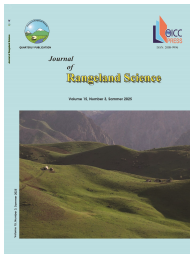

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Arid land degradation issues in Ethiopia: The case of the Borana and afar rangeland systems: A review

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Review Paper

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Abstract:

The unique feature of arid and semi-arid environments is that there is huge resource variability because of the climatic variation. Pastoralists are ecosystem experts and systematically live in the environment for a very long period. These savanna ecosystems are considered as a range of land for livestock and wild animals. Similar to other East African countries, most of Ethiopia is situated in an arid and semi-arid environment and there are pastoralists in this part of the country. There are approximately 10 million pastoralists in Ethiopia who make up almost 14% of the total population. Coming from at least 29 different nations and nationalities, Ethiopian pastoralists live in more than 133 woredas in seven National Regional States. Somali, Afar, and Oromo pastoralists are the majority in their states and constitute 87% of the total pastoralist population. Pastoral communities in the Southern part of Ethiopia (South Omo and Bench-Maji Zones), Benishangul-Gumuz, Dire Dewa, and Gambella make up the remainder. In the Borana and Afar rangelands of Ethiopia, bush encroachment has been expanding over the last four decades. The underlying causes for the bush encroachment are the breakdown of traditional land use practices (mainly mobility), expansion of farming in the rangelands, decentralization, and yearly grazing following the creation of permanent water points in the previous dry season grazing rangelands, and prohibition of range fire. Rangeland degradation has been occurred because of overgrazing, which may have altered the ecosystem in favor of the annual species and the extinction of highly palatable perennial species. Changes in soil surface conditions, notably compaction through trampling by livestock, lead to deterioration in soil-plant-water relationships and reduced germination rate, particularly of the palatable species. There are different options to restore such a degraded ecosystem, but the use of prescribed fire and acceptance of their customary resource management seems feasible in these areas.

Keywords: Rangelands; Arid land degradation; Bush encroachment; *Prosopis juliflora*; Restoration; Borana; Afar

Introduction

Rangelands are a vital part of the worldwide ecosystem, covering about 54% of the world's terrestrial area (Teillard et al., 2016). They are home to a wide variety of plants, animals, and microbes that are of ecological, economic, and cultural significance (Seid et al., 2016). Worldwide, savanna ecosystems cover one-fifth of the total land and more than half (65%) of tropical Africa (Osborne, 2000). This grassland with a scattered tree ecosystem has been a home for pastoralists and agro-pastoralists for millennia. The global estimation of pastoralists and agro-pastoralists is about 120 million of which 50 million are residing in sub-Saharan Africa (Rass, 2006). In some parts of Africa, especially East Africa, the savanna ecosystem is considered as the homeland of the livestock industry and wildlife animals. This most fascinating ecosystem is mostly found in arid and semi-arid environments. In East Africa, pastoralists and pastoralism are distributed throughout the region in countries like Kenya, Uganda, Tanzania, Ethiopia, South Sudan and Sudan.

The unique feature of arid and semi-arid environments is that there is huge resource variability because of the climatic variation. Pastoralists are ecosystem experts and systematically live in the environment for a very long period. In arid rangelands, herders highly rely on access to resources, especially pasture, and water, which are commonly owned and highly variable (McCarthy et al., 2003). Over generations, pastoralists have a wealth of knowledge to sustain their livelihoods in arid environments (Megersa et al., 2014).

Arid environments are characterized by low, erratic, unpredictable, and seasonal rainfall patterns and frequent drought (Behnke, 1992; Rass, 2006). Primary productivity is mainly governed by moisture availability in these areas. There is good productivity in the wet season while the productivity declines dramatically resulting in a huge number of livestock mortality in the dry season.

Similar to other East African countries, most of Ethiopia is situated in an arid and semi-arid environment and there are pastoralists in this part of the country. There are approximately 10 million pastoralists in Ethiopia who make up almost 14% of the total population. Coming from at least 29 different nations and nationalities, Ethiopian pastoralists live in more than 133 woredas in seven National Regional States. Somali, Afar, and Oromo pastoralists are the majority in their states and constitute 87% of the total pastoralist population. Pastoral communities in SNNPR (South Omo and Bench-Maji Zones), Benishangul-Gumuz, Dire Dewa, and Gambella make up the remainder (PFE IIRR and DF, 2010).

The Borana rangeland is situated in the southern part of the country. It covers about 95,000 square kilometers and is located at $4-6^{\circ}$ north latitude and $36-42^{\circ}$ east longitude with its altitude varying between 1600 m in the northeast to 1000 m at the extreme south end (Kamara et al., 2004). According to Kamara and colleagues, the area is characterized by high rainfall variability that varies between 300 mm to 900 mm per annum and is usually bimodal but hardly adequate for reliable agriculture (that means crop production). On the other hand, the Afar Region, along the Awash River in north-eastern Ethiopia covering an area of 108,860 km^2, is hosting a population of approximately 1.4 million people with around 87% living in rural areas, mostly depending on livestock production (CSA, 2010) featured by extensive areas of bushlands 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, the Afar Region encompasses biodiversity hotspots and several endemic species (Abiyot and Getachew, 2006).

Such ecosystems are highly sensitive and it is important to know how the entire system operates, the level of degradation and how pastoral communities are dealing with such ecosystems, their interaction with the system components, and the primary cause of ecosystem dynamics. Therefore, this paper aims to look into:

- The characteristics of Borana and Afar rangeland systems in terms of their structure, composition, and function.
- The cause/factor behind Borana and Afar rangeland degradation and its extent.
- The impact of *Prosopis juliflora* and bush encroachment specific to the Afar and Borana rangelands
- Possible ways of rehabilitating the rangelands.

Material and method

To conduct this review, the empirical analyses of the qualitative method were used. After a Google search of various issues on Afar and Borana arid land degradation using search phrases like Afar pastoralism, Bomana pastoralism, rangeland degradation in Afar and Borana, arid land management, etc., about 180 documents were downloaded. After retrieving the important issues with exclusion and inclusion parameters, about 66 important documents from journals and other sources were selected and reviewed critically. Major research and documents from journals, books, office documents, etc. were reviewed to understand what the Afar and Borana rangeland ecosystem degradation looks like. The known professionals' work and findings in rangeland degradation and management areas at global and country levels were evaluated and cited in appropriate sub-sections of the review paper. More emphasis was given to Ethiopian authors' findings due to the very nature of the familiarity of their findings compared with foreign writers who may encounter exposure to data in its original quality.

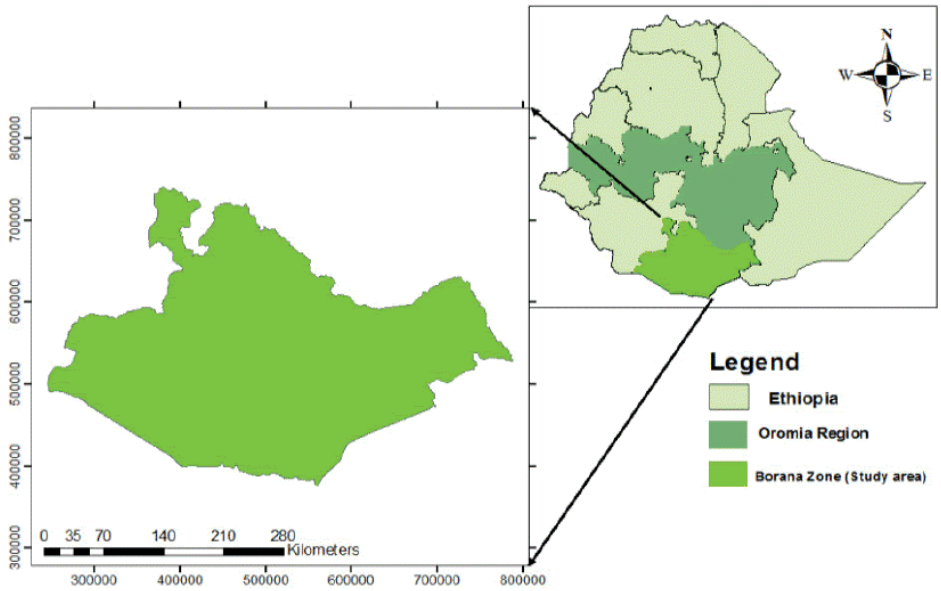
The case of Borana rangelands

Characteristic features of the Borana rangeland system

About 50% of the gross income of Borana pastoralists is from livestock raring. The Boranas are specialists in extensive cattle keeping and their land use system is characterized by sustainable rangeland exploitation based on seasonal heard mobility that makes stocking density flexible (Oba and Kotile, 2001). As indicated above, they live in arid and semi-arid environments that are characterized by low, erratic, unpredictable, and seasonal rainfall patterns and frequent drought (Behnke, 1992; Rass, 2006). Primary productivity is mainly governed by moisture availability in these areas. There is good productivity in the wet season while the productivity declines dramatically resulting in a huge number of livestock mortality in the dry season. Together with the spatial and temporal variability of rainfall, some other episodic events govern the animal and plant population. In the drylands, such events as fire and diseases that fluctuate unpredictably result in the fluctuation of animal and plant population which the area can support sustainably (Behnke, 1992). Not only did these, but the soils in these areas had spatial variability at local and regional levels (Rass, 2006).

The Borana rangeland (figure 1) in southern Ethiopia exhibits both spatial variability in resource patchy, and temporal variability of resources. This arid and semi-arid rangeland of the Borana plateau is almost entirely occupied by pastoralists that depend on commonly owned pasture and water resources and of course, some very few, newly introduced traditional grazing enclosures, locally called *kalo* (Tefera et al., 2007). Pastoralist households' susceptibility and adaptation to climate change depend on demographic, socio-economic, and institutional factors. Older pastoralists have more traditional knowledge but less exposure to new information (Awiti, 2022; Mwadzingeni et al., 2022; Atube et al., 2021; Zamasiya et al., 2017; Deressa et al., 2009).

In arid and semi-arid environments, the issue of resource management is about managing the rangeland in general



Note: Study area location map. It indicates Borana Zone administration, low land of southern Ethiopia which located in Oromia regional state. The zone capital town Yabello is 550 Km far from Addis Ababa, Capital city of Ethiopia and Oromia regional state.

Figure 1. Location map of Borana Zone in Ethiopia (Sorece: Bonaya and Demeku (2021)).

and key resources in particular. Resources are divided into key and non-key resources in dryland areas. The division is based on their ecological differences and their spatial and temporal variability for grazing management. East African pastoral communities consider a given parcel of land as a key resource if access to the land is crucial for livestock survival during dry periods, or if the land is found in the wet season of the arid ecosystem where there is rapid vegetation growth that can serve as fresh feed for weakened animals to re-gain their lost body condition and reduced reproductive capacity after drought (Angassa and Oba, 2007b). The key resources include wet and dry season grazing land, salt water, riverine lush vegetation, and some other resources. In such systems, the capacity of the local community to cooperate in the management of the existing resources is very important. The effectiveness of the managerial capacity has also a direct implication on the rate of exploitation of the existing resources and patterns of land allocation for different alternative uses (McCarthy et al., 2003). The effective management of socio-ecological systems involves understanding the contextual factors that drive changes in resource use patterns and affect the societal capability to adapt and cope with the stresses (Hertel et al., 2021). In both pastoral and agro-pastoral systems, livestock production is of essential position to the incomes, economies, and livelihoods of hundreds of millions of Africans in particular and the world at large (Abduletif, 2019; FAO, 2021).

According to Angassa and Baars (2000), the Borana pastoralists have a long-term experience in avoiding local overstocking around scarce water resources, which are considered key resources during the dry season. The management system of the Borana rangeland is basically through the direct management of water resources. There are two water sources in this area; namely the deep well-called *tula* and the recently introduced water ponds (Tefera et al., 2007). Nine wells in the Borana plateau have been operating for the last 500 years and still operating because of the underlying strong social organization that controls their construction, maintenance, use, or access to these wells. Livestock production was impossible without the wells in this area as there is no reliable water source for animal and human consumption, especially in the dry season with the most difficulty in the drought period. These deep wells, which were constructed by the local community in a very ancient manner, are found in a unique limestone geological formation and the access to water and stocking rate are regulated by strong socially set and enforced rules. These make them very unique as compared to the rest of the savanna ecosystem. The division of resources into key and non-key ones in the Borana pastoralists emanates from this scarce resource of water. Rangelands surrounding the *Tula* wells are considered key resources, while the rest are considered non-key resources. It is not allowed to graze within a 20 km radius of the *Tula* wells during the wet season, as it is conserved for the dry season (Angassa and Oba, 2007b). Therefore, grazing areas with less water availability are preferably used during the wet season when there is ample surface rainwater. However, in recent times, this trend has changed because of the construction of water ponds.

Ecological models that explain the Borana rangelands

The equilibrium succession model and non-equilibrium model have been under debate for a long period and scientists were polarized under these schools of thought. The ecological thinking behind the equilibrium model is that range land productivity is governed by biotic factors and the relation between grazers and rangeland capacity is density dependent. On the other hand, non-equilibrium model explains that the relation between herbivore and rangeland productivity is density-independent because it is the abiotic

factors that are more powerful to govern primary productivity than the biotic ones. Therefore, the management directions under these two models are different. Because the supporters of the equilibrium model think that there is a linear relationship between the livestock population and range land productivity, the management directives followed by these groups were revolving around stocking density, carrying capacity, and range condition assessment (Vetter, 2005). On the other hand, the supporters of the non-equilibrium model argued that the relationship between herbivores and primary producers is not as simple as the plant populations governed by some other stochastic events, and fixing stocking rate is more difficult (Oba et al., 2000). However in the old days, equilibrium thinking was more dominant and it was applied to different management aspects in the drylands of Africa for many years (Westoby et al., 1989).

The vegetation dynamics under equilibrium is explained as the response of vegetation to grazing in a linear way that can be manipulated and reversed through stocking rate where zero or light grazing can push the vegetation to its climax while heavy grazing pushes the trajectory backward to its pioneer stage which is dominated by unpalatable forbs and grass or weedy plants that are typical to the disturbed ecosystem (Vetter, 2005). Such systems exist in relatively predictable rainfall areas, hence livestock populations and forage production are regulated in a way that if the population is near the carrying capacity, then the competition for food increases and results in a population crash. Therefore, the population must be kept under the carrying capacity. On the other hand, productivity in dry lands is highly variable and unpredictable. There is high biomass production in the wet season and the opposite is true during the dry season. In such systems, the herbivore population is governed to a larger extent by rainfall and drought; the rainfall plays exactly the opposite role where drought pushes the vegetation condition to the pioneer stage while rainfall improves the range condition (Vetter, 2005) and the herbivore population will rarely reach the carrying capacity. Surprisingly enough, some plant species that are nutritionally good for animal production are stimulated by grazing. Studies in some parts of East Africa done on the balance between woody and herbaceous vegetation conditions by excluding the native herbivores reveal this fact. It is more explained by Oba et al. (2000); a new perspective on interactions among climate, plants, and herbivores suggests that rangelands influenced by highly stochastic weather and grazing disturbance are degraded, not by continuous grazing, but by the long-term absence of grazing.

Besides this, dry lands are highly resilient to changes, especially long-term grazing pressure. This is because the grass community is more dominated by annual grasses which hardly germinate in the absence of rainfall and if there is rainfall, then the biomass production after rainfall is more or less proportional to the amount of rainfall (Vetter, 2005). Therefore, rangelands in arid and semi-arid environments are better explained by the state and transition model, rather than the equilibrium models where each state and the transition between these states can be explained by unique vegetation composition. After assessing the bush encroached and non-encroached Borana rangeland, Angassa and Oba (2007a) identified five vegetation states and ten transitions between the states that are completely different in their density of matured trees, tree seedlings and saplings, bush cover, woody species composition and the ratio of invasive woody species. The role played by management here is that because each state has its unique characteristics, it is possible to avoid the undesirable state by understanding their character while preserving the desirable state as some of the changes (e.g. bush encroachment) cannot be reversed by the management over time-scales or may require high management inputs (Vetter, 2005). Therefore, in such systems, management plays a great role in the sustainable use of resources.

Rangeland management in the Borana pastoral system

Similar to the other parts of Africa, rangeland in southern Ethiopia is the source of direct income and consumption for the pastoralist populations, serves as a source of draught power for the agro-pastoralists in the highlands, and also serves as a source of export for the country's economy (McCarthy et al., 2003). Communities in the rural setting in general and pastoralists, in particular, rely on plant resources for different purposes such as food and forage, construction, making household equipment, herbal medicines, beds and sleeping mats, shading and firewood, etc. Because of these facts, pastoralists have deep knowledge of the management of such resources and they are also able to identify and name them. Out of the 327 plant species identified in the Borana rangelands, the Borana pastoralists were able to identify and name 86% of the plant species (Gemedo et al., 2005).

Borana pastoralists in southern Ethiopia have a well-established traditional system of range and water management. They use their indigenous knowledge to categorize landscapes not only in terms of seasons of use but also in terms of grazing capacity (Oba and Kotile, 2001). The Borana pastoralists classify their rangelands into *Kalo*, *Worra*, and *Foora* land use units (*Kalo* is grazing land for calves, *Worra* is for lactating animals and *Foora* is for dry animals) (Gemedo et al., 2006a). Because Borana pastoralists are cattle pastoralists, the existence and availability of grass play a key role in their economic actions (Angassa, 2005). Therefore, the management strategies that have been applied for many years in this area aimed to have more grass than the other plant species in the area. Heard diversification, fire, and mobility were the most popular management alternatives in most pastoral communities, including the Borana. As indicated above, water management is the most systematically applied management tool to manage other resources by the Borana pastoralists. By controlling water, the most limiting resource, they can easily control the other factor that contributes to resource degradation in the range of land. For example, the nine *tulla* wells (the reliable water sources all around the year in dry and drought periods) in the Borana plateau belong to well-defined groups or clans. Anybody, outside of the clan, must ask permission from the owners of the well who have absolute power to decide the amount of water extraction. If a low amount of water exists in the well, the owner denies water access but only allows

enough water for watering the animal for that specific day because they have due respect for cattle.

If we look at fire as a management alternative, it is important in range management because fire removes old and dead vegetation, which can be replaced by young re-growth of green flush. Moreover, there is an increase in the macronutrient concentration of above-ground vegetation post-fire in the East African savanna (Van et al., 1999), which is very important for the fast recovery of livestock from stress. There is an increased light intensity in the burned area and at the same time, the nutrient status of the soil is also improved after burning because of the ash that is reached in nutrients. At daytime, soil temperature also increases and it favors the plants in burned areas (Osborne, 2000). Fire also controls the dynamics between shrub cover and bush encroachment, which is considered as a major problem in many pastoral areas. Once the bush cover is beyond a certain limit, it is impossible to control it by fire because the grass that serves as fuel is absent (Roe, 1997). Therefore, herders used fire as a management tool to control vegetation dynamics in the Borana rangeland for many years. But they are no longer allowed to use fire as a management tool as a result of the ban on fire use by the government since 1974/57 (Solomon et al., 2007).

The most important management tool in dry land is mobility. Because resources exist in patchy and vary spatially and temporally, mobility is a must to track these scarce resources. The Borana pastoralists divide their herd for the ease of management into two groups of mobile herds (locally called *loon fora*), and those that stay around the homestead (*loon warra*). The *warra* herds include milking animals (that serve as a source of food), immature calves, weak animals, etc. while the *fora* herds include those highly mobile animals like bulls, immature cows of greater than two years, etc. (Angassa and Oba, 2007a). On the other hand, the Borana pastoralists, who were formerly cattle pastoralists, have been diversifying the species of livestock raising an enormous number of camels as a management option for bush encroachment (Angassa, 2005). A large number of herds in Borana society also have a social value because it indicates the wealth status of that clan and/or individual.

Bush encroachment and its impact on the Borana rangeland and pastoralists' livelihood

The pastoral livelihood system is a way of life practiced by people living in arid and semi-arid environments, using mainly long-lasting traditional knowledge to optimize the interaction between human beings, livestock, and the environment (PFE IIRR and DF, 2010). Pastoral livelihood will be in danger when the range condition is degraded. (Mengistu, 2006) deterioration in the rangelands. Rangeland is considered degraded when pastures are unattractive to livestock and support only low stocking rates (Rischkowsky et al., 2003). Prolonged dry seasons and drought very often result in a critical decline in the quantity and quality of feed and a shortage of water, leading to decreased productivity and increased mortality of animals, and a consequent collapse of livelihoods (Tolera and Abebe, 2021).

Until the 1980s, the Borana pastoral system in southern Ethiopia was regarded to be especially productive and had higher net primary productivity and returns of energy and protein per hectare compared to industrialized ranching systems in North Australia which only realized 16% of the energy and 30% of the protein per hectare compared to the Borana system (Hassen, 2013). However, increasing human and livestock populations, changes in fire regimes, expansion of crop production, and changing demographics and traditional institutional conditions have forced pastoralists to intensify grazing, which has resulted in the deterioration of the rangelands in the Borana (Oba et al., 2000; Angassa, 2005). Loss of vegetation cover, undesirable change in herbaceous species composition (e.g. perennial grasses are replaced by annual), soil erosion of various types as a result of intensive grazing and woody encroachment have been dominant features in the Borana rangelands (Hassen, 2013). In the Borana rangelands of *Ethiopia*, bush encroachment has been expanding for the last four decades. The underlying causes for the bush encroachment are a breakdown of traditional land use practices (mainly mobility), expansion of farming in the rangelands, resettlement and yearly grazing following the creation of permanent water points in the previous wet season of grazing rangelands, and prohibition of range fire (Oba, 1998; Oba and Kotile, 2001; Oba et al., 2000). Change in the customary rangeland governance also has contributed to the Borana rangeland degradation. Borana pastoralism is founded on extensive livestock keeping, flexible resource use, and seasonal herd mobility, and is governed by strong customary institutions known as the '*Gadaa* System'. The *Gadaa* system, which endured the Borana system livelihood for centuries, is under pressure from the change in government policies and expansion of farmlands in the area (Wassie, 2014).

Encroachment of woody plants has been among the major threats to the livelihoods of Borana pastoralists and their ecosystem. A study by Gemedo et al. (2006b) depicted that the bush cover that was less than 40% in the 1990s increased to 52% in 2006 of which *Commiphora africana*, *Acacia mellifera*, *A. drepanolobium*, *A. brevispica* and *Lannea rivae* were among the dominant encroachers in the Borana rangeland. Even though pastoralists are so smart in selecting the livestock types that can suit the type of vegetation existing in their vicinity, bush encroachment is negatively related to carrying capacity (Roe, 1997). For cattle pastoralists like the Borana, bush encroachment is considered a great problem. This is because it can serve as a home for many predators, reduce grass cover (the most important cattle forage), cause mechanical damage to the animals, reduce visibility and make cattle keeping difficult, and encroachment increases tick population (Angassa, 2005).

Assessment of the Borana rangeland by Oba et al. (2000) indicated that range degradation such as soil erosion is not the result of grazing and they are the result of bush encroachment that does not allow the growth of understory and results in bare soil. They also indicated that more than 70% of the rangelands in Borana are either in fair or poor condition that poses a threat to the pastoral livelihood as a result of bush climax, lost grass cover, and an increase

in the number of unpalatable forbs. According to Angassa (2005), the composition of grass and mean grass yield are affected by bush encroachment in Borana. Because safe stocking rates for the livestock are usually determined by the amount of grass biomass available in seasons of lowest production, the increase in unpalatable grass species and the decrease in mean grass yield have an impact on the stocking density which in turn affect the livelihood of the pastoral communities. Gemedo et al. (2006a) after assessing the condition of the Borana rangeland concluded that the Borana rangeland is on a transition from good range condition to poor and urged rehabilitation activities in the rangeland such as the use of fire. Information on the economic loss of the rangeland degradation in Borana is scarce. However, it is clear that when the rangeland is degraded, it accommodates less density of animals and this has an impact on the livelihood of pastoralists. It is also true that it can increase malnutrition in the community, especially children, as a result of a reduction in milk production. The problem with bush encroachment is to change the grassland ($<$ 10% bush cover) to bushland ($>$ 30% bush cover) and an increase in 10% bush cover results in a 7% reduction in grazing capacity in the East African context which can eliminate grazing when the bush cover reaches 90% (Oba et al., 2000). As the range condition and their livelihood are declining the Borana pastoralists becoming agro-pastoralists. A recent study by Elias et al. (2015) shows that the number of agro-pastoralists in Borana is increasing sharply. However, because the rainfall is erratic and the area is not suitable for permanent agriculture, soil erosion is one of the significant consequences of this practice in the study areas, and the intensity of erosions increased in the lowland which in turn aggravates the problem in the area.

The possible restoration options for rangelands

Restoration of degraded ecosystems requires a very good understanding of how the system operates. Restoration could be either passive restoration that aims at ceasing anthropogenic perturbations causing degradation (Kauffman et al., 1995) or active restoration that aims at biotic manipulation practiced by reintroduction of animal or plant species that have been extirpated from an area (Kauffman et al., 1997). Passive restoration can take care of ecosystem restoration when the degree of perturbation is minimal. Otherwise, active intervention is a must to restore a highly degraded ecosystem. The following active restoration is possible for Borana rangeland in particular and the degraded rangelands in general.

- **Prescribed fire:** Ban on the use of fire as a management tool was mentioned as the main reason why the Borana rangelands degraded (Oba, 1998; Oba et al., 2000; Oba and Kotile, 2001; Angassa, 2005; Gemedo et al., 2006b). Unmanaged use of fire is a problem while the managed use of fire in the rangeland can suppress/kill evasive tree seedlings and maintain ecological balances.
- **Recognition of customary institution in rangeland management:** operating for millennia, customary institutions in pastoral tribes have deep knowledge of how to manage rangelands. For example, Livestock assets, incomes, and productivity declined with the weakening of the '*Gadaa* system' (60% decline) customary institutions in the Borana rangeland (Wassie, 2014).
- **Grazing management:** Setting stocking at higher stock densities has commonly resulted in a decline in the most palatable perennial species and an increase in less favorable species. In arid and semi-arid environments, even a lower stocking density can result in rangeland degradation. Grazing management alternatives like herd splitting and mobility should be acknowledged because they allow the herders to maximize the use of the patchy resources (Oba, 1998; Oba et al., 2000).
- **Destocking of animals:** where there is heard congregation, the introduction of seeds in areas where the land already exhausted its seed bank, and other methods can also help to restore already degraded rangelands.

The case of Afar rangelands

Characteristics features of Afar rangeland systems

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 120 m below sea level to 1500 m above sea level. Temperatures vary from 20 °C in higher elevations to 48 °C 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 (ANRS, 2010).

The Afar Region is featured by extensive areas of bushlands and grassland used as pasture by local pastoral transhumant groups. Furthermore, the Afar Region encompasses biodiversity hotspots and several endemic species (Abiyot and Getachew, 2006).

The vegetation consists of scattered clumps of semi-desert shrubs, acacia woodland, grassland and wooded grasslands (Shiferaw et al., 2019). According to ANRS (2010), the northern part of the 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. Currently, livestock gets their feed from bushland, shrublands, riverine forests, grassland, and seasonal marshes and swamps (MCE, 2000).

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, (figure 2) the vegetation is lower and less dense (ANRS, 2010). 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 (herba-

ceous vegetation composed mainly of grasses and forbs and browses (shrubs, tree leaves, and pods) (ANRS, 2010).

Level of degradation in Afar rangelands

According to Ashebir et al. (2010), the Afar rangeland degradation has been taking place because of overgrazing, which may have altered the ecosystem in favor of the annual 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 encourages them to certain dominant in competition for soil nutrients and moisture regimes. Over the past six decades, grazing across the region has increased significantly, due in part to pressures from a growing human population and conversion to cultivated agriculture. Consequently, the few rangelands that remain are subjected to overgrazing or prolonged use which will likely lead to their loss. Additionally, owing to the fast population growth and associated demands for livestock products, the intensity and scale of grazing are likely to increase in the region, with subsequent ramifications for the remaining rangelands (Helland, 2015). 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 (Harrison, 2000; Wu et al., 2008). As a result, those individual species aggregating around similar habitats or regrouping themselves into community groups could be explained as plant species that require similar ecological niches in terms of soil type, moisture regime, land escape, and level of grazing responses (Amaha et al., 2008).

Causes and trends of rangeland degradation in Afar

Several interacting variables and processes contributed to land-use/cover changes in the Afar Region. The principal form of land cover change before the 1960s was temporary shifts from grassland to bushy grassland and vice versa dictated by fire and grazing. The 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 favor crop farming; (2) resettlement of pastoralists and increased overgrazing in dry-season grazing areas since the 1960s; (3) severe droughts in 1973/74 and 1984/85; and (4) shortage and poor distribution of rainfall during the last decade (Oba et al., 2000; Angassa and Oba, 2007a).
As reported by Getachew (2001a), rangeland degradation is the most serious challenge for pastoral livelihood in Afar. Major reductions 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 were reported. Reported 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

Figure 2. Location of Afar Region in Ethiopia (Feyissa, 2011).

retention, which ultimately causes a breakdown in soil structure and the inability of some local breeds (known grass and seed varieties) to cope with such changes. The pattern of such changes in the Afar Regional State and within the five administrative zones 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 the varying vulnerability of the land itself.

Asnake and Kassaye (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 the 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.

Between 1972 and 2007, the woodland in the landscape was mainly converted to bushland, scrubland, and bushy grassland. Grassland was mainly converted to scrubland and bushy grassland. Cultivated land is mainly converted from scrubland, bushy grassland, and grassland. Although scrubland was gained from bushy grassland and others, at the same time an equivalent area of scrubland reverted to bushy grassland and other land covers. The general trend observed in the Afar area implies a loss of grassland and woodland cover and an increase in cultivated areas and bushland cover. The following Table 1 shows the change in rangeland conditions classified into different land use classes.

Bush encroachment in Afar

Bush encroachment is the invasion of aggressive and undesired thorny and woody species resulting in an imbalance of the grass-bush ratio and a decrease in biodiversity and carrying capacity. It causes severe economic and ecological losses for pastoral communities in Afar. Previous studies and official reports from the regional administration offices in the Afar Regional State confirm that bush encroachment is the most important factor hampering sustainable livestock production, food security, and improved livelihoods. Accordingly, the problem is becoming a threat to feed and food security in the area (ANRS, 2003). It has invaded large grazing areas in the Dulecha area, Amibara, Gewane and Buremodaitu weredas (zone 3) and Mile, Dubti and Afambo weredas (zone 1). In addition, the most important palatable grass and tree species for livestock are replaced by unwanted plant species like *Partheniun hystrophorus*, *Tribulus Terrestris*, and other tree species such as *Acacia nubia* (MARD, 2008).

Despite the pastoralists' indigenous mechanism of coping with the problems of feed and water shortage during the dry season and drought years, the loss of specific feed varieties and their replacement by less palatable and hardy bush species is causing massive feed and livelihood loss 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

Table 1. Land-use/cover in 1972, 1986 and 2007 in Northern Afar rangelands, Ethiopia.

Land-use/cover	Absolute area cover (km^2)			Cover change between periods (%)		
	1972	1986	2007	1972–1986	1986–2007	1972–2007
Woodland	209.13	70.07	7.02	-66.5	-89.98	-96.64
Bushland	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

Source: Deressa et al. (2009)

prevent grass growth and propagation) could be significant and should be explored further (Admassie and Adenew, 2008).
The replacement of the productive and highly valued grass species with low-quality feed resources and unpalatable weeds has 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 the shortage of feed has resulted in a long calving period, weak physical condition, and less yield (milk, meat, lower market values) (Yacob, 2000).

The impact of *Prosopis juliflora* on the rangeland and pastoral livelihood in Afar

Exotic plant species have been introduced deliberately and/or accidentally to countries for various reasons. Some of such species have been proven to be helpful in their new places because of 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 that are found harmful after their introduction in different ways. For example: (a) by interfering with rural livelihoods activities; (b) by impeding land use systems; and (c) by incurring extra costs of management to their 'new home' because they invade a large amount of land within a short period. 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).
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 the 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.
It has at least four vernacular names in Ethiopia, *Yeferenj Biskut*/*Dergi-Hara*/*Woyane* in the Afar region and *Biskut* around Dire-Dawa. The four vernacular names mentioned have origins related to their relished pods and time reference. *Yeferenj Biskut* 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 the 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 (Pasiecznik et al., 2001).
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 the Middle Awash area of Afar National Regional State 30 years ago. 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 the Food for Work Program until 1988 (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 croplands are estimated to be occupied by Mesquite. These invaded resources are the key supporting units for livestock keeping, which in turn are the mainstay for Afar people in that fragile ecosystem.
Mesquite was planted as a hedge around offices, residential areas, and along roadsides within the compound of Middle Awash Basin Water Resources Agency based at Worer. This gave a 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 impact 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, research in the Middle Awash area revealed that about half of the seeds, which pass through animal digestive tracts, can germinate (Hailu et al., 2004).
The invasion leads to shrinkage of the rangelands and grasslands and will therefore threaten the 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 for predators near satellite camps in the area (FARM AFRICA, 2008). 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, 2001b).
Mesquite invasion forms impermeable and dense thickets. It reduces the 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 of diminishing groundwater (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 (Gavali et al., 2003).
In Afar, mesquite has encroached on thousands of hectares of valuable land. 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 a problem. People 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 is established (Pasiecznik, 1999; Zeila et al., 2004). As a result, the limited mobility of herds imposed by the 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 is the other problem imposed on the pastoral community of the Afar; while the invasion of burial places is stated as a problem more at Worer followed by Sideha-Faghe and Amibara (Zeraye, 2008).

For Afar pastoralists, pasture and livestock are key components of their livelihoods; though the concept of livelihood is diverse and contextual (Ellis, 2000). Competition for 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 (Elias et al., 2015).

Pastoralists take different measures to secure their livelihoods due to the situation where the sole dependency on pastoralism was not feasible. The different measures taken were: cultivation of land, sharecropping, formal employment in mechanized farms and other organizations, casual labor, and small trade.

The possible restoration options for rangelands

The following are various possible options for external intervention during disastrous range degradation as summarized by (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 improving water sources such as ponds:** protecting and managing dry season rangelands through customary institutions;
- **Promoting flood and rainwater harvesting:** to address chronic water shortages,
- Strengthening and rehabilitating water storage facilities;
- **Developing small-scale irrigation schemes:** for fodder production and livestock watering;
- Providing supplementary livestock feed: (importation of hay, grain or green feed, multi-nutrient block) in case of emergency; Identifying and fencing dry season grazing areas;
- **Supporting the development of fodder banks:** to increase the availability of fodder for livestock;
- **Implementing measures to control aggressive weeds:** and other invasive plants such as *Prosopis juliflora*.

Conclusion

Borana and the Afar rangelands are situated in the arid and semi-arid environment of Ethiopia. Rainfall is erratic, variable, and unpredictable in space and time. The Borana pastoralists developed a systematic way of resource utilization from such systems. Their knowledge is so deep and accumulated over centuries of experiments in practical life. Once considered the most productive rangeland, the Borana rangeland is becoming degraded these days. The most prominent forms of degradation are bush encroachment and erosion of rangelands. There are lots of reasons behind the degradation of the rangeland. However, the erosion of their customary resource management practices and the ban on the use of fire as a management tool are the most prominent reasons why the rangeland is degraded. The formerly cattle pastoralists are now diversifying their herd as a coping mechanism and the Boranas are also becoming agro-pastoralists. This in turn is now bringing soil erosion as another threat and restoration of the rangeland is a must so that the pastoral communities will lead their normal way of life.

The Afar pastoralists also share a more or less similar situation as that of the Borana. Their range land is degrading, more settlement is coming in and grass cover is converted to bushland. The major difference between the Afar and the Borana system is that in the Borana rangeland, there is no perennial river in the rangeland, while the life of most Afar pastoralists depends on the river Awash. In addition, the introduction of *Prosopis juliflora* in the Awash Valley for different reasons is posing a threat to the livelihood and rangeland management of the Afar pastoral community. Unless it is tackled, the rangeland degradation in Ethiopian pastoral communities, this systematic way of life that best suits very sensitive environments, the arid and semi-arid will be jeopardized and pastoral livelihood will be hampered. There are different options to restore such a degraded ecosystem, but the use of prescribed fire and acceptance of their customary resource management seems feasible in these areas.

Availability of Data and Materials
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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