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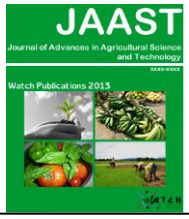

Degradation of Rangelands and Rehabilitation efforts in Ethiopia: The case of Afar rangelands

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Abstract

The Afar Region covers 10% of the total area of the country and 29% of the pastoral lowlands. Though most of the Region is arid and semi-arid, it is able to support the population of the Afar pastoralists mainly due to the presence of Awash River which is the life-belt of the Afar people and their livestock population. Afar is increasingly drought prone. The production system of the Afar region is dominated by pastoralism (90%) from which agro-pastoralism (10%) is now emerging following some permanent and temporary rivers on which small scale irrigation is developed. The altitude of the region ranges from 120m below sea level to 1500m above sea level. Temperatures vary from 20oC in higher elevations to 48oC in lower elevations. Rainfall is bi-modal throughout the region with a mean annual rainfall below 500 mm in the semi-arid western escarpments and decreasing to 150 mm in the arid zones to the east. About 14.8% of the total land area of the region is covered by grassland; 31.5 % shrubland, 1.7% woodland and 0.11% forest land. The main feed resources used for livestock feeding in the region are natural pastures (herbaceous vegetation composed mainly of grasses and forbs and browses (shrubs, tree leaves, and pods). A rapid reduction in woodland from 8.35% to 0.28% and grassland from 7.75% to 0.91% cover in the landscape took place between 1972 and 2007. The increase in bush land and cultivated land cover was large during the time period 1986-2007 compared to the earlier time period 1972-1986, whereas both time periods saw similar declines in woodland and grassland. Generally, heavy and light grazing pressure reduced the species diversity. The most considerable change affecting the livelihoods of the pastoral communities is the decline in rangeland productivity. Currently, prosopis juliflora (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. These invaded resources are the key supporting units for livestock keeping, which in turn are the main stay for Afar people 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. 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)., mesquite invasion is also affecting plant species diversity in the Middle Awash area. There is 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 settlement camps in the area. All these factors contribute to increased pressure on the remaining pasture and raise the Afar pastoralists' vulnerability to the recurrent moisture stress the area experiences.

KeyWords: *Afar region, rangeland degradation, over grazing, bush encroachment, prosopis juliflora, rehabilitation.*

INTRODUCTION

The majority of rangeland ecosystems are located in vegetation biomes such as grasslands, shrub lands, savannas and deserts (Friedel *et al*., 2000), and these areas are often characterized by an inherent arid climate that experience large daily and seasonal temperature extremes (Williams *et al*., 1968; Vetter *et al*., 2006).

Plant species composition will have an effect on forage quality, animal grazing behaviour (in terms of intake

rates, number of bites, bite volume and time of bites), abundance and distribution of the species in the rangelands (O'Reagain, 1996). Knowledge of the botanical composition and trends over time are essential for management decisions (Van der Westhuizen *et al*., 1999). Increases of undesirable perennial species and decreases of desirable species are important indicators of rangeland condition (Kirkman, 1995), but changes in the abundance of pioneer plants may be misleading in view of their quick response to rainfall and rapid disappearance afterwards (Shackleton, 1993). A decrease in palatable perennial grasses is often the result of continued selective and/or heavy grazing by livestock (Vetter *et al*., 2006), in which case they are normally replaced by unpalatable grasses, weeds and shrubs (Dyksterhuis, 1949). Forage species are commonly classified into broad quality categories such as high, medium and low, whereas determinants of palatability and acceptability are poorly understood with very little quantitative data available for rangelands in general (Meissner *et al*., 1999).

The rangelands of Ethiopia are home to many important plant species which contribute greatly to daily sustenance of local communities. These plants, which are diverse in nature, are primarily sources of fodder, fuel wood, resins, traditional medicines, etc., and in some cases, contribute significantly to food security in terms of wild food in marginal areas. Rainfall in these areas is erratic and highly variable. Pastures vary from place to place and from year to year. Therefore, herds are mobile to take advantage of this variability. Pastoralists in Ethiopia depend on their animals through for milk, meat and exchanging livestock or their products for grains and other goods and services. Pastoral areas in Ethiopia cover a little more than half of the land mass of the country and support12**-**15% (10-12 million people) of the country's human population and a large number of livestock. These rangelands are located in the arid and semi-arid lowland areas in the East, Northeast, West and South of the country. The rangeland resources of the country need to be properly managed and utilized to optimize the benefits to the pastoral community and the country at large (Gebru, 2009).

The Afar pastoralists face various problems that include recurrent drought and famine; flash floods; disease outbreaks; bush encroachment; loss of livestock, and impoverishment; pastoral conflict; population growth, etc. In Afar, overgrazing and deforestation contributes to reductions of ground cover and accelerates erosion processes. Further threats to indigenous trees such as *Accacia nilotica*, *Accasia tortilis* are also posed by the high dependency on fuel wood and charcoal, major sources of energy, that are estimated to contribute about 80-90% of the residential energy out of the fragile environment. Moreover, important grass species and wild food species either are pushed to extinction or are in a very short supply (IEA, 2002). Thus, this review paper tried to see the overall degradation status of the rangeland of Afar and some rehabilitation efforts.

CHARACTERISTICS OF ORIGINAL RANGELAND RESOURCE IN AFAR REGION

The Afar Region, along the Awash River in north-eastern Ethiopia covers an area of 108,860 km², is hosting a population of approximately 1.4 million people with around 87% living in rural areas, mostly depending on livestock production (CSA, 2010) is featured by extensive areas of bush lands and grassland used as pasture by local pastoral transhumant groups. However, almost 50% of the area is covered by sand and rocks while only 7% is estimated to be cultivable (Mengistu, 2006). Of utmost importance for the local pastoral population is the Awash River, which traverses large parts of the region and serves as a vital key resource. Furthermore, Afar Region encompasses biodiversity hotspots (Anonymous, 2011) and several endemic species (Abiyot and Getachew, 2006).

According to ANRS (2004) the northern part of Afar Region around the lower Danakil Plain is with thorny species of shrubs and acacia; further south in the Awash valley, steppe vegetation is dominant. The vegetation types, which are the main stay of the pastoral livestock economy, comprise riverine woodland, bushland, shrubland and grassland. Currently livestock get their feed from bushland, shrublands, riverine forests, grassland and seasonal marshes and swamps (MCE, 2001).

The major land cover patterns are closely related to patterns of rainfall and temperature, with local variations due to soil and drainage factors. In the southern and central parts of the western piedmont hills and plains, dense shrubland/woodland changes to open shrubland with decreasing altitude and rainfall. To the north with decreasing rainfall in Zones 2 and 4, the vegetation is lower and less dense (ANRS, 2004).

According to Shashie (2007), the feed resources that are available in Awash**-**Fantale are natural pasture and browse. The primary use of woody plants in the region was as a source of feed for livestock, which is in agreement with the findings of Diress *et al.* (1998) who reported that in the northern tip of the Afar region the pastoralists primarily use woody plants for livestock feeding.

From Table 1, the magnitude of land-use/cover change in the Northern Afar range lands, depicts the spatial land-use/cover changes. A rapid reduction in woodland from 8.35% to 0.28% and grassland from 7.75% to 0.91% cover in the landscape took place between 1972 and 2007. During the 35-year period, the proportion of bush land trebled, while the area of cultivated land increased eightfold. Although cultivated area still covered a small proportion of the landscape in 2007, its proportion in the alluvial dry-season grazing land is large. The increase in bush land and cultivated land cover was large during the time period 1986-2007

Table 1: Land use/ land cover in 1972, 1986, and 2007 in Northern Afar rangelands

	Absolute area cover (km^2)			Cover change between periods (%)a		
Land-use/cover	**1972**	**1986**	**2007**	**1972–1986**	**1986–2007**	**1972–2007**
Woodland	209.13	70.07	7.02	-66.5	-89.98	-96.64
Bush land	98.55	236.49	375.68	139.98	58.86	281.22
Bushy grassland	444.01	322.97	409.23	-27.26	26.71	-7.83
Grassland	194.30	44.79	22.85	-76.95	-48.99	-88.24
Scrubland	1490.61	1660.69	1530.09	11.41	-7.86	2.65
Cultivated land	7.68	18.22	67.24	137.22	269.11	775.62
Bare land	61.82	152.86	93.99	147.29	-38.51	52.05
Total	2506.09	2506.09	2506.09			

Source: adapted from *Dress et al* (2010)

compared to the earlier time period 1972-1986, whereas both time periods saw similar declines in woodland and grassland. Bare land increased moderately, whereas bushy grassland and scrubland cover showed little change during the 35-year period. Although it recovered between 1986 and 2007, bushy grassland cover was reduced in the earlier period, 1972-1986. Bare land increased between 1972 and 1986, but then declined between 1986 and 2007. From the changes of land use land cover shown in the table 1, the original ecosystem structure was changed due to different reasons.

Between 1972 and 2007, the woodland in the landscape was mainly converted to bush land, scrubland and bushy grassland. Grassland was mainly converted to scrubland and bushy grassland. Cultivated land mainly converted from scrubland, bushy grassland, and grassland. Although scrubland gained from bushy grassland and others, at the same time an equivalent area of scrubland reverted to bushy grassland and other land covers. The greatest net increase was for bush land, primarily converted from scrubland and woodland cover types. Of the natural vegetation cover types, woodland and grassland experienced the lowest persistence, whereas scrubland was the most persistent cover type. The general trend observed in the study area implies a loss of grassland and woodland cover and an increase in cultivated areas and bush land cover.

According to Ashebir *et al* (2010), the Afar rangeland degradation has been taking place because of over grazing, which may have altered the ecosystem in favor of the annuals species and extinction of highly palatable perennial species. From this context, it can be suggested that, the individual species or community groups show a difference in abundance due to their ecological niche that encourage them for certain dominance in competition for soil nutrients and moisture regimes. Therefore, high grazing intensities around watering points not only disturb the physical environment but also alter the botanical composition of the herbaceous layers, either by increasing species tolerant to heavy grazing or by reducing species regarded as highly desirable, as also reported by Harrison (2000) and Wu *et al.* (2008). As a result, those individual species aggregating around similar habitats or that regrouped themselves into community groups could be explained as plant species that require similar ecological niche in terms of soil type, moisture regime, land escape, and level of grazing responses (Amaha, 2008).

Generally, heavy and light grazing pressure reduced the species diversity, which was supported by findings of Willoughby (1995). Farther, heavy grazing pressure decreased the number of less grazing resistant species and increased those grazing tolerant species, but reduced the diversity. Likewise, low grazing pressure enhanced the dominance of some species by reducing the diversity, as also reported by Willoughby and Alexander (2007). In the moderate grazing pressure, the species diversity generally maximizes, and may be induced due to a favorable microhabitat for both heavy grazing tolerant and susceptible species to harmoniously survive, perform, and reproduce (Grime, 1973).

THE NATURE, EXTENT, AND CAUSES OF DEGRADATION

The most considerable change affecting the livelihoods of the pastoral communities is the decline in rangeland productivity. The continued reduction in the rangeland productivity is due to the recurrent drought caused by climate variability. The decline resulted in death of animals and reduced animal productivity. Consequently, the community's food security is seriously affected due to the drastic reduction in meat and milk production and reduced household income. This led to dependency of the community on food aid (Ali, 1996).

A number of interacting variables and processes contributed to land-use/cover changes in Afar Region. The principal form of land cover change prior to the 1960s was temporary shifts from grassland to bushy grassland and vice versa dictated by fire and grazing. Based on accounts from local people and secondary sources, major events that largely explain the changes in land-use/cover in the study area since the 1960s include:
(1) policy changes in land tenure that favors crop farming;
(2) sedentarization of pastoralists and increased overgrazing in dry-season grazing areas since the 1960s;
(3) severe droughts in 1973/74 and 1984/85.
(4) shortage and poor distribution of rainfall during the

last decade (Oba et al., 2000; Angassa and Oba, 2008).

The dominant anthropogenic land cover change processes responsible for the loss of the grassland and woodland cover during the first period (1972-1986) were: (1) wood extraction for domestic uses and charcoal production for commercial purposes, mainly by immigrants; (2) conversion of grassland into cropland; and (3) overgrazing in the remaining alluvial plain dry-season grazing lands (Angassa and Oba, 2008).

The driving forces behind these processes were the occurrence of two severe droughts in 1973/74 and 1984/85 (Meze-Hausken, 2004) and land tenure policies that encouraged sedentarization of pastoralists and crop farming. These two driving forces were important underlying causes that encouraged influx of people into northern Afar from highly populated and degraded areas in the neighboring Tigray region (Meze-Hausken, 2004; Tsegaye et al., 1999).

As a result of continued migration of people from neighboring areas and increased sedentarization of pastoralists, more alluvial dry-season grazing areas were converted to cropland in the second period (1986-2007). In-migration, sedentarization of pastoralists, shrinkage of grazing land, and a shift in livestock species composition from camel-cattle to small stock-camel dominated, recruitment failure of some plant species were the main consequences of land-use/cover change in northern Afar rangelands. The pastoralists explained a shift in livestock species composition is a response to changes in vegetation types and high demand for goat meat in recent years (Diress, 2010).

The Afars particularly believe that recruitment failure of the important food and fodder plant, *D. glabra*, in the alluvial plains could be an important indicator of either grazing/browsing pressure or rainfall variability or combinations of the two. They also remember that many of the wild animals disappeared. They attributed this mainly to the loss of woodland and long civil war that took place in the area between 1980 and 1990 (Meze-Hausken, 2004).

Asnake & Kassay (2005) reported that in some locations such as those in Amibara and Gewane Weredas, where years of drought induced overgrazing and hence led to important land degradation, and invasion with *prosopis juliflora* has a strong negative impact on grazing availability. Generally, the continuing or accelerating course of rangeland degradation in the Afar Regional state shows common features, including:

- Deterioration in the quantity, quality and persistence of native pastures, generally associated with a diminution of plant cover, but also with invasion by shrubs of low pastoral value; frequently unpalatable and of little economic value or practical use;
- Structural changes in the plant cover, notably the loss of shrubs and trees, partly through browsing, but also through gathering of fuel wood and clearing and burning for opportunistic farming;
- Changes in soil surface conditions, notably compaction through trampling by livestock, leading to deterioration in soil - plant - water relationships and reduced germination rate, particularly of the palatable species;
- Additional processes of sand drift siltation, leading to further destruction of the vegetation and commonly to deterioration of surface and shallow groundwater supplies.

In the past five decades the Afar subsistence pastoral system has been under pressure due to climate change and other internal and external factors. The Afar pastoralists face various problems that include recurrent drought and famine; flash floods; disease outbreaks; bush encroachment; loss of livestock, and impoverishment; pastoral conflict; population growth, etc. In Afar, overgrazing and deforestation contributes to reduction of ground cover and accelerates erosion processes. Further threats to indigenous trees such as *Accacia nilotica*, *Accasia tortilis* are also posed by the high dependency on fuel wood and charcoal, major sources of energy, that are estimated to contribute about 80-90% of the residential energy out of the fragile environment. Moreover, important grass species and wild food species either are pushed to extinction or are in a very short supply (IEA, 2002).

Temperature increase with reduced precipitation will result in reduction of livestock reproduction and breed loss that may lead to genetic erosion of important adaptation traits. Increases in the frequency of droughts, floods and disease epidemics will increase the risk of losing entire breeds and populations that have a limited geographic distribution. Climate change is also expected to create additional challenges, such as new diseases, indicating the use of genetic diversity will become more important in future breeding improvement programs. With increased urbanization, the magnitude of tree cutting for house construction and firewood is increasing in the region (ANRS, 2004).

THE INVASION OF *PROSOPIS JULIFLORA* AS THE MAIN CAUSE OF DEGRADATION AND ITS IMPACT ON LIVELIHOOD

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 (Zeraye, 2008).

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 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 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. They 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 (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).

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). Others also reported that *Prosopis juliflora* is native to the Caribbean, Central America, and northern South America (Pasiecznik et al., 2004).

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).

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 sea 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. Soil nutrient conditions and physical characteristics are hardly limiting the growth of mesquite (Pasiecznik et al., 2001). 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. The lateral roots are useful for utilizing erratic rains whereas the deep tap root can reach ground water. The species can survive as high as 50 ^{0}C and 70 ^{0}C air temperature and soil temperature, respectively. 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 (Pasiecznik et al.,

2001).

It has at least four vernacular names in Ethiopia, *Yeferenj biskut /Dergi-Hara/ Woyane* in Afar region and *Biskut* around Dire-Dawa. 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).

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). Greenish-yellow flowers crowded on 5-12 cm long staked spikes give rise to indehiscent pods. On average, a pod has 20-30 cm length and consists of up to 30 seeds.

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

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. Ulcro, who was in charge of the Middle Awash Irrigation Project, introduced the species unauthorized (Kassahun *et al*., 2005).

The pastoralists were told about the merits of mesquite (additional feed for livestock, fuel wood 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 semiarid and arid areas of the country in general and in Afar region in particular. Now, mesquite is the national no. 1 invasive alien plant (EARO and HADRA, 2005).

According to Ameha (2006), 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. These invaded resources are the key supporting units for livestock keeping, which in turn are the main stay for Afar people 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.

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)., mesquite invasion is also affecting plant species diversity in the Middle Awash area. There is 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 (Getachew, 2001).

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. 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. Apart from the initial plantings, those inherent characteristics of mesquite 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. 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)

Mesquite invasion forms impermeable and 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 km^2 (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. Farmers in the area could not afford the management cost which left them in trouble to secure their livelihoods. Considering the seriousness of the invasion, Sudan has passed a law to eradicate mesquite (Catterson, 2003).

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 uninvaded 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. 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.

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 has 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.

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 Mobility with livestock is synonymously used with transhumance and migration.

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 are the other problem imposed on the pastoral community of the Afar. If the pastoralists cease using a path for some time, then they will get it covered by *woyane*. Unless they clear it, it is impossible to use that path again. Even for the path they are using frequently, it needs periodic management. Otherwise it becomes narrower and narrower through time. They cannot walk side by side with their friends; they will be pricked (Zeraye, 2008).

Invasion of grazing areas and cattle tracks were among the most often mentioned inconveniencies created by mesquite on pastoral community. Although variability was observed among villages on proportion of grazing areas assumed to be invaded and pasture areas

Figure 1: Location of Afar Region

Figure 2: *Prosopis juliflora* invasion (Zeraye, 2008)

have been shrunk after the introduction of mesquite. According to Afar culture, thatch houses are constructed by women. In Amibara, Sideha-Faghe and Worer half to three fourth of the grazing lands are lost 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 (Zeraye, 2008).

Such circumstances, according to Mariara (2005), worsen the ability of pastoralists to cope using traditional strategies against environmental uncertainties, which raise their ecological vulnerability. 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.

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*). This puts heavy pressure on the remaining pasture and browse able 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).

According to Ellis (2000), different coping strategies will be taken by rural people that they think is feasible to overcome the encompassing situation. According to Zeraye (2008), a number of households tried clearing mesquite from grazing lands but, it was not promising due to its fast coppicing ability (Figure 3).

For Afar pastoralists, pasture and livestock are key components of their livelihoods; though the concept of livelihood is diverse and contextual (Ellis, 2000).

Figure 3: *Prosopis juliflora coppice* (Zeraye, 2008)

Figure 4: Efforts to cut *prosopis juliflora*

Competition to their labor is through clearing of mesquite from homesteads, footpaths, livestock tracks and even from grazing lands; and demanding more herders than used to be. Hyena and fox are the most mentioned predators to have been observed frequently around villages after the invasion of mesquite. This may be due to a good hideout created by mesquite near villages (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.

In Afar, animals play a central role in all walks of life. Cattle, goats and camels, in particular, have an importance that goes beyond the production of meat. Their value is based on the full set of services they supply (milk, meat, hides, draught power), their asset value as a form of savings, and their cultural symbolism. The animals feed predominantly natural grasslands and savannas, although tree leaves and crop residues are an important supplement during the dry season in agropastoral areas. In this way, pastoral livelihood systems in the region are determined largely by the seasonal variations in the quantity and quality of the natural pasture (Yacob, et al., 2000).

The rainfall in the region is bimodal, with a dry period of nearly 6-8 months, which causes serious challenges to the overall attainment of food security. It is normal for cattle to lose weight during the dry period, due to the unavoidable dry season under-nutrition. The critical point is to prevent excessive weight loss because the cattle might fail to recover fully during the following rainy season. In the region, periodic droughts aggravate the dry season under-nutrition, and wide spread cattle deaths are a common feature. In addition to the impacts of moisture stress, shrinkage of grazing land due to bush invasion (by a combination of bush encroachment, unpalatable fobs and shrubs), weakening of indigenous rangeland management systems, are fuelling the problem of rangeland degradation and hence feed scarcity and further land degradations and loss of livelihoods (ANRS, 2010).

The replacement of the productive and highly valued grass species with low quality feed resources and unpalatable weeds have greatly reduced available consumable herbage accentuating the problem of poor pasture and feed scarcity. Feed scarcity is a serious threat as livestock malnutrition is causing high miscarriage rates and distress, reduced reproduction

and production rates and mortality of weak livestock. Afar pastoralists believe that shortage of feed has resulted in long calving period, weak physical condition and less yields (milk, meat, lower market values) and reduced reproductive capacity (Yacob, *et al*., 2000).

Both the grazing reserves and communal rangelands in Afar are increasingly deteriorating as a result of drought and livestock grazing pressure. During stress periods, migration to the highlands seeking grazing areas is common, but land is becoming increasingly scarce due to land being occupied by farmers. Range degradation is aggravated due to moisture stress caused by climate variability and change. This in turn causes the disappearance of important grass species and invasion of unwanted species reducing range quality by competing with forage grasses and browse vegetation (Asnake & Kassay, 2005).

REHABILITATION EFFORTS AND STRATEGIES

Pastoralists take 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 employment in mechanized farms and other organizations, casual labor and small trade. As documented by Swallow (1993), most of these strategies were utilized by pastoralists for risk management strategies when sole dependency on livestock is in question.

The majority of the population of the afar region bases its livelihood on livestock rearing. However, there are a significant number of agro-pastoralists and sedentary agriculturalists. To support the agricultural sector the region, as of 2006, had 411 development agents in animal husbandry, plant production and natural resource. At the wereda level in Pastoral Agriculture and Rural Development Offices 47 animal health professionals out of which 8 are Doctors of veterinary medicine, 78 crop production and protection professionals, 174 natural resource professionals, 16 home economics professionals, cooperative section has 30 professionals and livestock husbandry 121 professionals, and there are 2 marketing professionals are giving services. In addition to this at the community (Kebele) level different associations have been established to support the community in the form of marketing agricultural produces and providing services these include 8 functional livestock marketing associations with 38739 members, 26 General service association with 1592 members, 13 irrigation association with 692 members, 5 veterinary medicine supply association 120 members, 2 livestock product marketing association with 83 members, and 11 saving associations with 494 members. Therefore, though investment on agriculture sector is expanding from time to time, its pace is not compatible with the pressure that climate change impact is imposing (ANRS, 2010).

In the last two decades, the federal government and the Afar Regional State government have implemented various development interventions in the form of livelihood diversification, asset protection, range rehabilitation, soil and water harvesting and management, irrigation infrastructural development, and bush clearing. Despite the limitations of financial resources, institutional capacity and logistics, these interventions have contributed to improved living conditions and building local resilience (ANRS, 2006).

As stated by Zeraye (2008), pastoralists tried to control the invasion of mesquite by cutting either in groups or individually. But mesquite's fast regenerating nature and ability to cover large area in a short period of time have discouraged the local people to continue their 'controlling' activity. They became hopelessness of cutting mesquite to reduce the expansion. They cut it many times being organized in groups. But it regenerates in the short time. Now, no other aid is worthwhile than eradicating *woyane* for them. 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. They need external agents' (governmental or nongovernmental organizations) support to help them to reduce mesquite population at least from the grazing areas (Zeraye, 2008).

Despite the pastoralists' indigenous mechanism of coping with the problems of feed and water shortage during the dry season and during drought years, the loss of specific feed varieties and their replacement by less palatable and hardy bush species is causing massive feed and livelihood insecurity in the area. With the increasing depletion of grasses, pastoralists tend to lop the leaves and branches of trees to feed their animals. Acacia pods are also used as important sources of dry season feed for goats, camels, and cattle. Although there are many other potential drivers of bush encroachment, including, overgrazing, and consequent land degradation, the contribution of changing weather patterns (such as increasing rainfall intensity, more frequent droughts, increasing temperatures, and shortening rainy seasons that prevent grass growth and propagation) could be significant and should be explored further (Admassie and Adenew, 2008).

Before starting a rangeland rehabilitation program, it is important to select the proper tools for range improvement method considering the following guidelines:

- Use only proven methods, first on small-scale trial bases and later undertake on a large scale only where practical and economical procedures can be used
- Try to use available local resources, labor, and equipment

- Determine the factors limiting animal production that can be improved by range improvement
- Analyze the expected cost benefit ratio (achievement of the goal)
- Concentrate on local range development in areas of greatest potential for increasing range productivity
- Plan to use livestock handling facilities that are beneficial to the rangeland and the range livestock
- Be flexible in planning

Based on the above guidelines, Reseeding program (Over sowing) can be implemented to improve degraded rangelands. Over sowing or range seeding is the broadcasting of pasture seed on grazing areas without cultivation or fertilizer application. Over sowing, is a useful method of increasing forage quality and production in existing pastures. It should be practiced:

- On poor soils
- In areas with light and loose soils
- Along road sides
- In pasture lands lacking a good legume content

The following are various possible options for external intervention during and after climate change disaster as summarized from various sources (Lars Otto Naess, 2009; Save the children UK, 2009; NAPA, 2007; Twigg, 2007).

- Facilitating livestock mobility: Provision of information where forage is available; management of conflict concerning access to key resources (water points, forage); provision of transport infrastructure;
- Developing and improve water sources such as ponds, protect and manage dry season rangelands through customary institutions;
- Promoting flood and rain water harvesting to address chronic water shortages,
- Strengthening and rehabilitate water storage facilities;
- Developing small scale irrigation schemes for fodder production and livestock watering;
- Providing of supplementary livestock feed (importation of hay, grain or green feed, multi-nutrient block) in case of emergency situation;
- Identifying and fencing dry season grazing areas;
- Supporting in the development of fodder banks to increase the availability of fodder for livestock;
- Feeding conservation (hay), rotation grazing and changing of the traditional feeding practices (cut and carry system).

Agro-pastoralism could be considered both a response to food insecurity and economic diversity. To support the introduction and expansion of crop cultivation in pastoral areas of Afar, the following support mechanisms can be considered:

- Creating enabling environment and supporting the construction of small scale irrigation facilities like micro dams, ponds, diversion canals and dikes;
- Providing agricultural skill training;
- Conducting research on stress/ drought and disease resistant as well as early maturing crop varieties;
- Improving agricultural extension service provision (pesticides, improved seeds, fertilizers and trainings);
- Improving agricultural productivity through improved inputs, adapting improved farm technologies, improved animal health service, strengthened disease and pest control mechanisms;
- Improving market and market information and facilitate loan services (microfinance) and
- Promoting income-generating activities;
- Providing micro credit and saving schemes and institutional support;
- Organizing women and youth in cooperatives and small businesses and support with funds so as to engage in small businesses and trade;
- Providing skill trainings to increase people's ability to take up loans and engage in income generating activities;
- Improving marketing and market information systems through formation of local marketing co-operatives;
- Facilitating and promoting of cross boarder livestock trade with controlled illegal trade (inter regional and abroad);
- Establishing community group managed cereal banks to stabilize cereal prices at all times;
- Improving access road, transport, communication access and improve road network between kebele, woreda and market centers;
- Facilitating the establishment of market centers and media programs for market information;
- Introducing commercial or community-based banking services at scheduled livestock markets;
- Disseminating information concerning timely weather, water and feed conditions, livestock and grain prices and drought management strategies;
- Strengthening indigenous early warning system;
- Building road and bridges to allow access to all districts at all seasons;
- Strengthening hazard escaping infrastructure and utilities; and
- Improving livestock market infrastructure and auction system.

Pastoralists have various traditional natural resource management strategies such as management of rangeland and livestock (identifying dry and wet season grazing, herd management, controlled soil burning, proper water management system, weed and pest management and others). The Afar traditional institution "mad'aa" governs the proper management and fair utilization of rangeland and water sources. To further strengthen the traditional system and support it with modern systems and technologies, the following appropriate interventions are recommended:

- Improving catchment treatment through land management, moisture and soil conservation and flood control methods;

- Implementing soil and water conservation programs and projects that promote local community participation;
- Focusing on rehabilitation and reclamation of degraded land, reforestation, conservation, management and protection of natural resources;
- Rehabilitating and managing dry season rangelands;
- Implementing measures to control aggressive weeds and other invasive plants such as *Prosopis juliflora* and
- Implementing plantation of non-invasive multipurpose trees at household level in areas where water is available from irrigation structures

CONCLUSION

Rangeland degradation is the most serious challenge for pastoral livelihood in Afar. Invasion of invasive species such as *prosopis juliflora*, reduction in the quantity and nutritional quality of the vegetation available for grazing in the rangelands as well as expansion of localized deserts and barren areas are the major problems. Other causes of degradation include climatic conditions causing drought and arid conditions and human factors leading to the overuse of natural resources. The effects of climate change and human pressures on the soil include a depletion of soil nutrients, with a decline in water retention, which ultimately causes a breakdown in soil structure and inability of some local breeds (known grass and seed varieties) to cope with such changes. The pattern of such changes in the region varies from place to place with the seasonality and variability of the climate system, the movements, and concentration of grazing animals, with seasonal conditions and with the varying vulnerability of the land itself.

Though livelihood diversification interventions such as expansion of opportunistic and irrigated farming agriculture have been proven to enhance food security of households and resilience to impacts of drought hazards, if ill planned can have negative impacts as well. The expansion of areas for agriculture may induce shrinkage in rangeland areas and hence affect mobility and recovery in the pastoral system. In addition, poor planning and management of irrigation projects can have unanticipated negative environmental impacts such as salinity of farmlands, incidence of malaria outbreak, siltation of irrigation infrastructures and farms. Moreover, government, NGOs, and other development actors should consider environmental sustainability, technological adaptability, and sociocultural acceptability factors when designing and implementing any rehabilitation, which involves water development and use and management of communal natural resources to avert possible conflicts among resource user groups.

Furthermore, any technological interventions such as construction of water supply points, irrigation schemes and others should be cost effective and easy for local management and maintenance. In general, though it is difficult to determine the best interventions and timing of an intervention, long-term development activities that are environmentally sustainable, cost effective, and socially acceptable can contribute to ecological rehabilitation and the development of local resilience and adaptive capacity to degradation.

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