to ease answering of those questions having proportions as a response. Besides, missed households were substituted by a household above or below them based on the produced list. On average a household interview took 50 minutes during the survey.

3.3 Data analysis

Data on demographic and socio-economic characteristics, perception about mesquite invasion level and its importance and livelihoods strategy against the invasion were analyzed using Mintab statistical software (mtb 14). Logistic regression[10] was used to identify influential variables for both diversification of livelihood strategies and utilization of mesquite resources as

[10] Logistic regression model is a commonly used model when the response variable is qualitative in nature (Gujarati, 2003; Montgomery, et al., 2006)

income by a household. In the logistic regression, logit model[11] was estimated using maximum likelihood[12] methods for predefined independent variables. Tropical livestock unit[13] (TLU) was used to measure the livestock asset of individual households in the regression model. This was done because households were observed having different composition of livestock; hence, a unit of measurement for livestock was needed to use livestock as an indicator variable to compare households.

The first logistic regression was run using 'mesquite as a source of income' as dependant variable on household head age, level of education, polygamy status, family size, livestock asset, change in livestock asset (between 10 years ago and current holding) and location of the household. The hypothesized effects of these independent variables were:

- Household head age - as the head's age increases, the potential to utilize mesquite as sources of income decreases due to limited working capacity and hence the household will not use mesquite as source of income.
- Level of education - negative relation with the dependant variable was assumed as the level of education for a household head rises. This is because the chance for such household head to engage in other activities like formal employment is higher in the study area.
- Polygamy status - when a household head is polygamy, his expenditure will be higher than non polygamy household head. This situation will drive the polygamy household head to use many sources of income, and hence mesquite.
- Family size - it was assumed that the expenditure will be higher and also more labor will be available for large sized families to utilize mesquite as source of income.
- Livestock assets - the more livestock a household owes, the more culturally defined way of life (i.e. pastoralism) the household will live; and hence it will negatively affect the dependant variable.
- Change in livestock asset - households that lost more livestock will use mesquite resources as means of income for survival.

[11] Logit and probit link functions of logistic regression are very similar (Montgomery, et al., 2006), hence I selected Logit model for ease of calculation

[12] Maximum likelihood method is a method for estimating unknown parameters with minimum variance where the error is assumed to be normally and independently distributed (Montgomery, et al., 2006).

[13] Tropical livestock unit (TLU) commonly takes 250 kg liveweight as a standard of unit; accordingly, a TLU conversion factor for camels, cattle and small stocks is 1, 0.7 and 0.1, respectively (Jahnke, 1982).

- Location - the assumption was that households in different areas will vary with regard to mesquite as source of income.

The second logistic regression was run using 'diversification of livelihood strategies', where Y = 1 pastoralism and/or others, Y = 0 pastoralism only, as dependant variable on household head age, level of education, polygamy status, family size, perceived size of grazing land abandoned due to mesquite, livestock asset, change in livestock asset (between 10 years ago and current holding) and location of the household. The hypothesized effects of these independent variables were:

- Household head age - it was assumed that as the head's age increases, he will be endowed with knowledge as to how to diversify his sources of income.
- Level of education - as the level of education for a household head increases, the head will easily adopt sources to diversify the household's livelihood.
- Polygamy status - as that of the first case, polygamy status of a household head will positively affect the dependant variable due to the same reason.
- Family size - it was assumed that the expenditure will be higher and also more labor will be available to diversify their livelihoods, like the first case.
- Livestock assets - for the same reason mentioned in the first case, it was assumed that livestock asset will affect the dependant variable negatively.
- Change in livestock asset - the expectation here was that reduction in livestock asset will positively affect livelihood diversification as households need to regain the livestock shock they have faced.
- Perceived size of grazing land abandoned due to mesquite - as more lands are abandoned due to mesquite, individual households will find other means of survival along with livestock thereby diversifying their livelihoods.
- Location - households at different areas were assumed to have different sources to diversify their livelihood.

For both of the logistic regressions, Worer was used as a reference place as it is a source of mesquite for the rest of the locations in the study area.

Wilcoxon signed rank test[14] was done for matched pair comparison between 10 years ago and current holdings of individual household's livestock assets. Chi-square analysis was used to compare frequencies. Frequencies were calculated using descriptive statistics and bar charts were drawn using Microsoft Office Excel.

A ten year time span was used to compare livestock assets, number of livestock that died due to the problem caused by mesquite pod and perception about milk productivity of their livestock by individual household. This span was selected because it is not recommended to rely on the memory of a given community who has no skill to keep diary on events for extended time [beyond 10 years] (Bryman, 2004). Considering this and noting that the Afar pastorals begin realizing the negatives of mesquite starting from the early 90s; a reference time which is 10 years behind 2007 was selected for these specific questions.

Open ended questions which were used in the analysis were first categorized to make them fit for analysis. Responses analyzed in this way included mechanism used to cope with the grazing availability and methods used to control the invasion of mesquite. Some of the respondents' narrations were also presented.

The conceptual framework presented at Section 2.1 was used to identify the category (see Table 1) and estimate the phase of mesquite (see Figure 2).

[14] Wilcoxon signed rank test is a test for comparing matched pairs when different weight is justifiable for observed differences of the pairs of a nonparametric variable (Johnson and Bhattacharyya, 2006).

4. Results and Discussion

4.1 Socio-economic and demographic characteristics

A small proportion of the respondents were below the age of 25 years (Table 2) with an over all mean age of 38.7 years (SD = 11.83). For the reason mentioned in section 3.2 most of the respondents were male of which 69% were illiterates. Most of the respondents who attended religious education had received primary education (χ^2 = 9.59, p = 0.002) in the study community. Of the married men, only 19.5 % had more than one wife. The mean household size was found to be 7 (Table 2).

Majority of the surveyed households responded livestock farming as a main livelihood activity (Table 2). Being a pastoral community, there is heavy dependence on livestock and around 91% of Afar people in Ethiopia are estimated to be herders (Tadesse and Yonas, 2007). The proportion of households using full time job or crop farming as main source of livelihood was not significant different from each other (p = 0.495) . Selling labor for state and investor farms and other construction projects in the area was the most important secondary livelihood.

A sole dependence on livestock has been facing pressure from environmental stress, demographic and institutional changes the pastoral community undergoing (Ayalew, 2001). And thus, there were implications on livelihood diversification in the study area (Table 2).

4.2 Pastoralists' perception about mesquite

The pastoralists' awareness about the existence of mesquite in their locality was assessed. According to their response, 74% of the respondents knew the bush within the last 20 years whereas the rest were aware before the past two decades. The awareness of local people about the existence of IAS basically depends on its abundance (Shakleton et al., 2006). The authors also noted that at early stage of introduction, a small proportion of a community are aware about the existence of such species in their area.

Concerning the importance of mesquite, eighty four percent of the surveyed pastoral households perceived it as undesirable species. Rural communities having similar livelihood strategy tend to categorize introduced species similarly (Pasiecznik et al., 2001). Being pastoralists, most of the local community have similar livelihood strategy and perceived likewise. It was only less than 2% of the respondents put mesquite under beneficial species; whereas the rest (14.2%) stated it as both beneficial and harmful. Variability in responses between 'both beneficial and harmful' and 'undesirable' categories was observed among villages (Table 3).

Table 2: Socio economic and demographic characteristics of the study households

Demographic information		Respondents frequency (n = 142)	Mean	SD
a) Sex	Female	5	-	-
	Male	137	-	-
b) Age	16-24	12	19.8	1.81
	25-34	41	29.3	1.90
	35-44	49	38.5	2.38
	>45	40	53.9	7.64
c) Marital Status	Married	138	-	-
	Single	4	-	-
d) Polygamy status	Yes	26	-	-
e) House hold size	Mean house hold size	-	7	4.08
f) Education status	Illiterate	93	-	-
	Primary	26	-	-
	Religious	32	-	-
g) Main livelihood	Livestock farming	101	-	-
	Full time job	22	-	-
	Crop farming	18	-	-
	Small trade	1	-	-
h) Other livelihood activities*	Piece jobs	61	-	-
	Livestock farming	39	-	-
	Crop farming	11	-	-
	Share cropping	9	-	-
	Small trade	7	-	-
	Share from clan land	5	-	-
i) No. of camel owned	None	67	-	-
	1-10	53	5.4	3.03
	11-20	15	18.6	2.73
	Above 20	7	37.2	8.93
j) No. of cattle owned	None	18	-	-
	1-10	91	6.4	3.20
	11-20	18	17.8	2.91
	Above 20	15	37.7	16.45
k) No. of Small Stock owned	None	19	-	-
	1-10	48	7.6	2.98
	11-20	40	18.8	2.021
	Above 20	35	40.9	17.23

* A household may have more than one supplementary activity

The proportion of respondents who put mesquite as both beneficial and harmful is significantly higher for Worer, Amibara and Sideha-Faghe, collectively than the rest of the villages ($p = 0.015$) (Table 3). This may be because in these villages there was a trial campaign to minimize the spread of mesquite by utilization; which took place for 18 months (from September,

2005 to March, 2006). In the campaign, pastoralists were organized under cooperatives to produce charcoal and involve in collection and grinding of mesquite pods for fodder. This may influence the perception of a few respondents in the campaigned villages to recognize mesquite both as beneficial and harmful.

Table 3: Importance of mesquite by village category

Response	**Village**		χ^2
	Campaigned villages	Non-campaigned villages	
Beneficial	1 (1.15)	1 (1.82)	
Both beneficial and harm full	20 (22.99)	4 (7.27)	5.87**
Harmful	66 (75.86)	50 (90.91)	

** Significant at $\alpha = 0.05$ ($p = 0.015$)
The χ^2-test does not include the beneficial row as their expected count is less than 5
Campaigned villages (Worer, Amibara and Sideha-Faghe)
Non-campaigned villages (Haladeghe, Awash Arba and Gewane)
Note: The numbers in bracket show the proportion

A detailed account of negatives and significances of mesquite were summarized in Table 4 & 5. Villages were differed very slightly in the opinion on significances and effects of the bush.

4.2.1 Effects of mesquite invasion on settlement areas and footpaths

Mesquite's invasion of settlement areas and footpaths were mentioned very often by respondents in all villages (Table 4). A significant proportion of the surveyed households complained that they could not resettle in their camp once they left it for a season in search of pasture. Similar problems were also faced elsewhere (e.g. Gavali et al., 2003; Anonymous, 2004; Esther and Brent, 2005). This in turn affected the mobility[15] of the Afar pastoralists (Table 4). However, seasonal migration is one of the risk strategies for pastoralists to ensure maintenance of their livestock and culture in their fragile ecosystem. According to Western and Nightingale (2002), transhumance allows marked recovery of grazing lands after rainfall due to *de facto* 'protected' grazing. This ensures year round pasture availability and may help to increase productivity and size of pastoral herd. The other fact with mobility is that, grazing lands in drier

[15] Mobility with livestock is synonymously used with transhumance and migration.

environments are characterized by annual grasses and herbs due to the lower rainfall amount it receives. And hence, mobile nature of grazing allows optimum utility from the grazing lands. However, the limited mobility of herds imposed by mesquite invasion broke the usual cycle. It also resulted in overgrazing of the remaining pasture sources which further aggravated the depletion problem in the area.

Invasion of footpaths was the other problem imposed on the pastoral community of the whole villages; while the invasion of burial places was stated as a problem more at Worer followed by Sideha-Faghe and Amibara (Table 4). A woman from Serkamo shared her experience about the invasion on footpaths as:

> If we cease using a path for some time, then we will get it covered by *woyane*. Unless we clear it, it is impossible to use that path again. Even for the path we are using frequently, it needs periodic management. Otherwise it becomes narrower and narrower through time. You can not walk side by side with your friends; you will be pricked (Respondent 6, 49 years old).

4.2.2 Perceived effects of mesquite invasion on the community traditions

Mesquite invasion has affected the traditions and institutions of Afar pastoralists in the study area as confirmed by a high rate of response, 84%. Traditional games, some cultural settings and self helping institutions (like contributing stocks to rebuild neighbor's stock shock during disasters and providing milk for poor village members) are among the threatened ones.

In Afar culture there is high degree of reciprocity. If a household looses its livestock asset due to rustling, epidemics or other agent, the risk is divided among the whole clan thereby the household gets some stocks for rebuilding its stock asset. However, nowadays the possibility for risk division is very rare as each household is under pressure of losing its livestock asset due to pasture shortage. The effect of the bush against traditional games and night walk seems due to the invasion of playing areas and footpaths besides its poisonous thorn. Whereas for self helping institutions, it is the ill functioning of the livestock system due to narrowed dry and wet season grazing lands (Table 4).

> We (Afar men) like to walk during night, either to visit distant relatives, for patrolling our area or for other reasons. I do not think anyone is doing it nowadays. Because, you do not know the footpath and you may get lost. Let alone long distance, I have stopped visiting my neighbors for *dagu* [a setting where detailed account of information is exchanged] when it gets dark. What if I lost my eye and also injure my

> feet? After it gets dark, we are locked in our houses like a prisoner. Even our children quit night cultural plays which were done in the past days. Current generation does not play[16] *geba-ku'uso, alsa-hada, sede'a, seso-seso, kula-habe* and the likes. This is because, 1: the invasion is everywhere and 2: the thorn is poisonous so no one dares to play (Respondent 29, 52 years old, from Adobtele village).

This view summarizes many respondents' idea as I observed during the household survey. Invasive species, thus, threat to demolish rural traditions and institutions as also reported by Gavali et al. (2003) and Siges et al. (2005).

[16] - *Alsa hada* it is a traditional playing which is played during moon night only by 'hiding' a short stick. Two groups each ten are formed then on draw basis a group will start the game. The starting group will throw the stick as far as possible. The second group will start finding the stick.

- *Geba Ku'uso* is a kind of traditional Afar youth game which it is played by dribling ball only by hand. A player continously dribles the ball against the ground and then kicks it to the sky and recieves it and does the same until the ball is out of his controll.

- *Kula-habe* is a kind of play played by two groups during moon night. Here the two groups will make some distance between them and then put any kind of symbol by their fingers on the ground. And they exchange their sites to rub well what was done by their opponent. Those who rub well will score higher point.

- *Sede'a* is a kind of girls play during moon night by singing traditional songs.

- *Seso-seso* is children play during night where one among the players will cover his eyes letting others to hide. Then he/she will start finding each of them. The one who is caught/discovered first will play the next round and so on.

Table 4: The negative aspects of mesquite in the Middle Awash Area of Ethiopia based on the household survey in six villages

	Worer	Sideha-Faghe	Amibara	Halaideghe	Awash Arba	Gewane
Invasion of wet season grazing sources	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Invasion of dry season grazing sources	XXXX	XXXX	XXXX	XXX	XXXX	XXXX
Affect seasonal mobility of herds	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Affect traditions and institutions	XXXX	XXXX	XXXX	XXXX	XXX	XXXX
Invade farming land +	XXXX	XXXX	XXXX	XXXX	-	XXXX
Competition for labor	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Probable danger on household members due to the thorn	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Probable danger on livestock due to the thorn	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Invade villages / settlement areas	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
The invasion trouble herders for their site control of herds	XXX	XXXX	XXX	XXXX	XXXX	XXXX
Blocking footpaths	XXX	XXXX	XX	XX	XXX	XXX
Invade burial places	XXX	XX	XX	-	-	-
Host to predators	XX	XXX	XXX	XXXX	XXX	XXXX
Host to rustlers	XX	XX	X	X	X	-
The pod is probable danger for livestock health	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
The leaf is probable danger for livestock health	X	-	-	X	-	-
Inhibit under canopy growth of grasses	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Endangers indigenous tree species	XXX	XXXX	XXX	XXXX	XXXX	XXXX
Narrowing/blocking cattle tracks	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Minimizing water availability[17]	XXX	XXX	XXX	XXX	XXXX	XXX
Litters under water cause stringent smell	X	X	-	XX	-	-

+: among those who cultivate land; X: Very rarely mentioned (25% or less); XX: Rarely mentioned (between 26 and 50%); XXX: Often mentioned (between 51 and 75%); XXXX: Very often mentioned (76% or above)

[17] The availability of water and mesquite was seen from a different angle from the case mentioned in literature part. According to the respondents, areas which were holding water after rain are occupied by mesquite and hence hold no more. Such areas were temporary sources of water for both livestock and household consumption.

4.2.3 Benefits of mesquite for Afar pastorals

As shown in Figure 2, for highly competitive IAS like mesquite, most of the local people start mining its benefits after Phase 1. The motive for utilization may be preference against others or abundance driven. For Afar pastoralists, most of the significances mentioned in Table 5 were found to be abundance driven. Such motive for the utilization of invasive shrubs by rural people was noted in different literature (e.g. Anonymous, 2004; Esther and Brent, 2005; Siges et al.,2005; Shackleton, et al., 2006). Since the invasion affects the abundance of multi-use indigenous species (Manchester and Bullock, 2000; D'Antonio and Kark, 2002; Amaha, 2006), it drives the local people toward replacing the uses of endangered indigenous species by the abundant IAS. Majority of the respondents vowed during the survey that they prefer the indigenous plants against any of mesquite's benefits. According to them, they are using it because of 'no options'; they said the invasion undermined other indigenous plants.

Table 5: The benefits of mesquite in the Middle Awash Area of Ethiopia based on the household survey in six villages

	Worer	**Sideha-Faghe**	**Amibara**	**Halaideghe**	**Awash-Arba**	**Gewane**
Means of income	XX	X	XX	X	XX	XX
Forage/ Fodder	XXXX	XXX	XXX	XXX	XXXX	XXXX
Shade tree	XXX	X	XX	XX	XXX	XX
Fuelwood	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Fencing homestead	XXXX	XXXX	XXX	XXXX	XXXX	XXXX
Barn construction	XXXX	XXXX	XXX	XXXX	XXX	XXXX
For house construction	XX	XX	XX	X	XX	XXX
walking stick	X	X	X	-	-	XX
Temporary platform for resting	X	-	-	-	-	X
For making traditional bed (*Olo'ytaa)*	X	-	-	-	-	X

X: Very rarely (25% or less) XX: Rarely (between 26 and 50%)
XXX: Often (between 51 and 75%) XXXX: Very often (76% or above)

Even though the proportions of respondents who earn income from selling firewood and/or charcoal from mesquite were smaller in Sideha-Faghe and Halaideghe than the rest villages, there is an implication that pastoralists are using the bush as source of income (Table 5). In order to identify factors influencing utilization of mesquite as a source of income, logit model was estimated using maximum likelihood method.

Mesquite as a source of income is a dichotomous variable which takes the value of 1 if a household utilized mesquite as source of income and 0 otherwise. The logit estimates for the independent factors of mesquite as a source of income are presented in Table 6. The likelihood ratio for the goodness of fit test ($G = 20.83$, $p = 0.022$) shows that there is at least one variable which significantly affects a household to utilize mesquite as source of income in the study area. According to the result, household head age, change in livestock assets and location significantly affect a household to make income from mesquite.

As per the assumption, old headed households tended lesser than young headed households to earn income from the bush. Five years increment in a household age is found to decrease the probability of exploiting mesquite for economic reason by around 25%. This may be due to the fact that as one gets older, he loses the strength to provide firewood and charcoal for sale. Unlike the prior expectation, loss of livestock assets is proved to negatively affect a household to use mesquite as a source of income. This may be explained as the social value for those households who previously had much livestock assets will be high putting them in a position not to involve in lower class jobs. Or, they have other means to win their bread. Households' location dummies indicate that residents at Halaideghe range land are less likely to use mesquite than Worer's; whereas higher likelihood is noted for Gewane than Worer households.

Even if the impact of level of education and polygamy status are not significant, they affect the dependant variable in the expected direction (Table 6). Unlike the assumptions made, family size and livestock asset are found having opposite effect, though not significant. The observed early marriage of young male in the study area will cause a household to lose potential labor force to utilize mesquite as source of income. On the other hand, households who own more livestock assets may have the potential to hire labor to utilize mesquite as an income. These may be reasons for the variables, family size and livestock asset, to influence the dependant variable opposite to the expectation.

Table 6: Logit mesquite as source of income model: Maximum likelihood result (Dependent variable, Y = 1 if a household uses mesquite as source of income, Y = 0 otherwise)

Variable	Coefficient	Std. error	Marginal effect
Age of house hold head	-0.045	0.023**	-0.010
Primary school dummy (1= yes, 0= No)	-0.002	0.534	-0.001
Polygamy status (1 = yes, 0 = No)	0.657	0.742	0.152
Family size	-0.095	0.104	-0.022
Total livestock units	0.018	0.018	0.004
Change in total tropical livestock unit (10 years ago – Current holding)	-0.011	0.006*	-0.003
Division in which household is located (reference is Worer)			
Amibara (1= yes, 0 = No)	0.541	0.713	0.126
Awash Arba (1= yes, 0 = No)	0.552	0.671	0.128
Halaideghe (1= yes, 0 = No)	-1.461	0.865*	-0.339
Gewane (1= yes, 0 = No)	1.169	0.666*	0.271
Sideha-Faghe (1= yes, 0 = No)	-0.337	0.783	-0.078
Constant	1.481	0.993*	0.344
Numbers of observation		142	
LR(G)		20.83**	
Log likelihood		-63.36	

Note: **, * Significant at 5% and 10%, respectively.

Firewood, fencing and barn making materials were the most common uses of mesquite provided for all villages (Table 5). Most of the women, who involved in the interview along with their man, complained about the poisonous thorn during fire wood collection. These women also criticized the heat from mesquite wood not lasting long unlike the indigenous *kasalto* (*Acacia nilotica*). In spite of their critics, the empirical study from WARC (2005) shows that the two species have comparable burning quality. Smoke produced by mesquite firewood was also blamed poisonous by rural women to the extent of avoiding using mesquite as fuelwood (Anonymous, 2004). Situations where local people's responses disagree with research findings may arise from the general detest of the community against the matter.

Majority of the respondents were using mesquite for constructing barn (Figure 8). However, according to the respondents, the longevity of barns constructed from mesquite stem is not as those which are made from indigenous sources like *adengali* (*Cadaba rotundifolia*), e'ebto (*A. tortilis*) and *kasalto* (*A. nilotica*). The reason given was that there is a beetle which attacks it

and produces a lot of holes ultimately making the structures collapse. Powder coming out through the hole was also blamed itching both for them and their livestock. The respondents even accused the insect as itching when it moves on their body. This was also the main reason given by the women for their failure to use mesquite stem in thatch house[18] (Figure 8) construction. I was informed by women at Worer that when it is a must to use mesquite, they treat the stem traditionally before use. They soak the fresh cut stem in water for about two weeks and then sun dry. According to them, treated mesquite stem is relatively resistant to being bored by the beetle; however, literature is insufficient in this regard.

Figure 8: Small stock barn and traditional Afar thatch house frame made from mesquite (Gewane)

4.3 Mesquite invasion and the grazing lands

Invasion of grazing areas and cattle tracks were among the most often mentioned inconveniencies created by mesquite on pastoral community (Table 4). Although variability was observed among villages on proportion of grazing areas assumed to be invaded (Chi-Sq = 24.283, p = 0.007; Table 7), all of the surveyed households reflected that pasture areas have been shrunk after the introduction of mesquite. The proportion 'up to half is invaded' was rated by quite few respondents[19], whereas, both proportions of 'half to two-third' and 'two-third to three-fourth' were given higher weight (contributed about 80% of χ^2 value) than 'three-fourth and above'

[18] According to Afar culture, thatch houses are constructed by women.
[19] Two respondents from each of Amibara and Sideha-Faghe and one from Worer rated up to 50% of grazing lands in their locality was invaded by mesquite.

invasion. This implies majority of the surveyed households assumed that they lost half to three-fourth of their grazing lands due to the invasion. Despite this fact, it was the extended fodder/forage source areas which would guarantee the existence of the pastoral system in that fragile ecosystem. Affecting such a survival unit is one way that IAS like mesquite interferes with the rural livelihoods. Such circumstances, according to Mariara (2005), worsen the ability of pastoralists to cope using traditional strategies against environmental uncertainties which raise their ecological vulnerability.

Table 7: Perceived proportion of grazing lands invaded by mesquite on the six villages

	Amibara	**Awash Arba**	**Gewane**	**Halaideghe**	**Sideha -Faghe**	**Worer**
Less than half invaded	2 (11.1)	0 (0.0)	0 (0.0)	0 (0.0)	2 (8.0)	1 (2.3)
Half to two-third invaded	4 (22.2)	4 (28.6)	2 (10.0)	1 (5.0)	2 (8.0)	14 (31.8)
Two-third to three-fourth invaded	8 (44.4)	3 (21.4)	4 (19.0)	11 (55.0)	7 (28.0)	7 (15.9)
Three-fourth and above invaded	4 (22.2)	7 (50.0)	15 (71.0)	8 (40.0)	14 (56.0)	22 (50.0)

($\chi^2 = 24.283$, $p = 0.007$)
The χ^2-test does not include the 'less than half invaded' row as their expected count is less than 5
Note: The numbers in bracket show the proportion

In addition to shrinkage of grazing lands, the change in grass cover of mesquite encroached areas was also mentioned as a problem.

4.3.1 Mesquite invasion and forage/fodder availability on grazing lands

All of the respondents claimed that forage/fodder cover of grazing areas has reduced in the past ten to fifteen years. The key reasons given were the invasion of mesquite and the frequent rain shortage the area experienced. Most of the respondents and elders in the group discussion stressed that the invasion has also threatened multipurpose indigenous trees/bushes.

> In places where she [mesquite] grows, nothing will grow. Before her [mesquite invasion], the grass cover of our land was good. Under other trees, grasses can grow but never under *woyane* (Respondent 93, 56 years old, from Andido village).

Another respondent from Halaideghe added,

> Whenever there is *woyane*, grasses will never grow. Previously [before the invasion of mesquite] grasses and herbs could grow with little rain but now, even if there is enough rain they do not grow (Respondent 52, 40 years old).

As also noted by the local people, species diversity under the canopy of mesquite in Middle Awash area was less than that of under the indigenous *Acaccia nilotica* (Amaha, 2006). Moreover, sparsely encroachments of mesquite were relatively more appreciated than deep thickets for feed availability by most of the respondents. This may be because under grown species richness is better for sparsely mesquite encroached-grazing lands than the deep thickets (Gavali et al., 2003; Amaha, 2006). Different authors (e. g. Mugasi et al., 2000; Moleele et al., 2002; Angassa, 2005) also proved that encroached grazing lands produces significantly lower herbage yield. According to Mugasi et al. (2000), lower herbage yield hampers animal productivity (milk production, first puberty age, lactation period and calving interval) thereby influencing the sustainability of pastoralists.

Durfu, isissu, melif, denkito and *ayti-adoyta* were frequently mentioned grasses to have been affected by mesquite invasion in the basin; whereas the invasion's effect on *sitabu* and *gedoyta* were specific to Gewane only (Table 8). Among the indigenous trees, *adaito*, *e'ebto, adadoita*, *adengali* and *kasalto*, which are browseable, were perceived to be affected more than others (Table 8). Mesquite's allelopathic nature (Al-Humaid and Warrag, 1998; Nakamo et al., 2003), highly competing (Pasiecznik et al., 2004), ability to distract habitats and increased grazing/browsing pressure on the remaining feed sources may be the reasons to affect under canopy grown and open land habituated plants. The grasses/herbs are basically main feed items; and their unavailability will influence the livestock system of the area. Some of the grasses are also having other uses like for roofing the traditional thatch houses (i*sissu* and *melif*) and for household consumption during drought periods (*sitabu*[20]). This puts heavy pressure on the remaining pasture and browseable trees which, according to Esther and Brent, 2005, leaves [pastoral] communities under frequent conflicts in the course of utilization.

Affecting the abundance of indigenous plants is also another way by which invasive species are undermining rural livelihoods (Siges, et al., 2005; Gemedo, et al., 2006; Angasa and

[20] Most households at Gewane told me that they use boiled stabu's bulb as food during drought.

Oba, 2008). Perhaps due to this and other reason, more than 97% of the respondents would prefer complete eradication of mesquite from their sites. I have observed a sort of strong phobic developed against the bush by the pastoralists.

Table 8: Plant species perceived to be threatened by mesquite invasion

Grass/Herbs			Tree/Bush		
Vernacular Name	Scientific name	Frequency	Vernacular name	Scientific name	Frequency
Ayti-adoyta	*Terapogon cenchriformis*	77 (54.2)	Adadoita	*Acacia senegal*	81 (57.0)
Bonket	*Tribulus zeyher*	35 (24.6)	Adaito	*Salvadora persica*	93 (65.5)
Delaita	*Setaria acromelaena*	41 (28.9)	Adengali	*Cadaba rotundifolia*	79 (55.6)
Denkito	*Eragrostis cylindriflore*	49 (54.8)	E'ebto	*A. tortilis*	86 (60.6)
Durfu	*Chrysopogon plumulosus*	97 (68.3)	Gerento	*A. oerfota*	67 (47.2)
Halal	*Ipomoea sinensis*	38 (26.8)	Gerssa	*Dobera glabra*	47 (33.1)
Irareyta	*Cyndon dactylon*	69 (48.6)	Hedayto	*Grewia tenax*	44 (31.0)
Isissu	*Cymbopogon pospischilii*	96 (67.6)	Kasalto	*A. nilotica*	76 (53.5)
Ka'ato	*Sedge species*	35 (24.6)	Mederto	*Cordia Sinensis*	25 (17.6)
Melif	*Andropogon canaliculatus*	78 (54.9)			
Serdoita	*Cenchrus cilaries*	39 (27.5)			
Anterba*	*Ipomoea aquatica*	6 (28.6)			
Gedoyta*	*Cyprus spp.*	18 (85.7)			
Sitabu*	*Vossia cuspidata*	19 (90.5)			

* Grasses grown at swampy grassland found at Gewane and their proportion is relative to respondents from Gewane.
Note: The numbers in bracket show the percentage

Households were asked about the possible reactions they have made against the reduced fodder/forage availability. Transhumances, reducing stock number and using additional feeds were the techniques used by the households to cope with the problem. According to Ellis (2000), different coping strategies will be taken by rural people that they think is feasible to overcome the encompassing situation. Households that used no measure against the problem were accounted 9.1% of the total surveyed household. Keeping a few lactating livestock with the household and sending the rest to distant non-invaded areas for long season was found the most used strategy (52.4%). In this case, most of the livestock will be taken care of by a household or extended

family member who will migrate with them in search of feed. Those kept at home are let to graze in their compound with supplemental feed, harvested grasses from agricultural fields and ginnery byproduct. The strategy combines both limited grazing and transhumance. The second most used strategy was transhumance only (34.7%). Only 3.8% of the respondents used reduction of stock as a coping way. Beside these, clearing mesquite from grazing lands was tried by a number of households but, according to them, it was not promising due to its fast coppicing ability.

4.3.2 Cattle tracks and mesquite invasion

Invasion of cattle tracks to grazing areas and watering sources was the other problem faced by the pastoral community which also competes for their labor[21] (Table 4). A villager from Worer explained the impact of the invasion on cattle track as:

> We [Afar men] always hold machete to clear *woyane* on our ways; herders also hold machete. A herd which used to be cared by one is demanding more than one. Someone is needed to guide the herd and others to protect cattle from entering to the deep thicket, to feed on pods. Once they get in, it is very, very difficult to get them out. The other effect for example: there are some cattle who know their place. Even if you leave them on grazing field, they will come when it gets dark. Now, this does not work; at least someone must guide to get them back (Respondent 55, 35 years old).

The problem seems common when mesquite and pastoralists exist together. In Ng'ambo area of Kenya, herders were quoted saying that they will not rescue once a cattle is trapped by mesquite enclosure as they prefer their safety (Anonymous, 2004); which may be due to the poisonous thorn pricking their body. Along the invasion, 71% of the respondents said that predators are nearer to their village than before in the hideout created by mesquite. According to them, nocturnal predators[22] like hyena eats trapped livestock even during the day.

4.4 Mesquite invasion and Afar pastoral livelihoods

For Afar pastoralists, pasture and livestock are key components of their livelihoods; though the concept of livelihood is diverse and contextual (Ellis, 2000). For pastorlists, it can be the capability to accumulate livestock assets, their access and claim to grazing areas and other

[21] According to the respondents, competion to their labour is through clearing of mesquite from homesteads, footpaths, livestock tracks and even from grazing lands; and demanding more herders than used to be.

[22] Hyena and fox are the most mentioned predators to have been observed frequently around villages after the invasion of mesquite. Seventy-one and sixty percent of the surveyed households responded that hyena and fox were seen frequently, respectively, in their places after mesquite. This may be due to a good hideout created by mesquite near villages.

activities done to their livelihoods (Chamber and Conway, 1991). According to Scoones (1998), agents imposing access to resources (like pasture) will put pressure on rural households. Based on this idea, factors affecting these livelihoods components, like mesquite invasion, may directly or indirectly influence rural households. Its effect on access to pasture and others related problems were discussed in the above sections. In this section, livestock rearing under the invasion and measures taken are presented.

4.4.1 Impact of mesquite invasion on Livestock rearing

A comparison between '10 years ago' and 'current holdings' of livestock assets for individual surveyed households was made (Figure 9). Surprisingly, the average household lost about 80% of stock. The Wilcoxon signed rank test (T^+) also shows that the reduction is highly significant for all livestock categories within a household (Figure 9).

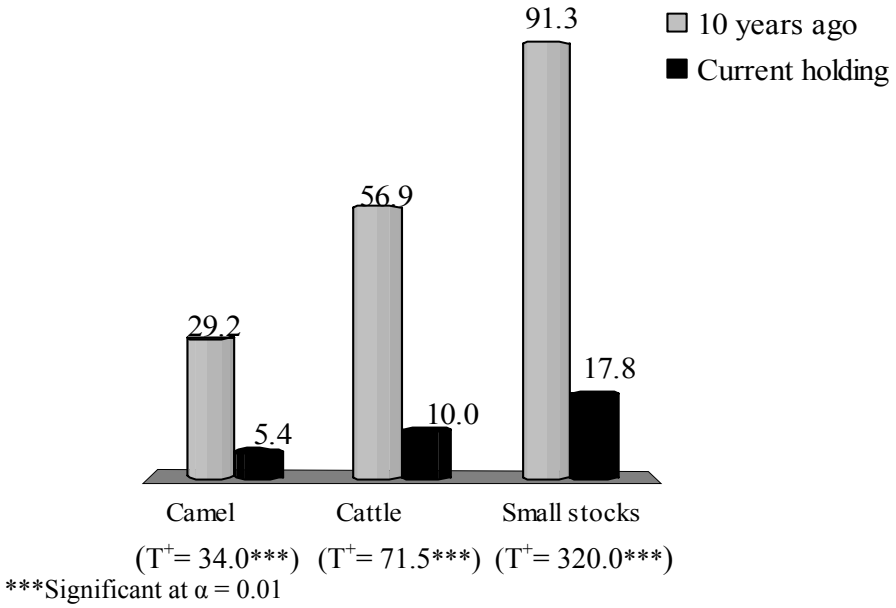


Figure 9: Mean household's 10 years ago and currently livestock holding

The main reasons given for the reduction in livestock assets were shortage of pasture due to mesquite invasion (48%) followed by recurrent drought (40%) and disease (10.6%). Less than 2% of the respondents blamed rustling. Those who primarily mentioned drought as a major factor were observed saying 'mesquite invasion aggravated the rain shortage problem.' According to them, they would get dry pastures on the field before the invasion even if it was drought.

Ellis and Swift (1988) stated that livestock can survive on dry mesquite pods during drought periods; others also presented the high nutritional value of mesquite pod (e.g. Benedito, 1988; Paseicznik et al., 2004; Esther and Brent, 2005). Despite this fact, all households were accusing mesquite for fueling the problem because of the health hazard on livestock when mesquite pods were given alone. But, according to them, the risk is minimal when the pod is given along with grasses or other additional feeds. Each household on average lost about 6.5 small stocks and 7 cattle in the past 10 years due to a complexion caused by the pod. Locally the disease is called *armeko*. It is characterized by twisted neck and dental disfiguration.

> I know well livestock diseases and their symptoms in my area. However, the agent causing my small stock death was strange for me. They become extremely skinny with swollen stomach. I was surprised saying, 'what a new thing is it?' Then I tried to investigate it. I opened the tract of my dead female goat. You know what I got? A big ball formed by *woyane* seeds and germinated *woyane* seeds in its stomach. Then and on, I try to keep my animals from eating the pods as much as I can (Respondent 17, 30 years old, from Serkamo village).

According to the respondents, *armeko* was severely seen during 2001/02 drought period. This may be because, heavy dependency of livestock on mesquite pods for survival as it can abundantly be found even during drought periods. Prolonged consumption of the pod by cattle may cause the above symptoms (Esther and Brent, 2005). A study by Tabosa et al. (2006) showed that mesquite pod has the potential to affect cranial nerves which control muscles of neck. This proves what has been observed by the local people. Other studies also showed that the problem was also faced by herders elsewhere (e.g. Anonymous, 2004; Esther and Brent, 2005). In addition to this problem, the poisonous thorn was mentioned as a potential danger for their livestock (Table 4). A respondent from Halaideghe bitterly explained the situation as:

> The thorn is like a nail. It pierces both us and our livestock. There are also some who lost their eyes. Among livestock, the heaviest damage is on camel. Camel by its nature tries to avoid anything on its body forcibly and thus it tramples its leg against the ground when the thorn pierces it. Hence, the thorn will go deep inside. As a result, its leg will swell and inhibit it walking. The camel will then stay at barn and we will be forced to collect grasses and tree branches to feed until it cures. But feeding a camel at such condition is terrible as it eats a lot. The pain and hunger together may lead to death (Respondent 63, 78 years old).

Households' perception about milk productivity of their stocks was also assessed. Eighty-six percent of the households responded that milk yield of a cow has reduced; while the percentage rises for small stock and camel (92%, each) as compared with ten years ago (Figure 10). According to the respondents, reduced pasture availability (caused by mesquite invasion) and frequent rain shortage caused the problem. Pasture availability is of course one of the factors determining milk productivity. A comparative study conducted by Mugasi et al. (2000) showed that livestock reared under relatively highly encroached grazing fields yielded less milk than those reared under less encroached fields.

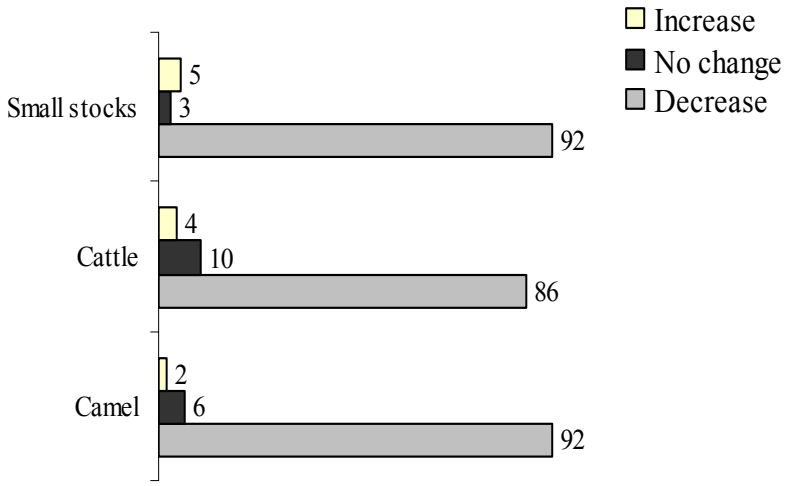


Figure 10: Proportion of households based on their perception about milk productivity of their livestock currently and ten years ago

Livestock is not only a source of livelihoods for pastoralists like Afar; it is also a key component in risk avoiding strategies. Pastoralists use their livestock asset to minimize, absorb and control risk for their survival. They accumulate the asset to minimize the risk they are facing; keep most valuable stock and sell the rest for absorbing risk; and at the end sell their most valuable animals to ensure their survival (Swallow, 1993). However, mesquite invasion affected the accumulation of livestock asset (Figure 9) for reasons mentioned above and became obstacle for the subsequent risk absorption and risk control strategy. This ultimately raises the Afar pastoral vulnerability for any kind of uncertainties.

It appears that the pastoral community was betteroff before mesquite invasion (Figure 9 & 10). According to Seid (1994), a purely pastoral household in the Middle Awash area needs on

average, 80 small stocks, 41 cattle and 27 camels to meet the needs of the household; and be guaranteed to rebuild stocks after drought or other shocks. These requirements appear to be met ten years ago (Figure 9). The average current holdings of livestock are by far lower than what was put by Seid (1994) (Figure 9). Hence, dependency on livestock rearing as a sole source of livelihoods, according to him, seems difficult in the current situation.

4.4.2 Measures taken by pastoral households to secure their livelihoods

Respondents have taken different measures to secure their livelihoods due to the situation where sole dependency on pastoralism was not feasible. The different measures taken were: cultivation of land, share cropping, formal employemnet in mechanized farms and other organizations, casual labor and small trade. Most of these strategies were documented by Swallow (1993) as utilized by pastoralists for risk management strategies when sole dependency on livestock is in question. In order to identify factors affecting diversification of livelihoods, a logit model was estimated using maximum likelihood method.

Diversification of livelihood strategies is a dichotomous variable which takes the value of 1 when a household has extra source(s) of income in addition to pastoralism and 0 otherwise. The logit estimates for the independent factors of livelihood strategy are presented in Table 9. The likelihood ratio for the goodness of fit test ($G = 36.23$, $p = 0.000$) show that the intercept only model is statistically non significant. Most of the factors' effect was found to be unlike to the hypothesized one.

According to the result, household head age, level of education, change in livestock asset, location and perceived size of grazing land invaded by mesquite significantly affect a household to diversify source of income or change life style. Contrary to the expectation, age of the household head negatively influences the decision of a household to diversify its source of income. As per the result, young headed households are more likely to have diversified livelihood than aged headed households. This may be because old persons are more stuck to traditional way of life than younger people. And also younger people are more ambitious and risk taking to try new sources of income than old people. The level of education is found positively and significantly affecting the dependant variable (Table 9). The reason that was put at the hypothesized effect may have something to do. The probability of diversifying livelihood is about six times higher for a household having some level of educated head than other.

Table 9: Logit diversification of livelihood strategies model: Maximum likelihood result (Dependent variable, Y = 1 pastoralism and/or others, Y = 0 pastoralism only)

Variable	Coefficient	Std. error	Marginal effect
Age of house hold head	-0.036*	0.025	-0.006
Primary school dummy (1= yes, 0= No)	1.744*	0.717	0.314
Polygamy status (1 = yes, 0 = No)	-0.202	0,802	-0.036
Family size	0.139	0.133	0.025
Total livestock units	0.025	0.023	0.005
Change in total tropical livestock units (10 years ago – Current holding)	-0.903*	0.034	-0.163
Perceived size of grazing land invasion (1 = above 2/3 is invaded, 0 = 2/3 or less is invaded)	0.987*	0.639	0.178
Division in which household is located (reference is Worer)			
Amibara	-1.790**	0.854	-0.322
Awash Arba	-0.257	0.889	-0.046
Halaideghe	-2.483**	0.789	-0.447
Gewane	0.132	0.911	0.024
Sideha-Faghe	-1.051	0.838	-0.189
Constant	1.318	1.169	0.204
Numbers of observation		142	
G		36.23***	
Log likelihood		-51.31	

Note: ***, **, * Significant at 1%, 5% and 10%, respectively.

As opposed to the initial assumption, households that lost much livestock asset in the past ten years have relatively less diversified sources of income than those who did not. This may be explained as such households may be rigid to traditional ways of living, i.e. pastoralism. Perceived size of grazing lands which are abandoned due to mesquite invasion positively affects households' livelihood diversification as per the assumption. Households' division dummies show that households at Amibara and Halaideghe have less tendency to diversify their livelihoods relative to households at Worer. The fact that a higher number of governmental and non-governmental organizations are present at Worer, will widen the chance of a pastoral household to get employment or engage in other activities.

Though the influence of family size to drive a household diversify its income was not significant, its effect was as expected (Table 9). However, polygamous status of a household head

and livestock asset influenced the dependant variable opposite to priori expectation, even if it is not significant.

4.5 Proposed solutions for mesquite control by pastoral households

More than 80% of the respondents have tried to control the invasion of mesquite by cutting either in groups or individually. But mesquite's fast regenerating nature and ability to cover a lot of area in a short period of time have discouraged the local people to continue their 'controlling' activity. A respondent from Bedlu-Ale expressed his hopelessness of cutting mesquite to reduce the expansion as:

> We tried to control *woyane* many times. We cut it many times being organized in groups. But it regenerates in the afternoon after being cut in the morning. Now, no other aid is worthwhile than eradicating *woyane* for us. I believe that I can survive on a single she-goat if *woyane* is eradicated (Respondent 44, 60 years old).

I realized an attitude among the pastoralists that they can not pull themselves out from the problems caused by mesquite invasion. This may be because they could not see any promising reduction in mesquite population despite their effort to control the invasion. However, their campaign was too small scale as compared to the invasion to prohibit mesquite from widening its territory.

Elders at group discussion mentioned the need of external help as a solution for minimizing the expansion. According to them, external agents (governmental or non-governmental organization) need to help them to reduce mesquite population at least from the grazing areas. According to them, once the population is reduced, seasonal cutting of mesquite as subsequent management activities will be taken by groups which are going to be organized in each village.

> When a country is invaded by enemies, the government will not sit idle. It will send its troops to subdue the enemies. Likewise, *woyane* is our enemy. Therefore, the government should take action to eradicate it. Even the government should order the military to eradicate it by any means as it is our enemy (Respondent 96, 45 years old, from Awash Arba village).

Most of the respondents also said that change in land use system will be a preferable approach to check the expansion. According to them, changing the invaded area to farming land will inhibit the re-invasion of mesquite because of frequent land preparation activities on agricultural lands. I was also shown lands under cultivation which were previously invaded by mesquite. But this was feasible for areas which are near to irrigation sources. Other households which are distant from irrigation cannels whished water pump generators as rain fed agriculture is hardly possible. All in all, the high initial cost to change such areas into agricultural land was blamed as the reason by majority of the respondents not to engage in the activity.

5. Conclusions and recommendations

5.1 Conclusions

In the Middle Awash area, mesquite is a strong competitive bush with low beneficial traits for Afar pastoralists. The bush has reached a level to impair the pastoral livelihoods. Some of the clues are: the high rate of response for its being non-important for the pastoralists (84%); invasion of 1/2 to 2/3 of the total grazing lands (according to the local people perception) and other areas; and its impact on livestock assets, traditions and institutions.

As per the study, the invasion of mesquite has affected the livelihood of the pastoral community in many ways. Such as: (a) by reducing pasture availability; (b) inhibiting mobility through its invasion effects; (c) poisonous thorn for both the people and their livestock; (d) posing health hazard on livestock due to the pod; and (e) influencing traditions and institutions. These effects were found interacting to one another and complex to have magnified the negatives of mesquite invasion against the pastoral livelihoods.

The invasion has affected pasture cover of grazing areas. The circumstances, then, put heavy pressure on livestock assets demanding long distance travel in search of feed to survive. But, due to the invasive nature, the bush has also invaded footpaths, cattle tracks and settlement areas; which in turn left mobility at risk. This, on the other hand aggravated the overgrazing of the remained pasture land and intense pressure on multipurpose indigenous trees/bushes. On due courses, the livestock has become more exposed to the poisonous thorn and pods. All these together heavily tested the livestock system of the Middle Awash area to the extent affecting local institutions in the basin. In addition some traditions are hardly possible to be entertained within the invasion. The daily exposure of the people to the bush has also enhanced the effect of the poisonous thorn against them. The inter-linkage among these factors is more complex than this in the real world scenario. And these all has ultimately made the Afar pastoral extremely vulnerable to environmental uncertainties than ever.

Household age, change in livestock asset and location of villages are the most determining factors for exploiting mesquite for economic reason by pastoralists and to diversify their livelihoods in the Middle Awash basin. According to the result, the younger the household head the wider the chances for the household to utilize mesquite as means of income and diversify sources of livelihoods.

5.2 Recommendations

Experiences elsewhere tell that eradication of mesquite is not economically feasible. However, based on the results of the study, there are spaces for the Afar pastoralists in the basin to take actions toward reducing the rate of mesquite expansion. These are: (1) forming groups of individuals in each village who are responsible for periodic uprooting of mesquite seedlings (targeting seedlings will make the job easy) from grazing areas; (2) the pastoralists should appreciate the utilization of mesquite as a source of income; and (3) effort by pastoralists in changing potentially agricultural lands which are invaded by the mesquite into crop lands. These will help in reducing mesquite seed bank in the basin which in the long run reduces the invasion. In addition to reduction of mesquite invasion, the activities are also helpful for having diversified pastoral livelihoods in the Middle Awash area.

Extension work needs to be given priority by Pastoral and Agro-pastoral Office of the region in order to enhance the extremely low level of exploiting mesquite as a source of income by pastoral households. Besides, the Office should consider organizing the pastoralists into cooperatives to provide firewood and charcoal from mesquite to the market; and supporting the cooperatives both technically and financially.

Further studies about the social and economical impacts of mesquite and management techniques which are cost effective and practical to the Afar pastoralists need to be conducted.

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Appendices

Appendix 1: The negative aspects of mesquite in the Middle Awash Area of Ethiopia based on the household survey in six villages

	Frequency					
	Worer	**Faghe -Sideha**	**Amibara**	**Halaideghe**	**Awash Arba**	**Gewane**
Invasion of wet season grazing sources	38	19	18	20	11	17
Invasion of dry season grazing sources	36	20	18	16	12	18
Affect seasonal mobility of herds	37	19	18	19	11	20
Affect traditions and institutions	34	19	17	19	10	20
Invade farming land +	12	4	7	2	-	13
Competition for labor	35	20	16	17	11	21
Probable danger on household members due to the thorn	38	19	18	19	11	21
Probable danger on livestock due to the thorn	38	19	18	19	11	21
Invade villages / settlement areas	36	22	18	18	12	21
The invasion trouble herders for their site control of herds	30	21	12	18	13	20
Blocking footpaths	28	19	7	9	8	13
Invade burial places	29	6	5	-	-	-
Host to predators	20	16	13	17	10	21
Host to rustlers	13	9	2	1	3	-
The pod is probable danger for livestock health	43	19	17	18	11	20
The leaf is probable danger for livestock health	2	-	-	1	-	-
Inhibit under canopy growth of grasses	41	23	18	20	12	20
Endangers indigenous tree species	25	23	11	20	12	20
Narrowing/blocking cattle tracks	40	21	18	20	13	21
Minimizing water availability	26	14	11	13	12	11
Litters under water cause stringent smell	5	3	-	7	-	-

+: among those who cultivate land. All of those who cultivates land accuse mesquite for invading their farm lands

Appendix 2: The Benefits of mesquite in the Middle Awash Area of Ethiopia based on the household survey in six villages

	Frequency					
	Worer	**Sideha-Faghe**	**Amibara**	**Halaideghe**	**Awash-Arba**	**Gewane**
Means of income	15	3	5	2	4	9
Forage/ Fodder	34	17	12	16	11	17
Shade tree	23	4	8	9	9	6
Fuel wood	36	17	17	18	14	21
Fencing homestead	35	19	18	17	11	21
Barn construction	33	15	11	17	10	21
For house construction	12	7	9	6	4	17
walking stick	4	2	2	-	-	10
Temporary platform for resting	5	-	-	-	-	3
For making traditional bed (*Olo'ytaa)*	2	-	-	-	-	1

Appendix 3: Group discussion checklist

- When and how did mesquite introduce to Middle Awash area?
- What benefits does mesquite provide for the pastoral community?
- What impacts does mesquite has on pastoral community and their livestock?
- What measures the community takes to check mesquite invasion?
- What do you think the Afar pastorals claim about mesquite?
- What changes have been observed in livestock holdings and pasture availability in the Middle Awash area during the last decade?
    - What causes the change?
    - How is the changing event responsible?
- How is the grazing area availability after the introduction of mesquite?

Appendix 4: Questionnaire for household survey

Questionnaire no._____

Enumerator name_____

Name of respondent_____

I. Background information about the sample household

1. Village name_____
2. Clan name_____
3. Household head name_____
   3.1 Age_____
   3.2 Sex_____
   3.3 Marital status_____
   3.4 Number of wives_____
4. Number of children (from all wives for male headed household)_____
5. Educational level of household head
   a. basic education (religion)
   b. formal schooling (grade)_____
   c. illiterate

II. Assets and income

6. Shelter type _____
7. Livelihood of the household depends on

	Rank
7.1 Pastoralism ___	___
7.2 Farming ___	___
7.3 Trade ___	___
7.4 Share cropping ___	___
7.5 Share from clan land___	___
7.6 Others, specify __	___

8. How the source/s of income affected by mesquite invasion? _____

9. If livelihood depends fully or partly on cultivation

9.1 Size of the land owned (ha) _____

9.2 Cultivated area_____

9.3 List of crops cultivated by importance

A. _____

B. _____

C. _____

10. What is the trend of livestock size in the last ten years?

Species	10 years ago	Current holding
Camel Cattle Small stocks		

11. Main reasons for the livestock trend (chose only one):

a. Shortage of grazing land

b. Drought

c. Disease

d. Other, specify

12. For 'Q 11', if 'a' is choosen, please explain_____

13. Milk productivity of livestock during the last ten years

Species	Increase	Decrease	No change
Cow Sheep Goat Camel			

14. If it has changed, what are the major causes for the change in yield? _____

III. Mesquite and the pastoral livelihood

15. How long did you know mesquite?
    a. Less than 10 years
    b. 11-20 years
    c. More than 20 years
16. Is the effect of mesquite on the household?
    a. beneficial
    b. harmful
    c. both a and b
    d. no effect
17. What are the beneficial effects of mesquite?
    a. source of income (charcoal and/or fuel wood selling)
    b. forage /fodder
    c. shade
    d. fuel wood for household consumption
    e. fence construction
    f. barn construction
    g. house construction
    h. walking stick
    i. local furniture
    j. others, specify_____
18. If 'b' is chosen in 'Q 17',
    i. Which season? _____
    ii. Explain health condition of the livestock eating it_____
    iii. If you lost any livestock due to the illness in the past ten years, please quantify:
        Camel____
        Cattle____
        Small stocks_____

19. What are negative effects of mesquite on the household?
    a. denied access to
        i. wet season grazing land____
        ii. dry season grazing land____
        iii. both____
    b. disruption of seasonal mobility of herds
    c. disruption of traditional way of life and institutions
    d. loss of crop land (hectare)
    e. Competition for labor
    f. Injury to family (due to its thorn), explain_____
    g. Injury to livestock (due to its thorn),
    h. Invading settlement areas/ villages
    i. Troubling herders for site control of their herds
    j. Others, specify_____

20. If there is injury to livestock due to the thorn of mesquite, explain: _____

21. Do you feel that the expansion of mesquite is shrinking grazing lands? Yes/ No

22. If yes to 'Q 21', by how much?
    a. Less than one third
    b. Less than half is invaded
    c. Half is invaded
    d. More than half is invaded
    e. More than two third
    f. Completely invaded

23. Does the invasion of mesquite affect watering of your animals? Yes/No

    If yes how?
        a. Narrowing watering ways
        b. blocking watering ways
        c. blocking access to watering source
        d. reducing water availability
        e. others, specify_____

24. What should be the mesquite population from:

	Villages	Paths	Grazing areas	Banks of watering points	Other areas; specify_____
Eradicated					
Reduced					
- If reduced by how much					
Remain as to day					

25. Has the vegetation cover of grazing lands changed compared to prior to invasion by mesquite? Yes/No

Please, explain _____

26. Can you mention grass/herb whose population increase or decrease after mesquite invasion?

Increase Decrease

27. What importance do these grasses/herbs have to the society? _____

28. Can you mention tree/shrub whose population increase or decrease after mesquite invasion?

Increase Decrease

29. What importance do these trees/bushes have to the society? _____

30. Can you mention wild animals whose population increase or decrease after mesquite invasion?

Increase Decrease

31. What importance/ effect do these wild animals have to the society? _____

32. What mechanisms are used to cope with change in grazing availability?

_____

33. What traditional methods are used to avoid invasion of mesquite?

_____