IMPACT OF *Acacia drepanolobium* (AN INVASIVE WOODY SPECIES) ON GUM-RESIN RESOURCES AND LOCAL LIVELIHOOD IN BORANA, SOUTHERN ETHIOPIA

[IMPACTO DE *Acacia drepanolobium* (UNA ESPECIE LEÑOSA ÍNDIGENA INVASORA) SOBRE LOS RECURSOS DE GOMA-RESINA Y ESTRATEGIAS DE VIDA LOCAL EN BORANA, SURESTE DE ETIOPÍA]

B. Terefe[a], M. Limenih[b], A. Gure[b], A. Angassa[c,d*]

[a]Samara University, Ethiopia,
[b]Wondo Genet College of Forestry and Natural Resource Management, Hawassa University
[c]Department of Animal and Range Sciences, Hawassa University, [d]Botanical Institute, University of Cologne
E-mail: ayanaangassa@yahoo.com
**Corresponding Author*

SUMMARY

We investigated the impact of *Acacia drepanolobium*, a species threatening rangeland resources including Gum-resin production and pastoralists' livelihoods in Borana. Data were collected through vegetation surveys, key informant interviews, use of formal questionnaires and focus group discussions. We found a total of 22 woody species in the study area. *A. drepanolobium* was found to be the most dominant (22%) and abundant (65%) invasive woody species with an importance value index (IVI) of 103. According to our respondents, *A. drepanolobium* was the first widely expanded woody species followed by *Dichrostachys cinerea* and *A. mellifera.* Eighty seven percent of our respondents ranked *A. drepanolobium* as the most invading woody species during their life time. Overall, our results demonstrated that the impact of *A. drepanolobium* had greatly affected the condition of rangeland vegetation. The implication is that the reduction in the capacity of rangelands for livestock grazing could reduce the resilience of local livelihood under changing environmental conditions. Furthermore, pastoralists' perception indicated that the expansion of *A. drepanolobium* had reduced the survival of Gum-resin producing species. Generally, the shift from cattle based pastoral economy to mixed livestock types could be attributed to the expansion of *A. drepanolobium* that forced the community to shift their mode of production. We confirmed that *A. drepanolobium* is an invasive indigenous woody species with multiple effects on the ecology of rangelands and on the livelihood security of pastoral communities.

Keywords*: Acacia drepanolobium;* Borana; Bush encroachment; Importance value index; Invasiveness; Livelihood security; Rangeland ecology.

RESUMEN

Se investigó el impacto de *Acacia drepanolobium*, una especie que amenaza los recursos disponibles en los agostaderos, incluyendo la producción de goma-resina y las formas de vida pastoralista tradicional en Borana. Se colectó información mediante muestreos de vegetación, cuestionarios, entrevistas a informantes clave y grupos focales de discusión. Se encontró que de un total de 22 leñosas en el área de estudio *A. drepanolobium* fue la especie dominante (22%) y abundante (65%) con un índice de valor de importancia de 103. De acuerdo a los resultados, *A. drepanolobium* es la leñosa con mayor expansión seguida de *D. cinerea* y *A. mellifera.* Ochenta y siete por ciento de los encuestados calificaron *A. drepanolobium* como la especie más invasiva durante su tiempo de vida. En general, los resultados muestran que *A. drepanolobium* ha tenido un gran efecto sobre l vegetación del agostadero. La implicación es una reducción en la capacidad de los agostadores para pastoreo y pudiera reducir la capacidad de respuesta de las formas de vida a los cambios ambientales. Más aún la precepción de los grupos pastorales indica que la expansión de *A. drepanolobium* ha reducido la sobrevivencia de especies productoras de goma-resina. Generalmente, el cambio de un sistema de ganadería pastoral a un sistema mixto pudiera ser atribuido a la expansión de *A. drepanolobium.* Se confirmó que *A. drepanolobium* es una invasora nativa con múltiples efectos en la ecología de los agostaderos y las formas de vida de las comunidades pastoralistas.

Palabras clave: *Acacia drepanolobium;* Borana; índice de valor; índice de importancia; invasividad; agostadero; medios de subsistencia.

INTRODUCTION

The spread of invasive woody plants is a common phenomenon in arid and semi-arid regions worldwide. In arid and semi-arid rangelands bush encroachment is considered as a major bottleneck for the survival of pastoral production and the conservation of biodiversity. The incursion of bush encroachment in savanna rangelands is usually triggered by the suppression of fire (Oba et al., 2000), heavy grazing pressure (Coppock, 1994) and anthropogenic factors (Angassa and Oba, 2008a, 2009). In parts of East African rangelands, large numbers of invasive woody plants were identified (Tamene, 1990; Coppock, 1994; Oba et al., 2000; Angassa and Baars, 2000).

Similarly, extensive areas of the Borana rangelands of southern Ethiopia have already been encroached by native woody species (Tamene, 1990; Coppock, 1994; Angassa and Oba, 2008b), which dramatically affected the structure and function of rangeland ecosystems with implication on local livelihood systems. Previous studies (e.g. Hogg, 1997; Oba, 1998; Oba et al., 2000; Gemedo et al., 2006; Angassa and Oba, 2008b, 2009) have shown that the grazing capacity of arid and semi-arid rangelands has significantly diminished in terms of sustainable forage production for grazers that supported local livelihood for centuries. Others (e.g. Primental *et al*., 2000; Wittenberg and Coke, 2001; Stohlgren, 2002; Tesfaye, 2002) have also argued that the expansion of invasive woody plants have already affected the productivity of economically important woody species, especially Gum-resin resources (Limenih, 2005).

In the Borana rangelands of southern Ethiopia, the proliferation of indigenous invasive woody species has been widespread since the last four decades threatening the cattle based pastoral economy and the livelihood security of most inhabitants. Generally, many invasive woody species have been documented in the southern rangelands of Ethiopia (Assefa et al., 1986; Tamene, 1990; Coppock, 1994; Oba et al., 2000; Gemedo et al., 2006; Angassa and Oba, 2008b). According to Tamene (1990), most invading woody species are thorny plants, particularly the Genus *Acacia*. *Acacia drepanolobium*, commonly known as a whisthing thorny plant (family Fabaceae) is one of the indigenous species widely distributed in the Borana rangelands. The species is believed to be native to northeast tropical Africa including Ethiopia and other East and central African regions (USDA, ARS, National Genetic Resources Program, 2008 and ILDIS, 2008). However, the species for several reasons is notoriously invading the Borana rangelands and emerging as an indigenous invasive woody plant in the southern region of Ethiopia (Tamene, 1990; Coppock, 1994).

Another peculiar feature of *A. drepanolobium* is its association with populations of symbiotic ants (Young et al., 1997; Young and Okello, 1998), with several impacts on the ecology of grazing (Oba, 1998). On the contrary, earlier evidence (e.g. Okello et al., 2001) has also shown that *A. drepanolobium* might be used for charcoal making and as feed for some browsers. Furthermore, Limenih (2005) has reported that its Gum could be collected and traded as Gum Arabic for income generation by pastoral households.

Generally, it is argued that a ban on the use of traditional range fire is probably one of the reasons for the expansion of bush encroachment at the expense of important rangeland species and human livelihood (Coppock, 1994; Oba, 1998; Oba et al., 2000). Most threatened plant species have significant values as human food, for medicinal purposes, feed for animal, construction materials, Gum-resin sources and/or are useful for other cultural purposes (Coppock, 1994). According to Gemedo *et al.* (2005), Gum-resin bearing species are among the predominant components of rangeland resources in Borana. However, the influence of *Acacia drepanolobium* on rangeland resources and useful woody species has been rarely investigated. Due to its potential impact on the resilience of rangeland resources, conservation of biodiversity and local livelihood security, understanding these multiple impacts of *Acacia drepanolobium* is a priority. Thus, this paper attempts to address the invasiveness of *A. drepanolobium* and its impact on rangeland resources and local livelihood. Therefore, our objectives were: (1) Assessing the impact of *A. drepanolobium* on rangeland Gum yielding species and livelihoods of pastoral communities in Borana; (2) Understanding herders' perception about the characteristics of *A. drepanolobium* in Borana*;* and (3) Understanding the role of traditional management in preventing impacts of *A. drepanolobium* on Gum yielding species and other rangeland resources.

MATERIAL AND METHODS

Study area

The study was conducted in the districts of Arero, Dirre and Yabello in the Borana rangelands of southern Ethiopia. The Borana rangelands cover a total area of approximately 95,000 square kilometer (Coppock, 1994). The northern parts of the Borana rangeland is bordered by Jemjem high forest landscape with a combination of Arsi and Guji Oromo land use systems. The southeastern and south limit of the Borana rangeland extends to the Ethio-Somalia and Ethio-Kenya borders, respectively (Figure 1). Generally, the elevation of the Borana rangelands is within the range of 1000 - 1500 meter above sea level with few hills up to 2000 m.a.s.l. (Coppock, 1994).

The Borana rangeland is characterized by arid to semi-arid climate with extreme inter-annual rainfall variability (Coppok, 1994). The mean annual rainfall is about 500 mm (Angassa and Oba, 2007). The rainfall is bimodal with long rains (*ganna*) that occurs between March and May and the short rains (*hagayya)* usually between September and October. The long rains account for 60% of the total annual rainfall, while the short rains contribute about 30% (Coppock, 1994). Pastoralists state that about 10% of the total rainfall is expected from the occasional rains termed as *furmaata*, which offer irregular relief by interrupting the dry season stress on human and livestock populations. The mean annual temperature is about 24 ºC with a mean maximum of 28 ºC and mean minimum of 17 ºC (Adefris, 2006).

The inhabitants of Borana are estimated at 966,467 (CSA, 2008). The Borana Oromo are numerically the dominant ethnic group inhabiting the lowlands of Borana, and are predominatly pastoralists. Their economy is mainly based on cattle herding (Oba, 1998; Gemedo et al., 2005). The vegetation is tropical savanna with varying proportions of open grassland, and perennial herbaceous and woody vegetation (Pratt and Gwynne, 1977). The Borana rangeland also has stretches of *Acacia-Commiphora* small-leaved deciduous woodlands, with a mixture of the genera *Acacia, Boswellia* and *Commiphora*. Other important genera include *Boscia, Maerua, Lannea, Balanites* and *Aloe* (Coppock, 1993; Gemedo et al., 2005; Adefris, 2006).

Methods of data collection

Initially, a reconnaissance survey was conducted and contacts with the local leaders and development agents (DAs) were established. Both vegetation and socio-economic data were collected to capture important information in order to address the specific objectives of the study. Then, we established a total of 50 circular sampling plots of 500 m^2 (radius 12.56 m) to gather data on vegetation variables (Limenih et al., 2003). We excluded villages and agricultural lands from sampling. Sampling plots were systematically placed along eight transect lines running parallel on both sides of the high way between Yabello and Maga towns, a gravel road between Yabello and Arero, as well as from Mega to Wachile. The distance between roads and transect lines was 2.5 km, while the distance between sample plots was 7 km. All woody individuals within each plot were counted, and their species was recorded. Diameters at breast height (dbh) of tree individuals ≥ 5 cm were recorded. Local names of species were recorded with the assistance of local key informants. Based on the local names of species, corresponding scientific names were obtained with the aid of taxonomic publications (Bekele, 2007; Kelecha, 1987; Edwards et al., 1995; Hedberg and Edwards, 1989).

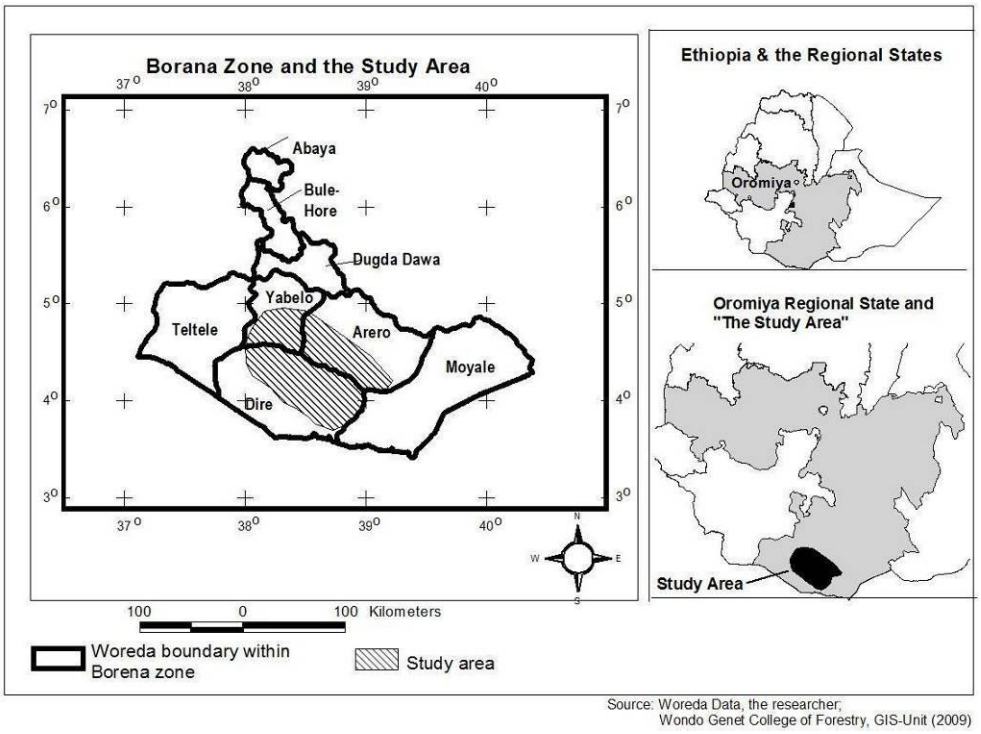

Figure 1. Map of the study area in Borana, southern Ethiopia.

The socio-economic data were collected using a structured questionnaire survey with 215 households encountered on the transect lines of the vegetation study. The questionnaire was translated into *Afaan Oromo*, the Oromo language, pre-tested and adjusted subsequently. Then, ten trained enumerators were used to conduct the socio-economic survey with close supervision of the principal investigator. Special attention was given to capturing information on the impact of *A. drepanolobium* on rangeland resources, as well as on local livelihood systems. Furthermore, key informant interviews, focus group discussions and personal observations were used to gain an in-depth understanding of specific conditions related to the species. Knowledgeable key informants were selected with the help of DAs and PA administrators. These informants were mainly elderly men, women, religious leaders and opinion makers in the community especially of the Abba Gada (Legesse, 1973, 2000; Watson, 2003). Additionally, an interview with 27 individuals involving DAs, PA administrators and experts from Yabello Pastoral Development office was conducted. Furthermore, a total of seven focus group discussions (FGD) each comprising 5 to 7 participants was undertaken, while FGD's participants included: Abbaa Gada, DAs, development experts and knowledgeable community representatives (Watson, 2003). We used checklists with important topics to facilitate discussion during key informant interviews and focus group discussions.

Data analysis

Data were analyzed by various techniques. Qualitative data obtained through key informant interviews and focus group discussions were summarized and analyzed using a Statistical Package for Social Sciences (SPSS) version 15.0 for windows. The quantitative data were analyzed using MINITAB version 13. The importance value index (IVI) that indicates the importance of species in an ecosystem was calculated as follows (Kent and Coker, 1992):

$$\text{Relative density} = \frac{\text{Number of individuals of species}}{\text{Total number of individuals}} \times 100$$

$$\text{Relative dominance} = \frac{\text{*Dominance of species}}{\text{Total dominance of all species}} \times 100$$

$$\text{Relative Frequency} = \frac{\text{Frequency of species}}{\text{Frequency of all species}} \times 100$$

*Dominance is defined as the mean basal area per tree times the number of species.

The importance value index for each woody species is the sum of its relative abundance, relative dominance and relative frequency was used to evaluate the importance of woody species. The information collected through vegetation surveys was analyzed using MINITAB version 13. The invasive woody species ratio (IWSR) was computed to assess whether *A. drepanolobium* is an invasive species or not. The ratio is defined as the density of species regarded as invasive divided by others regarded as non-invasive (i.e. a ratio of > 1.0 is an indication of a high invasive threat, while < 1.0 represents a lesser threat of encroachment) (Angassa and Oba, 2008a).

RESULTS

Vegetation composition

We recorded a total of 22 woody species belonging to five families (i.e. Fabaceae, Burseraceae, Tiliaceae, Balantaceae and Ebenaceae, Table 1). Our results showed that *Acacia drepanolobium* was the most dominant (22%) and abundant (65%) invasive woody species followed by non-invasive species such as *Acacia nilotica* and *Acacia tortilis* in the study area (Table 1, see also Figures 2 and 3). Results also indicate that *A. drepanolobium* was the most frequently recorded woody species in almost all sampled plots, i.e., in 48 plots out of a total 50 (Table 1). In terms of the importance value index (IVI), *A. drepanolobium* was the most important invasive woody species accounting for 103% (Table 1). It was followed by *A. nilotica* (33%), *Dichrostachys cinerea* (23%), *A. mellifera* (20%), *Lannea triphylla* (15.4%), *A. tortilis* (15.11%), *Commiphora africana* (13.02%), *A. seyal* (12.21%), *Commiphora ogadensis* (12.10%) and *A. bussei* (11%) (Table 1). Seedlings and saplings of *A. drepanolobium* were the highest (96%) species recorded in the majority of our sampling plots. The results of the present study indicated that 10% of the total sampled area was occupied by *A. drepanolobium.* For instance, seedlings and saplings of *A. drepanolobium* accounted for 69% (i.e. 2005 individuals per hectare) as compared to seedlings and saplings of all other species, which accounted for 31%. Furthermore, our results showed higher IWSR (3.02) for *A. drepanolobium* when compared to other species (Table 2).

Perceived trends of species composition and change

Respondents perceived that as *A. drepanolobium* advanced in abundance, important rangeland species declined over time (Table 3). Our respondents emphasized that although *A. drepanolobium* was the dominant species, *D. cinerea* and *A. mellifera* were also increasing in abundance next to *A. drepanolobium* (Tables 1 and 3). The majority of respondents (62%) ranked *D. cinerea* as the second most expanding woody species in the study area. Respondents ranked *A. mellifera* as the third invasive woody plant. Participants from group discussions attributed a decline in important rangeland condition to the

expansion of *A. drepanolobium*. Our respondents emphasized that fire was used to be a key tool in the management of invasive woody species. The use of fire in rangeland management was prohibited by the former military government and local administrators. The suppression of range fire was perceived to give *A. drepanolobium* and other invasive species to expand at the expense of valuable species.

Pastoralists' perception on the characteristics of *A. drepanolobium*

Almost all respondents characterized *A. drepanolobium* as the most invading woody species in the study area. About 96.3% of our respondents believed that the invasion of *A. drepanolobium* was mainly facilitated through seed dispersal although the species could have multiple dispersal mechanisms (Oba et al., 2000). Respondents conceived animals (i.e. grazers and browsers), water and wind as major dispersal agents in disseminating seeds of *A. drepanolobium*. Pods of *A. drepanolobium* were considered by few respondents as suitable feed for goats, camels, and other animals during dry season. The majority of respondents did not generally consider *A. drepanolobium* as important livestock feed even in times of drought. *A. drepanolobium* was perceived to have a high regeneration potential in terms of coppicing ability following fire and cutting. It was reported that *A. drepanolobium* was mainly expanding in the bottomland areas in association with high silt deposition. Overall, respondents' opinion showed that *A. drepanolobium* is a typical invasive plant (see Table 3).

Impact on the rangeland resources

Respondents perceived that *A. drepanolobium* greatly affected key forage species and pasture condition. Pastoralists were concerned that such a threat had not only affected pastoral production and local livelihood security, but also had consequences on rangeland biodiversity (Table 3). Respondents mentioned that without grasses it was impossible for them to own cattle and that survival was entirely dependent on livestock production. Generally, our results showed that the impact of *A. drepanolobium* had forced local communities to change their lifestyle in terms of livestock type and herd size, which subsequently influenced milk production and local livelihood systems.

Table 1. List of woody plant species, their family, and their relative frequency (Freq.) and relative dominance (Dom.), as well as their absolute and relative abundance (Abun.), their Importance value index (IVI) and their respective ranks (Rank) on vegetation plots in Borana, Ethiopia

Species	Family	Relative Freq. [%]	Relative Dom. [%]	Abun. [indiv. ha^{-1}]	Relative Abun. [%]	IVI	Rank
Acacia bussei	Fabaceae	5.69	4.05	18	1.21	10.95	10
Acacia drepanolobium	Fabaceae	17.08	21.88	941	64.48	103.44	1
Acacia mellifera	Fabaceae	12.46	3.84	55	3.73	20.03	4
Acacia nilotica	Fabaceae	9.96	21.05	35	2.39	33.40	2
Acacia senegal	Fabaceae	1.78	0.59	18	1.21	3.58	16
Acacia seyal	Fabaceae	4.27	5.75	32	2.19	12.21	8
Acacia tortilis	Fabaceae	3.56	9.63	28	1.92	15.11	6
Commiphora ogadensis	Burseraceae	2.85	7.47	26	1.78	12.10	9
Commiphora confusa	Burseraceae	1.42	0.18	16	1.10	2.70	20
Commiphora schimperi	Burseraceae	1.42	0.05	16	1.04	2.52	21
*Andara***	unidentified	1.42	0.49	17	1.12	3.04	19
Balanites aegyptiaca	Balanitaceae	2.14	0.59	18	1.21	3.93	14
Boswellia neglecta	Burseraceae	2.85	1.34	22	1.48	5.67	11
Commiphora africana	Burseraceae	6.41	4.69	28	1.92	13.02	7
Commiphora habessinica	Burseraceae	2.85	0.85	20	1.34	5.04	12
Dichrostachys cinerea	Fabaceae	12.81	5.78	66	4.50	23.09	3
Euclea racemosa	Ebenaceae	1.42	0.6	21	1.43	3.45	18
Commiphora erythraea	Burseraceae	1.42	1.1	19	1.29	3.81	17
Grewia bicolor	Tiliaceae	2.14	1.1	18	1.23	4.47	13
Commiphora fluviflora	Burseraceae	1.78	0.7	20	1.34	3.82	15
Lannea triphylla	Burseraceae	5.34	7.96	30	2.06	15.36	5
Erythrina brucei	Fabaceae	1.42	0.33	1	0.03	1.78	22
Total			100.02	1465	100.00	300.02	

**Local name

Impact of *A. drepanolobium* on Gum-resin and incense trees

Our respondents reported that economically important woody species were declining due to the impact of *A. drepanolobium*. For example, respondents attributed the decline in *A. nilotica* to the invasiveness of *A. drepanolobium***.** Similarly, respondents indicated that *Lannea triphylla*, a key plant species in terms of its medicinal value for humans and cattle had declined due to the spread of *A. drepanolobium*. Overall, as reported by our respondents many other useful Gum-resin and incense producing species such as *Boswellia neglecta* and *Commiphora* species were adversely affected by the expansion of *A. drepanolobium.* Respondents claimed that *A. drepanolobium* was mostly expanding in areas where soil moisture was relatively high.

Table 2**.** Woody species, their invasiveness (Type), and their Invasive Woody Species Ratio (IWSR) in Borana rangelands, southern Ethiopia

Species	Type	IWSR
Acacia bussei	I	0.06
Acacia drepanolobium	I	3.02
Acacia mellifera	I	0.18
Acacia nilotica	NI	0.03
Acacia senegal	NI	0.02
Acacia seyal	I	0.11
Acacia tortilis	NI	0.02
Commiphora ogadensis	NI	0.02
Commiphora confusa	NI	0.01
Commiphora schimperi	NI	0.01
*Andara***	NI	0.01
Balanites aegyptiaca	NI	0.02
Boswellia neglecta	NI	0.02
Commiphora africana	NI	0.02
Commiphora habessinica	I	0.07
Dichrostachys cinerea	I	0.21
Euclea racemosa	NI	0.02
Commiphora erythraea	NI	0.02
Grewia bicolor	NI	0.02
Commiphora fluviflora	I	0.06
Lannea triphylla	NI	0.03
Erythrina brucei	NI	0.001
Total		

** Local name; I= invasive species, NI= non-invasive species; note: categorization of species' invasiveness is based on pastoralists' local knowledge.

Attitude of respondents about *A. drepanolobium*

All respondents stated that *A. drepanolobium* was an impediment for rangeland resource management and their livelihood security that emphasized that *A. drepanolobium* had no contribution in terms of ecological value and socio-economic importance. For instance, it was stated that charcoal from *A. drepanolobium* was less valued by local communities due to its low quality. As a result about 93% of our respondents reported that they used to control the invasion of *A. drepanolobium* through bush clearing methods. However, respondents also noticed that due to its symbiotic association with biting ant species, it was difficult for the community to fully succeed in removing *A. drepanolobium*. Respondents also believed that *A. drepanolobium* could be more successfully suppressed by fire as a management tool.

DISCUSSION

The findings of our results show that saplings and seedlings of *A. drepanolobium* were expanding in abundance and frequency by dominating other species in the rangelands of Borana. The IWSR for *A. drepanolobium* was very high (3.02), suggesting that the species is largely expanding throughout the study area, posing a major threat to rangeland resources and local livelihood system. Similarly, previous research (e.g. Angassa and Oba, 2008) has reported that *A. drepanolobium* is among the most encroaching species with a high IWSR. The ecological mechanisms for that might be complex (Riginos and Young, 2007) as tree growth depends on several factors. These characteristics and the indicative trends mentioned by our respondents could signify the potential threat of *A. drepanolobium* as an indigenous invasive species (see Figure 3). This is in agreement with other field studies from the mid 1980s and early1990s (e.g. Assefa et al., 1983; Tamene, 1990; Coppock, 1994; Oba, 1998; Oba et al., 2000) and also reported by remote sensing studies on bush encroachment in this area (e.g. Hacker, 1990; Gadd et al., 2001). Others (e.g. Gemedo et al., 2006; Angassa and Oba, 2008a) suggested that vast areas of the Borana rangelands have experienced bush encroachment. These observations also corroborate well with the information generated from socio-economic surveys. Local observation suggested that *A. drepanolobium* and other invading woody species were expanding in abundance following the ban on bush fire related to government policy matters.

Table 3. Rank of woody species which were perceived as increasing by local communities in the Borana rangelands, Ethiopia

	Species ranked first		Species ranked second		Species ranked third	
Species	Frequency [%])		Frequency [%]		Frequency [%]	
Acacia drepanolobium	187	87	27	12.6	_	_
Dichrostachys cinerea	17	7.9	129	60	63	29.3
Acacia mellifera	11	5.1	58	27	136	63.3
Acacia senegal	_	_	1	0.5	10	4.7
Acacia oerfota (A. nubica)	_	_	_	_	5	2.3
Acacia nilotica	_	_	_	_	1	0.5
Total	215	100	215	100	215	100

Although many factors could be responsible for the changing conditions of the Borana rangelands, the expansion of *A. drepanolobium* and other encroaching species is attributed to inappropriate land use policy linked to the ban of fire. According to Alemayehu (1998) and Homann et al. (2008), suppression of fire is probably a primary factor for the expansion of *A. drepanolobium*. Furthermore, Homann et al. (2008) stated that the proclamation issued by the Government of Ethiopian that prohibited burning of forests in the highland areas equally applied to the rangeland areas without considering the potential impacts on pastoral production. However, our results on the basis of key informants' and experts' opinion suggest that the ban on fire has never been formalized and no legal guideline existed on fire ban as a tool for rangeland management. Thus, the present result indicated that the ban on fire was implemented in pastoral areas without any legal authorization. Borana elders generally blamed the heavy sanctions through PAs and district administrators that restricted the use of fire in preventing the encroachment of invasive woody species. An earlier study (e.g. Angassa and Oba, 2008b) has reported the ecological role and effectiveness of fire with other factors such as bush clearing in the control of bush encroachment in the study area.

Based on respondents' indicators and opinion, the character of *A. drepanolobium* was similar to that of other invasive species. Pastoralists' observation indicated that *A. drepanolobium* had multiple dispersal agents. Camels and goats were believed to facilitate the spread of *A. drepanolobium* as compared to other livestock types.

Unfortunately, our results from the socio-economic survey indicated that *A. drepanolobium* had little to contribute to livelihoods of pastoral communities. Through accumulated experience, herders stated that *A. drepanolobium* has no significant contribution either to their livelihood security or to ecosystem performance. The thorny nature of *A. drepanolobium* and its ecology, particularly the symbiosis with stinging ants (Young, 1987; Young et al., 1997, 1998) makes the species more tolerant and resistant to browsing by animals (Figure 4). Pastoralists' observations indicated that the presence of heavy and elongated thorns and its symbiotic relation with biting ants leads to the labeling of *A. drepanolobium* as the most invasive woody plant with no contribution to livestock feed. Similarly, a study by FAO (2008) in the Borana rangelands indicated a low forage value and household use of *A. drepanolobium*. On the contrary, a study in Kenya (Okello et al., 2001) has demonstrated a positive contribution of *A. drepanolobium* to households' economy mainly through charcoal making. In line with the contribution of *A. drepanolobium*, Limenih (2005) reported that its Gum production could be used as an adulterant to the true Gum arabic from *A. senegal*.

Figure 2. Dense population of *A. drepanolobium* trees mixed with *A. seyal* and few other species in the Borana rangelands, southern Ethiopia.

Figure. 3 a, b. *A. drepanolobium* with its long bulbous thorns, which are occupied by ants (*Crematogaster spec*.) when young (Madden and Young, 1992).

The results of our findings suggest that dramatic changes in species composition of rangeland vegetation related to the impact of *A. drepanolobium* had a negative implication on ecosystem processes and environmental changes in southern Ethiopia. Thus, beyond its socio-economic impacts *A. drepanolobium* might also cause a shift in the ecological balance of rangeland ecosystems and contribute to a loss of biodiversity. For instance, Kueffer et al. (2004) have reported similar results regarding the negative impact of invasive species on the sustainable use of rangelands.

Our results confirmed that the invasion of woody plants is becoming a major concern in the study area. Specifically, the present study suggests that the spread of invasive woody plants such as *A. drepanolobium* would end up the productivity of rangelands for cattle keeping and contribute to the loss of indigenous Borana cattle breed in the region. As a result, appropriate management practices for the control of bush encroachment including *A. drepanolobium* in the study area are urgently needed. Similar results by Angassa and Oba (2009) have suggested the need for the application of appropriate control measures, which should also be the focus of development actors in the study areas. Current management efforts in the control of invasive woody plants should be integrated and supported by research and policy so as to efficiently suppress *A. drepanolobium* and other species of major concern. Moreover, stinging ant species that live symbiotically with *A. drepanolobium* could hinder the efficiency of control measures. *A. drepanolobium* is hardly accessible to browsers as stinging ants are an excellent deterrent to herbivores (Figure 4).

Figure 4. *S*cale tending by ants (*Crematogaster spec*.)

Our results show that local peoples' interactions with their environments, i.e. own indigenous knowledge to live with and manage resources is probably a good opportunity to explore how to design future strategies for the control of bush encroachment. Borana Oromo could be one of the pastoral communities that have developed indigenous ecological knowledge and institutions for sustainable natural resource management. The traditional institution (*Gada)* plays a great role in mobilizing the community for suppressing the expansion of *A. drepanolobium* in the rangelands. Our respondents mentioned that about four decades ago they used to manage the population of *A. drepanolobium* in order to synchronize the natural balance of the rangeland ecosystem through the use of range fire. However, herders blamed the policy of the former Military government for prohibiting the use of fire as a tool for rangeland management that also undermined their indigenous knowledge in ecosystem management, which in turn contributed to the current

situation. In line with this, Helland (2000) argued that development and policy interventions have eroded vital indigenous institutions and adversely affected the local environment.

Overall, Borana pastoralists perceived that the expansion of woody encroachment greatly contributed to the deteriorating nature of rangeland condition. Gemedo (2004) argued that because of heavy encroachment, the Borana rangelands might have already crossed a threshold towards shrub-invaded grassland. In congruence to this the present observation indicated a poor grass diversity with a low proportion of perennial grasses, while less palatable grasses were common and dominated the herbaceous community in some cases. According to Homann et al. (2008) this process of bush encroachment and decline in perennial grasses were started some three decades ago with the initial interference of development interventions. Our results suggested that the expansion of *A. drepanolobium* in the rangelands of Borana forced the pastoral community to shift their herds from cattle (i.e. grazer) to browsers such as camels and goats. A similar finding (Angassa, 2005) has also showed that the Borana pastoralists have been diversifying their livestock species, and raising an increasing number of camels.

CONCLUSIONS

From the results of our study we confirmed that the encroachment by *A. drepanolobium* greatly influenced rangeland productivity and the life style of pastoral communities. The invasion of *A. drepanolobium* and its threat to the pastoral way of life is one of the most urgent issues in the rangeland management of Borana. According to our respondents' observations, in addition to *A. drepanolobium* three other major woody species are currently threatening the rangelands. The increased trends of woody encroachment, decline in forage resources, change in livestock type, decreased milk production, deteriorated local livelihood conditions and the implications on local food insecurity were some of the emerging issues. Overall, respondents' observations indicated that *A. drepanolobium* is the most invasive woody species with a typical invasive plant character. It poses a serious socio-economic thread on livelihood security in Borana pastoral areas.

A. drepanolobium is threatening the rangeland resources and other multipurpose tree species in the study area. Hence, it is a species emerging with serious implication on rangeland resources and communities' livelihoods. It was also a learning experience that pastoralists are knowledgeable about the adverse impact of *A. drepanolobium* on the ecology of grazing and rangeland performance. As it was evident from field observations, girdled *A. drepanolobium* individuals died. Thus, it can be concluded that girdling could be one of the management options in the control of *A. drepanolobium*. The Borana had a traditional system of rangeland management through the use of fire. We suggest to integrate communities' indigenous ecological knowledge with the scientific approach in the formulation of policy and development strategies for future interventions in the management of invasive woody plants. Further research is needed to look into the socio-economic and ecological value of *A. drepanolobium* in terms of its Gum utilization. It is also important to explore the impact of *A. drepanolobium* on soil properties and the soil seed bank in the Borana rangelands.

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