Impact of *Prosopis juliflora* on People's Livelihoods and Rangeland Ecosystem: Its Control and Management in Kabridahar, Somali Region, Ethiopia

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Abstract

Prosopis juliflora is a multipurpose tree of different functions. However, most of its benefits are not well known in non-native places, particularly in pastoralist dominated dry lands of sub-Saharan Africa. In Ethiopia, this invasive alien tree has shown a rapid expansion into rangelands affecting local livelihoods leading to conflicts between pastoralists. However, little is done to either control or manage it properly. This paper examined the impact of *Prosopis juliflora* on pastoralist and agro-pastoralists' livelihoods and rangeland ecosystem and the subsequent control and management options in Kabridahar woreda of the Somali regional state, Ethiopia**.** In order to investigate the spatial and temporal rangeland dynamics, the researchers selected land SAT ETM+ for 2007 and 2017 based on the bench mark given by the local communities who agreed that visible land-use/land-cover changes occurred, particularly, through the expansion of *Prosopis juliflora*. Surveys, focus group discussions and key informant interviews were held to collect primary data. *Prosopis* invasion in Kabridahar affected people's livelihood and significantly reduced size of grazing land. Despite the extent and magnitude of the tree's expansion, the application of management and control options was little.

Keywords: Livelihood, management and control, Prosopis juliflora, rangeland, Somali region, Ethiopia

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1. Introduction

Vigorous growth potential and high adaptability to harsh environments made invasive species serious challenges to global biodiversity and ecosystems thereby affecting people's livelihood and ecosystem goods (Manchester and Bullok, 2000; D'Antonio and Kark, 2002; Zeraye, 2008). In Ethiopia, where the pastoralist dominating lowlands of the country has long been marginalized from the State's attention, a number of invasive species have contributed to rangeland deteriorations and affected local livelihoods. *Prosopis juliflora,* an evergreen tree native to South America, Central America and the Caribbean, is a species threatening pastoralist livelihoods. Prosopis was introduced to many tropical areas in the 1970s and 1980s to combat desertification, deforestation, and rangeland degradation and to respond to fuel wood demands. The tree is fast growing and nitrogen-fixing with high level of tolerance to arid conditions and saline soils where its invasion is causing tremendous challenges to rangelands and peoples' livelihood in different parts of the world (Catterson, 2003; Esther and Brent, 2005; Gavali et al., 2003; Stefen, 2005; Zeila et al., 2004).

People's perception about the costs and benefits of prosopis depends on their livelihood strategy. Rural poor, who cannot afford alternative energy sources, value the tree for its use as fuel and fodder source. Similarly, ranchers, pastoralists and agro-pastoralists, whose main livelihood strategy is keeping livestock and farming, view it negatively because it invades pasture and farm lands (Saxena, 1997). In India and countries of its origin (South America, Central America and the Caribbean) prosopis is referred to as a "poor man's tree" or a valuable tree from which considerable number of people in the dry lands make their living. For example, in Latin America, most parts of the tree supply raw materials such as fuel, charcoal, fodder, food, bio-char, bio- control, and functions as windbreak, shade, construction and furniture materials, and soil stabilization. It is also used to improve physiochemical and biological properties of soil under its canopy through creating spots of fertility (Mohammed et al, 2017; Vallejo et al., 2012). In Africa and Asia, however, it remains under-utilized and is often regarded as an invasive weed. Studies in these regions of the world show that the possible benefits of the plant have been dramatically outweighed by the

multiple negative impacts associated with its invasion and propose its eradication through possible means. This might be related to the fact that the indigenous knowledge surrounding its wise management and use was not introduced along with the tree and there is lack of appropriate technologies that reduce its spread by increasing its utilization (DFID, 2005).

Despite some speculations on how prosopis is introduced to Ethiopia, precise evidence does not exist. According to Zeraye (2008), however, *Prosopis* was observed in the Middle Awash area of the Afar region in the 1970s. EARO and HDRA (2005) indicated that it was introduced by the Ministry of Agriculture for water and soil conservation and fight against desertification. It was also introduced at similar time in the Ethiopian Somali region, at a nursery near Dire Dawa town (Zeraye, 2008). This was confirmed by Issa clan elders in Shinile woreda (district) of the Siti zone. Since then, prosopis is spreading over the rangelands rapidly while colonizing areas occupied by other plant species in the region. It resulted in massive scales of damage to people's livelihood and destruction of important species in the range.

1.2 Challenges from Prosopis Invasion

In Ethiopia, *Prosopis* has covered an area of one million hectares (MoARD, 2008). The introduction of prosopis in Ethiopia, in general, and in Somali region in, particular, was done without due attention to the invasive nature of the plant. The rapid expansion of prosopis in the pastoral and agro-pastoral regions is significantly affecting rangelands and resources in which people depend largely for their livelihood. Like in the remaining pastoral dry lands in Ethiopia, the tree is spreading, particularly along water courses, posing huge threats to mobile pastoral production systems through blocking access to water points and invading riverine cultivation areas and pasture lands including limiting agro-pastoralists access to traditional irrigable lands. *Prosopis* invasion blocked paths to water points, grazing areas and between villages and served as shelter for predators (Shakeleton et al., 2006; Easther and Brent, 2005; Zeila et al, 2004). This is further worsening the lives of many pastoralist and agro-pastoralist communities along with the recurrent drought due to the impact of El Nino. *Prosopis* expansion,

therefore, is a major challenge for pastoralists in Somali region. It particularly is expanding fast in Korahe zone, Kabridahar district, where the research site is most affected. Its expansion is not well mapped for control and management practices both in Kabridahar and in the region.

2. Material and Methods

2.1 Description of the Study Area

The study was conducted in the Somali Regional State, geographically located in the eastern and south-eastern part of the country. The region is one of the nine administrative regions and the second largest in Ethiopia covering an area of 363,300 km^2. The region has the longest international boundary and it shares border with Djibouti, Somalia and Kenya in the east, north and south, respectively. Within Ethiopia, the Somali region shares borders with Afar and Oromia regions in the northwest and west, respectively and is bounded between the geographical coordinates of 38.758884° East – 47.986780° East longitude and 3.393054° North – 11.226088° North latitude and the elevation ranges between 210 and 2000 m.a.s.l. (see Fig. 1).

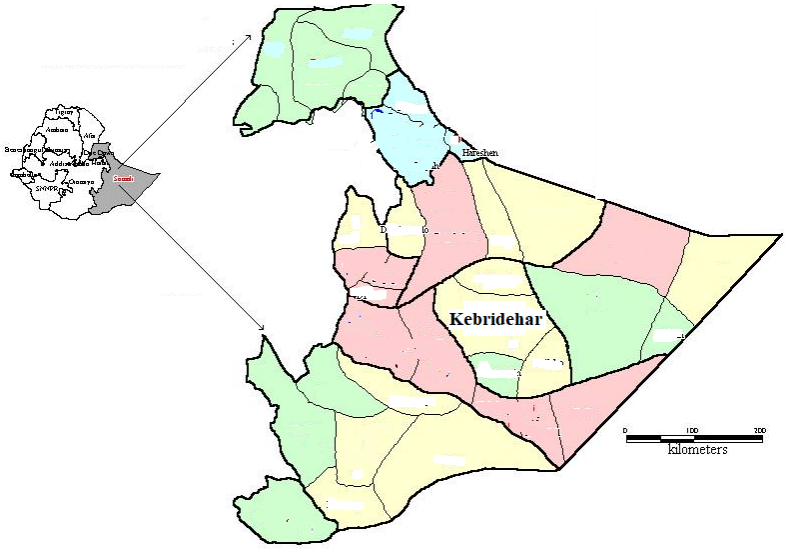

Figure 1. Map of Kabridahar woreda
Source: Modified from http://reliefweb.int/sites/reliefweb.int/files/resources/C34B49E56C9E7265C1256F2D0047FE82-ngo_somali.jpg

Kabridahar district is the specific location where the actual research was conducted (Figure 2.1). Somali region is characterized by two rainy season namely the Deyr (October through December) and Karan (late July up to September).

Somali region is dominated by pastoralist population. There is also significant number of agro-pastoralist population that is dependent on livestock and cultivation of crops for survival. Somali region has 17 rural livelihood zones generically classified as pastoral, agro-pastoral, riverine and sedentary farming. Due to the dominance of pastoralism caused by the suitability for livestock rearing, the major sources of income include live livestock and livestock product sales, crop sales, firewood and charcoal sales, petty trade and remittance from Somali Diaspora. According to the CSA (2007), Korahe zone has a population size of 312, 713 of which 15.2% are urban inhabitants and 47.7% are pastoralists. The Zone hosts 10% of the total livestock population of the region (ESR, 2014)

2.2 Data Collection and Analysis Techniques

2.2.1 Qualitative data collection and sample size determination

Both qualitative and quantitative techniques were employed to collect and analyze data. Qualitative data was collected through the use of Focus Group Discussion and Key Informant Interviews. Quantitative data was obtained by conducting a survey on 315 agro-pastoral households (75 females and 240 male headed) to examine their educational and livelihood background as well as their knowledge of Prosopis management and changes they witnessed over a ten-year time period. Their response on changes in land use-land-cover in Kabridahar woreda was analyzed through descriptive statistics. Knowledge on Prosopis management, changes in land use and land cover made the basis for selection of households and contents of the survey questions. The existing literature debates on the issue of successful selection and meaningful sample-size was reviewed. Sample size determination is an important element in any survey research and it varies for various types of research designs. Accordingly, Yamane (1967:886) provides a simplified formula to calculate sample sizes.

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

Where,

n is the sample size,

N is number of Households in the target kebeles, and

e is the level of precision.

The research adopted Yemane (1967) approach where sample size was calculated from purposefully selected kebeles in Kebridahar woreda. The total population size of the households in the selected kebeles was 1490. At 95% confidence level and e = 0.05,

$$n = \frac{N}{1+N(e)^2}$$

$$n = \frac{1,490\ \text{HHs}}{1+\ 1490\ \text{HHs}\ (0.05)^2} = 315$$

Therefore, 315 households were, therefore, randomly selected from the total population of the Kebeles.

2.2.2 Spatial data collection and analysis

In order to investigate the spatio-temporal land-use and cover change of the woreda, in general, and *Prosopis juliflora,* in particular, land use-land-cover classification was done for the woreda. In doing this, multispectral satellite imagery of Land ETM+ with two different epochs was required. Hence, the researchers have selected land sat ETM+ for 2007and 2017 based on the bench mark assigned by the local communities in Kabridahar. Images were downloaded from USGS and Libra websites and then re-projected to fit with the shape file of the study area, and extraction was made from the large images followed by enhancements such as histogram equalization and haze reduction in order to improve visibility of the downloaded images for further analysis. In addition, unsupervised image classification was conducted prior to the field work to extract information from Land-Sat and understand general land-cover class of the study area. According to the results from unsupervised classification, sample site was selected for data that was collected during field work. Finally, ground truth data were

collected using GPS for different purposes such as for image classification and accuracy assessment. During this time 120 GPS points were collected for the purpose of image classification and 20 GPS points for accuracy assessment.

2.2.3 Accuracy assessment

In order to evaluate the results of the land-use and land-cover classification, ground control points were used and the accuracy assessment was made for the signature value of classified image. The kappa statistics calculation was used to represent the agreement between the classified land-use land-cover and the observed land use.

3. Results and Discussion

3.1. Pastoralist Livelihood and Livestock Production in Kabridahar

Pastoralism is the dominant livelihood in Kabridahar district despite some agro-pastoral practices. This is due to the good rangeland conditions to rear livestock. Particularly the Banka Korahe is a huge plain with a variety of grass species and often used as dry season grazing reserve in times of drought. Large part of the Banka Korahe is a flood recession plain that potentially increases access to water and pasture. According to responses obtained from informants in focus group discussion prosopis covered this huge plain and it was expanding from time to time. The expansion of prosopis took over the rangelands and resulted in loss of local grass species. This caused critical shortage of pasture directly affecting access to livestock fodder mainly to cattle and sheep. Elderly respondents stated that following the invasion of prosopis on the rangelands, access to pasture became very limited thereby triggering mobility to distant places in search for pasture.

Moreover, during the focus group discussion, informants revealed that livestock products, such as milk yield, were highly affected owing to critical shortage of pasture and available browse. Similarly, observations of Esther and Brent (2005) assert this fact. According to them, prosopis thorns usually attack and restrict movement of livestock in prosopis invaded plains. Moreover, prosopis invasion potentially increases the distance livestock travel in search of pasture (Esther and Brent, 2005).

Furthermore, as elders indicated prosopis caused health problems for the livestock. Although livestock feed on the seed pod, consuming much is associated with stomach poisoning due to partial digestion that later may result in death. The elders' explained to have observed this situation causing increased livestock mortality in their area. On the other hand, some other elders pointed out prosopis thorns to have often caused severe damage to livestock particularly to their mouth, teeth and legs. Persistently, the herds are prone to suffer from tetanus and bacterial infections as a result. Similarly, Nakano *et al.* (2003) stated that, 1% of livestock that fed over prosopis seed pods got sick while some others died due to compacted pod balls in their rumen. In addition, Mohammed et al (2017) and Dos Santos et al (2013) stated that the high sugar content of the pods leads to more bacterial infection in the rumen and to death. Its impact can be observed on livestock during feeding. The livestock's neck will get twisted resulting in death cases (Nakano *et al.*, 2003; Shiferaw *et al.*, 2004).

3.3. Land-use Land-cover Changes

Table 2.1 presents the changes in land-use/land-cover from 2007 to 2017. The land invaded by prosopis in 2007 was 60,910 ha. This grew to 90,505 ha in 2017. Similarly, shrub land and wood land coverage increased from 22.7% and 19% in 2007 to 29% and 40.54% in 2017, respectively. In contrast, the amount of grassland and bare land decreased from 45% and 4% in 2007 to 7.7% and 3% in 2017, respectively (Table 1).

Table 1. LULC of 2007 - 2017 expressed in (ha) and percentage

Year	2007		2017	
LULC Type	Area (ha)	%	Area (ha)	%
Wood land *	183,272	19.0	389,941	40.54
Grassland	432,720	45.0	74,566	7.70
*Prosopis juliflora**	60,910	6.3	151,415	15.70
Shrub land *	218,279	22.7	279,387	29.00
Bare land	38,180	4.0	29,290	3.00
Settlement *	28,420	3.0	37,182	4.00
Total	961,781		961,781	

Land-use/land-cover has shown=* continuous increase in area coverage in 2007 - 2017

The land-use/land-cover map produced through supervised classification of the Landsat ETM+, 2007 and 2017 is shown by Figures 2 and 3.

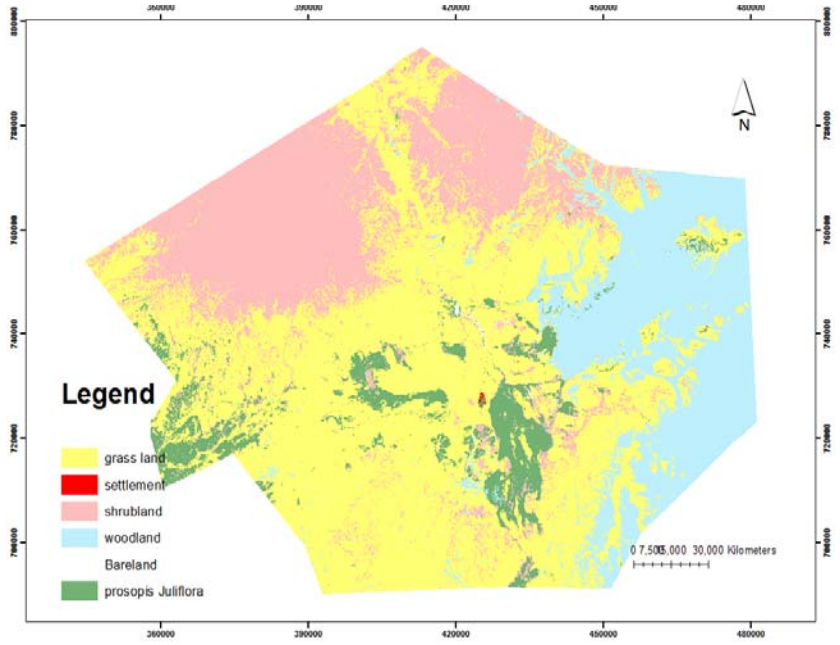

Figure 2. Land Use/Cover Map of 2007

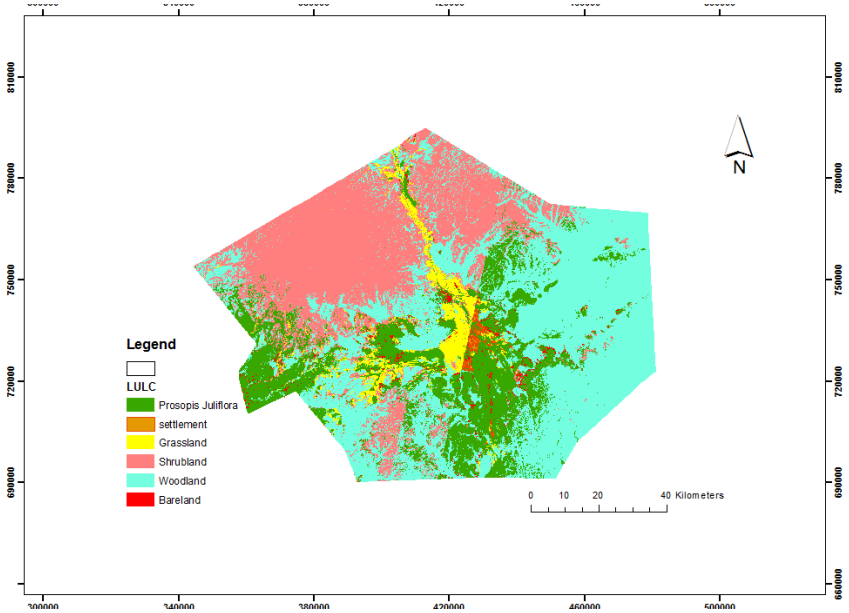

Figure 3. Land Use/Cover Map of 2017

3.4. *Prosopis* Expansion in Kabridahar Woreda

Prosopis heavily expanded in Kabridahar woreda in the last ten years. Expansion happened in multiple ways. The study found out that the main contributors included domestic and wild animals, water in the form of rain through rain (floods, and irrigation channels), vehicles, and careless prosopis clearance. Respondents revealed livestock to be major agents of spread. Seeds excreted by livestock easily germinated and remote road infestations were attributed to livestock and truck movements due to dung being spread as the truck moves. The trucks carry the seeds along with soil and spread it across their routes particularly along main roads. Livestock routes also were found to be major areas and means of infestation. According to key informants, prosopis was seen in Kabridahar in 1987 including five other species and it was planted in the zonal office as an ornamental tree. Later on it appeared in the forefront of the banks of Korahey River where the locals called it *Aftinta.* Gradually it spread all over the banks of the river in Korahey zone and Faafan areas.

3.4.1. *Spatial distribution of prosopis*

Most respondents of both Focus Group Discussion and Key Informant Interviews agreed that prosopis was seen in Kabridahar woreda in 1987 for the first time and it was intentionally introduced for urban beautification purposes. This was 17 years after its introduction in the country, specifically in the Afar region, in the 1970s. The Ministry of Agriculture brought it from India in an effort to improve water and soil conservation and fight desertification (EARO and HDRA, 2005). People in the woreda became familiar with the tree starting from 2000 onwards.

3.4.2. *Spatial Distribution of Prosopis in 2007*

The 2007 classified map (Figure 2) clearly shows that prosopis invaded about 60,910 ha in the central and southern part of Kabridahar woreda. The former is fertile land where sediment from Jarar and Fafan valley deposits. In 2007, the study area had grass land coverage of 45%, which was nearly half the cover the study area followed by shrub land (22.7%), woodland (19%), prosopis (6.3%), *bare* land (4%) and settlement (3%). *Prosopis* was

the fourth largest in terms of land coverage taking the fertile part of the woreda (Figure 2 and Table 2).

3.4.3. *Spatial Distribution of Prosopis in 2017*

The land-use/land-cover map of 2017 (Figure 2) shows the extent of area invaded by prosopis over a decade. The central and southern part of the woreda was invaded by prosopis. Table 2 presents coverage of different land uses over the decade.

Table 2. Rate of Change of LU\ LC from 2007 to 2017

Year LU/LC List	2007	2017	Change between 2007 and 2017		Annual rate of change in hectare
	Ha	Ha	Area (ha)	%	
Wood land *	183,272	389,941	206,669	21.49	2,066.9
Grassland	432,720	74,566	-358,154	-37.24	35,815.4
*P. juliflora**	60,910	151,415	90,505	9.41	9,050.5
Shrub land *	218,279	279,387	61,108	6.35	6,110.8
Bare land	38,180	29,290	-8,890	0.92	889
Settlement *	28,420	37,182	-8,762	0.910	876.2
Total	961,781	961,781			

*Continuous increase in area coverage between 2007 and 2017

The land invaded by prosopis in *2017* was 151,415 ha which is 15% of the total land area and prosopis invaded land increased by more than double in coverage as compared to that in 2007. Over the years, prosopis continued invading fertile lands of central and southern part of Kabridahar that previously were grassland. Key informants in the woreda associated the invasion of prosopis with the loss of important local grasses like *Dikil, Garawle, Kunde, Harfo, Hubno Ase, Jarbi* and *Naaseye* and trees/shrubs such as *Gob, Mara, Iriir Maded* and *Dur* on which livestock used to feed.

3.5. Temporal Distribution of Prosopis

Prosopis has been continuously spreading to a larger extent in the woreda since 2007 (Table 3). The land under *Prosopis* was 60,910 ha (6.3%) of the total land area in 2007 and grew to 151,415 ha (15%) of the total land area in 2017. Between 2007 and 2017, the land under Prosopis coverage increases by 9,505 ha per year.

Accuracy assessment

The confusion matrix developed for accuracy assessment (Table 3) indicates the overall accuracy and overall kappa coefficient to be 83.3% and 77.6%, respectively. This falls under very good classification status of 70 - 85% (Mensorud, 2002 cited in Moges *et al.,* 2015).

Table 3. Confusion matrix for 2007 LULC of the study area

	Ground Truth (%)					
Settlement	Settlement	Bareland	Grassland	Shrubland	Woodland	Prosopis
Settlement	100.00	0.00	0.00	0.00	0.00	0.00
Bare land	0.00	33.33	0.00	0.00	0.00	0.00
Grass land	0.00	0.00	71.43	0.00	0.00	0.00
Shrub land	0.00	0.00	0.00	91.66	0.00	0.00
Wood land	0.00	0.00	0.00	0.00	83.33	0.00
Prosopis	0.00	0.00	0.00	0.00	0.00	83.33
Total	100.00	33.33	71.43	91.66	83.33	83.33

Accuracy Assessment Matrix for 2017
Overall Accuracy = 83.33%
Kappa Coefficient = 77.63 %

Seeds are deposited on banks of the rivers and in the fields. This is a major cause of prosopis expansion along riverbanks. The lack of information about how best to control invasion of prosopis also contributed to its expansion.

3.6. Household Survey Results

3.6.1. Education

According to the survey results, the total respondents of the research were 315 households. Of these, 75 households (23.8%) were female headed while 240 households (76.2%) were male headed. The average age of the respondents was 47 years. The oldest and the youngest respondents were 87 and 19 years old, respectively. The average family size of the respondents' household is matched with that of Somali region and it was 6.7. Family size of respondents ranged from three to 11 members. Of the respondents, 55.6% could not read or write; 34.6% were able to read and write; only 9.8% attended primary school and none of them attended tertiary level.

3.6.2. Cultivated land and Livestock Ownership (TLU)

Cultivated land of the surveyed households was also an important variable in the study. The result indicated that, nearly 9.2% of the households do not own cultivated land; 20.3% of them have less than one hectare; 30.2% have approximately one hectare; and 40.3% have more than one hectare of cultivated land. For most households who owned land, scarcity was not reported as a serious challenge. However, protection of the existing land from *Prosopis* invasion through the application of appropriate control and management mechanisms was believed to be crucial. However, water availability, especially underground water, was reported to have reduced. Changes in the quality and taste of water were reported by respondents. Cultivation is supported by livestock husbandry. Only 5.1% of the households reported to have no ownership of livestock; 40.3% of the respondents owned less than 10 TLU; 34.9% of them owned between 10-20 TLU; and 19.7% owned more than 50 TLU. Hence, livestock is the major determinant of the livelihood in the study area. A significant percentage of the respondents owned TLU greater than 50 which implied the need for extensive grazing land.

However, trends in prosopis invasion (Figures 1, 2 and Tables 1 and 2) indicated a growing concern through reductions in the size of available grazing land. According to respondents, over the years, livestock pasture reduced and livestock diseases increased resulting in heavy livestock loss and the role of prosopis was mentioned as host to livestock disease vectors. The tree was also reported to have blocked livestock routes and rural roads creating inconveniences to get an access to grasslands and water points. The study of Derege *et al.* (2019) in Harshin woreda of Somali region recommended the need to integrate emerging trends of protecting grazing lands through rangeland closures which proved successful drought coping mechanisms by contributing to feed security.

3.6.3. People's knowledge of Prosopis and the magnitude of its expansion

Knowledge of the history of prosopis invasion contributes to the designing of proper control and management practices. Therefore, the respondents were asked about their knowledge of prosopis invasion in their localities. The result revealed that, 49.5% of them had been observing the invasion

since the past 10 years; 40.3% of them experienced it between the past 11 to 20 years. The remaining 10.2% indicated that the invasion started 20 years ago. People had locally named the tree as "*Kaligii Noolaade*" and "*Garanwaa*" which translates into "Living Alone" and "Unknown", respectively. The study on the magnitude of the expansion of prosopis indicated that, to 65.1% of the respondents, the magnitude of expansion was severe within the past 20 years. About 25% believed that the highest expansion occurred in the last 10 years. Only 5.1% of the surveyed households stated that it had expanded within the past 30 years. Another 5.1% indicated that expansion to have occurred since 30 years ago.

3.6.4. Application of control and management mechanisms

People responded to challenges from prosopis in many different ways to sustain their regular lifestyles. The study revealed that 75% of the respondents indicated that they did not apply any control mechanisms to protect their cultivated and rangelands from prosopis invasion. Only 25.1% of them applied control mechanisms. Managing land that was invaded by prosopis was necessary to minimize its expansion and the side effects that followed. However, 54.3% of the respondents mentioned that they did not apply any management practice, while 45.7% indicated that they applied different traditional management practices. This shows the need for the adoption of management practices and strategies to control prosopis expansion.

3.6.5. Impact of Prosopis on livelihoods

Prosopis has an impact on areas it invades. However, the type and magnitude differs based on the different agro-ecologies. In dry land pastoral areas like Kabridahar, prosopis heavily affected their livelihoods in different ways with different dimensions. The harmful aspect of prosopis was stated by 78.1% of the respondents who clearly stated that prosopis was invasive, harmful and devastating to their livelihoods. They found the tree to have both negative and positive effects on the livelihood of the invaded community and it deteriorated the rangeland quality. Positive contributions include use of the tree during charcoal making and fencing purposes. The remaining 17.1% of them indicated that prosopis exhibited both harmful and useful aspects. Major impact experienced by people in Kabridahar was

invasion of cultivated land that led pastoralists and agro-pastoralist to poor harvest and food insecurity. Some 4.8% of the respondents reported prosopis to have no impacts on their livelihood. None of the respondents, however, stated about particular benefits to their livelihoods. Eighteen years ago, for example, cultivators in Meraato area in Kabridahar used to produce sorghum and maize and export the surplus to Somaliland and Punt land. Today nearly half the population depends on food aid.

4. Conclusion

In a nutshell, the livelihood of people in the area was challenged by the invasion of *Prosopis juliflora*. The significant reduction in the size of grasslands and increase in the coverage of areas invaded by prosopis and shrubs is a very good indication of such a challenge.

Recommendation

It is evident from the results of this research that the community alone was not able to deal with the impact of the tree on local livelihoods. Such an impact was felt to the extent of leaving productive livelihoods to a complete dependence on food aid interventions. This requires a concerted scientific effort to control the rapid expansion of the invasive tree in the area and put in place management practices on the useful aspects of the tree. With careful attention and planning, prosopis spread can be managed. A careful examination into the different expansion mechanisms is required to design appropriate control and management interventions as very few people in Kabridahar apply control mechanisms.

References

Catterson, T. 2003. USAID strategic integrated plan in the Sudan, 2003-2005environmental threats and opportunities assessment. Washington: USAID/REDSO/NPS and the USAID Sudan Task Force.

Central Statistical Agency (CSA). 2007. Population and Housing Census of Ethiopia-National Statistical Summary Report, Addis Ababa.

D'Antonio, C.M. and Kark, S. 2002. Impacts and extent of biotic invasions in terrestrial ecosystems. *Trends in ecology and Evolution, 17, 202-204.*

Derege Tsegaye, Muhyadin Moahmmed and Dahir Yosuf. 2019. Estimating carrying capacity and stocking rates of rangelands in Harshin District, Eastern Somali Region, Ethiopia. *Ecology and Evolution, 9:13309–13319.*

DFID. 2005. Reducing poverty by tackling social exclusion. *A DFID policy paper*. UK.

Dos Santos, E. T., Pereira, M. L., da Silva, C. F., Souza-Neta, L. C., Geris, R., Martins, D., Santana, A.E., Barbosa, L. C., Silva, H. G., Freitas, G. C., Figueiredo, M. P., de Oliveira, F. F., and Batista, R. 2013. Antibacterial activity of the alkaloid-enriched extract from *Prosopis juliflora* pods and its influence on in vitro ruminal digestion. *International journal of molecular sciences*, 14(4): 8496–8516.

EARO and HDRA. 2005. Controlling the spread of *Prosopis* in Ethiopia by its utilization. Addis Ababa, Ethiopia.

ESR. 2014. Bureau of Finance and Economic Development Report. Ethiopian Somali Regional, Jigjiga.

Esther, M., and Brent, S., 2005. Invasion of *Prosopis juliflora* and local livelihoods: Case study from the lake Baringo area of Kenya. ICRAF Working Paper – no.3. Nairobi: World Agro forestry Centre.

Gavali, D.J., Lakhmapurkar, J.J., Wangikar UK, Newsletter DS. 2003. The impact of Prosopis juliflora invasion on biodiversity and livelihood on the Banni grassland of Kachchh. *Gujarat Ecology Society,* No. 48. Synergy House, Gujarat, India.

Manchester S.J. and Bullok, J.M. 2000. The impacts of non-native species on UK biodiversity and the effectiveness of control. *Journal of Applied Ecology*, 37(5):845 - 864

MoARD. 2008. Relief interventions in pastoralist areas. Ministry of Agriculture and Rural Development of Ethiopia, Addis Ababa.

Moges Kidane, Amare Swenet and Alemu Bezie. 2015. Multi temporal land-use land-cover change and dynamics of Blue Nile basin by using GIS and Remote sensing techniques, North-western Ethiopia. *International Journal of Environmental Sciences*, Vol.4 (2): 81- 88.

Mohammed Mussa, Abdulkerim Ute and Tefera Regasa. 2017. *Prosopis juliflora* L: Distribution, impacts and available control methods in Ethiopia. *Tropical and Subtropical Agroecosystems,* 20(1):75-89.

Nakano, H., Nakajima, E., Yoshiharu, F., Yamada, K., Shigemori, H., and Hasegawa, K. 2003. Leaching of the allelophatic substance, L-tryptophan

from the foliage of mesquite (*Prosopis juliflora*) plants by water spraying. Plant Growth Regulation, 40(1): 49-52.

Saxena, N.C. 1997. The saga of participatory forest management in India. CIFOR Special Publication. Indonesia.

Shackleton, C.M., McGarrt, D., Gambiza, J., Shackleton, S.E., and Fabricius, C. 2006. Assessing the effect of invasive alien species on rural livelihoods: Case examples and a framework from South Africa. *Human Ecology*, 35:112-127.

Shiferaw Hailu, Teketay Demel, Nemomissa Sileshi, and Assefa Fassil. 2004. Some biological Characteristics that foster the invasion of *Prosopis juliflora* (Sw.) DC at Middle Awash Rift Valley Area, north-eastern Ethiopia. *Journal of Arid Environments, 58: 135 –154.*

Stefen, A. 2005. Spread of the introduced tree species *Prosopis juliflora* (Sw.) DC in the lake Baringoarea, Kenya.

Vallejo, V.E, Arbeli, Z., Teran, W., Lorenz, N., Dick, R.B. 2012. Effect of land management *and Prosopis juliflora* (Sw.) DC trees on soil microbial community and enzymatic activities in intensive silvopastoral systems of Colombia. *Agriculture, Ecosystems and Environment*, 150: 139–148.

Yamane, T. 1967. Statistics: An Introductory Analysis, 2nd edition. New York: Harper and Row.

Zeraye Mehari. 2008. Invasion of *Prosopis juliflora* (SW). DC and Rural livelihoods. The case of Afar pastoralists at Middle Awash Area of Ethiopia. Department of International Environment and Development Studies (Noragric). Norwegian University of Life Sciences.

Zeila, A., Mwangi, E., and Swallow, B. 2004. *Prosopis juliflora*: Boon or Bane for dryland Agroforestry? The Prunus Tribune, Jan-March 2004 edition. Nairobi: World Agroforestry Center.