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Control of bush encroachment in Borana zone of southern Ethiopia: effects of different control techniques on rangeland vegetation and tick populations

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Abstract

A study on effects of bush encroachment control techniques on rangeland productivity and tick population dynamics was conducted in Arero district of Borana zone, southern Ethiopia, for three consecutive years. The study targeted two main and dominant encroaching bush species in Borana rangeland, *Acacia drepanolobium* and *Acacia mellifera*, and their effects on some vegetation attributes and tick population dynamics. A hectare of rangeland encroached by these two acacia species was replicated/divided into three plots, and each plot was subdivided into five sub-plots to receive five treatments: cutting at 0.5 m above ground and pouring kerosene on stumps (T1), cutting at 0.5 m above ground and debarking the stumps down into the soil surface (T2), cutting at 0.5 m above ground alone (T3), cutting at 0.5 m above ground and dissecting the stumps (T4) and control (T5). Data on basal and litter covers, soil erosion and compaction, dead and re-sprouted encroaching tree/shrub species and nymph- and adult-stage tick populations were collected before and after treatment applications. The applied treatments significantly influenced ($p < 0.05$) basal cover, nymph- and adult-stage tick population and the two encroaching tree species. The results of this study showed that T3 and T2 were good in controlling *A. drepanolobium* in that order. T4 and T2 had a significant effect in controlling *A. mellifera* in their order. Controlling bush encroachment had also a positive effect in eradicating the tick population. The most dominant grass and non-grass species observed after the control actions were *Cenchrus ciliaris*, *Chrysopogon aucheri*, *Abutilon hirtum*, *Pennisetum mezianum*, *Dyschoriste hildebrandtii*, *Zaleya pentandra* and *Eragrostis papposa*. Therefore, controlling encroaching tree/shrub species had created a conducive grazing area with palatable herbaceous species for the livestock and unequivocally reduced tick population which play a role in reducing cattle milk production through closing off teats. The management of bush encroachment, if sustained, will contribute in stabilizing rangelands and help minimize the negative effects of feed and food crises in the future.

Keywords: Borana; Grass and forbs; Vegetation dynamics; Tick population

Background

Worldwide, rangelands contribute about 70% of the feed needs of domestic ruminants and contribute about 85% of the total feed needs of ruminants in African and South American countries (Holechek et al. 2005). In Ethiopia, rangelands account for more than 60% of the country's total land mass (Hogg 1997). Past studies have indicated that Borana rangelands in the southern parts of the country were considered to be one of the best grazing lands (Coppock 1994). However, these rangelands are experiencing increasing pressure from livestock and human populations, bush encroachment and tick infestation (Ayana 2007). According to Gemedo et al. (2006a), in the Borana rangelands, woody plant cover increased from 50% as reported in the late 1990s by Oba (1998) to 60%. Bushes are transforming open grazing lands into impenetrable thicket-forming noxious trees/shrubs and suppressing desirable grasses and non-grasses

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through competition, thus becoming unsuitable for browsing and grazing (Tamene 1990). Acacia species such as *Acacia drepanolobium*, *Acacia reficiens* and *Acacia mellifera* and *Commiphora* species are identified as the most encroaching species (Oba 1998). Oba et al. (2000) reported that bush encroachment in the Borana rangelands reduces livestock productivity and survival particularly during drought years, when forage scarcity is the greatest.

Furthermore, livestock production in Borana pastoral communities has been constrained by ticks. Ticks have a great importance in the production of animal diseases. Heavy infestation can cause direct production loses, apart from their role as vectors and potential reservoirs of infectious and often fatal East Coast fever (ECF). A survey of 560 milking cows in Borana in 1989 revealed that 15% of the cows' teats were closed off due to tick damage. This situation exacerbates the pastoralists' potential to secure their household food needs as milk is the predominant food for the pastoralists in the study area.

Therefore, this study was aimed to determine the response of herbaceous and woody vegetation to different bush control techniques and to assess the efficacy of controlling excessive tick loads in the rangelands.

Materials and methods

Study area

The study period elapsed between the hot dry season of 2008 and the main rainy season of 2011 in Arero district of Borana zone, southern Ethiopia, which is about 630 km south of the capital Addis Ababa. Land use in the Borana rangelands is largely communal, but crop cultivation and private enclosures appear to be increasing in recent decades (Coppock 1994). In this extensive communal semi-arid rangeland of Borana, herbaceous plants are the major feed sources of grazers. The area has a bimodal pattern of rainfall, with the long rainy season between March and May and the short rainy season between September and November. Spatial and temporal variability in both the quantity and distribution of rainfall renders the area semi-arid, with an average annual rainfall ranging from 400 mm in the south to 600 mm in the north. The average temperature varies from 13.1°C to 25.2°C per annum (Coppock 1994). The site is dominated by black clay soils.

Methods

Local community leaders and elders (pastoralists' representatives) who have a deep knowledge about the intended site were purposefully selected to take part in site selection. Meetings and discussions were held with government officials, local community leaders and elders to raise awareness on the objectives of the study. Through discussion, the community leaders and elders ranked *A. drepanolobium* as the first and *A. mellifera* as the second most encroacher tree/shrub species in the study district (Figures 1 and 2). Finally, based upon the consensus reached by the community, a land encroached predominantly by *A. drepanolobium* and *A. mellifera* was delineated for the planned activity.

A hectare of land encroached by *A. drepanolobium* and *A. mellifera* was divided into three plots. Each replication (plot) with an area of 33.33 m by 100 m was divided into five sub-plots, each with 20 m by 33.33 m ready to accommodate five treatments, namely cutting at 0.5 m above ground and pouring kerosene on the stumps T1, cutting at 0.5 m above ground and debarking the stumps down into the soil surface T2, cutting at 0.5 m above ground alone T3, cutting at 0.5 m above ground and dissecting the stumps T4 and no cutting T5.

Data on basal and litter covers, soil erosion and compaction, tick population dynamics and standing *A. drepanolobium* and *A. mellifera* were collected before treatment application. Data collections on tick population dynamics, basal and litter covers and soil erosion and compaction were carried out on the third year after treatment application. However, data on dead and re-sprouted *A. drepanolobium* and *A. mellifera* were collected on the first year after treatment application. The percentage basal and litter covers and estimated soil erosion and compaction were obtained by randomly throwing five 0.5 m × 0.5 m quadrats within each sub-plot. Tick population was determined by dragging a transect cloth of 3 m × 2 m over the sub-plots, and then ticks attached to the cloth were counted separately according to their growth stage as nymph and adult. Percentage basal and litter covers were estimated using visual assessment in each quadrat. Soil compaction percentage was estimated by assessing the degree of inserting any sharpened materials (sharpened trees were used in this study) into the soil in each quadrat. The assessment of soil erosion was based on the method described by Baars et al. (1997). The values in percentage given are as follows: no soil movement (0% to 15%), slight sand mulch (16% to 30%), slope-sided pedestals (31% to 45%), steep-sided pedestals (46% to 60%), pavements (61% to 75%) and gullies (76% to 100%).

Data were analysed using SAS (SAS Institute 2002) software, and Tukey's studentized range (HSD) tests were used for *post hoc* multiple comparisons of means.

Results and discussion

Response of *A. drepanolobium* and *A. mellifera* to treatments

Stump death of *A. drepanolobium* was highest for T2 (cutting at 0.5 m above ground and debarking) (36.4%). However, stump death of *A. mellifera* was highest for T4 (cutting at 0.5 m above ground and dissecting) (69.5%). However, we observed during the experiment that T3 was

Figure 1 *Acacia drepanolobium* **with its long swollen thorns, which are occupied by ants (***Crematogaster* **species) when young.**

effective only on aged *A. drepanolobium* rather than on the juveniles, and hence, the level of vulnerability might be related to tree sizes and stage of growth (Oba 1990; Pinard et al. 1999; Clark and Wilson 2001). A similar finding in Burkina Faso (Sawadogo et al. 2002) showed that probability of mortality among woody species is greatest immediately after disturbance. Almost total death was recorded for thoroughly debarked stumps of *A. mellifera* and *A. drepanolobium*. Overall, dead stumps of *A. mellifera* was 32.3%, which was higher than dead stumps of *A. drepanolobium* (19.4%), showing that *A. mellifera* was more susceptible to the applied treatments than *A. drepanolobium* (Table 1). Previous studies (e.g. Vesk 2006) have indicated that woody species have different strategies for survival.

Effects of treatments on soil erosion and compaction and on tick population

Soil compaction was decreased from 52.9% pre-control to 44.1% after the control actions. During the same time, soil erosion was also decreased from 13.4% pre-control to 10.1% after the control actions (Table 2). The reductions in soil erosion and compaction might be due to the increment in basal cover by 15.9% and litter cover by 8.4%. Hence, erosion losses are minimized and large quantities of root and aboveground biomass are returned to the soil. This in turn increases water infiltration rates into the soil and decreases runoff (Jiang et al. 1996). The importance of soil cover in reducing soil erosion has been shown, for example, by Becher (2003). Besides, reduction in soil erosion and soil compaction could be explained by complete removal of bush density normally accompanied by an increase in herbaceous production and desirable shifts in herbaceous species composition (Archer 1990; Ward 2005; Gemedo et al. 2006b), mainly due to zero or less competition for available soil water, nutrient and light.

Bush control effects on vegetation structure and basal and litter covers

Out of all herbaceous species identified, the number of grass species and forbs (non-grass species) was 16 and

Figure 2 *Acacia mellifera* **with no grass under its bunch-type canopy after the main rainy season.**

Table 1 Effects of treatments on different parameters after treatment application

Treatments	Basal cover (%)	Litter cover (%)	Soil erosion (%)	Soil compaction (%)	Nymph-stage tick/ha	Adult-stage tick/ha	Dead *A. drepanolobium* (%)	Dead *A. mellifera* (%)
1	54 bc	31.7 a	9.3 a	45.0 a	5,555.6 d	555.6 b	17.4 b	33.3 ab
2	55 bc	30.7 a	10.7 a	40.0 a	13,888.9 b	2,777.8 a	36.4 a	39.3 ab
3	71.7 a	34.0 a	10.0 a	43.0 a	10,555.6 bc	3,888.9 a	24.3 ab	19.4 ab
4	61.3 ab	33.3 a	11.3 a	53.0 a	8,888.9 cd	3,333.3 a	19.1 b	69.5 a
5	46.7 c	23.3 a	9.3 a	39.3 a	22,222.2 a	3,888.9 a	0.0 c	0.0 b
Overall mean	57.7	30.6	10.1	44.1	12,222.2	2,888.9	19.4	32.3
±SE	4.1	3.8	1.1	5.9	1,138.5	621.1	3.3	14
CV (%)	12	21.7	19.3	23.3	16.1	37.2	29.3	75.1
R^2	0.72	0.55	0.23	0.34	0.94	0.78	0.89	0.65

Key: Means in the same column followed by the same letter were not significantly different ($p > 0.05$).

16, respectively. In total, we recorded 3 annual and 13 perennial grass species after the control actions. The high proportion in perennial grass species might be attributed to the removal of encroaching tree/shrub species which have had a negative impact on the perennial grass species through competing for nutrients, water and light. Over the same time, 10 perennial and 6 annual non-grass species were identified. Forage desirability was grouped into classes by livestock preferences, based on the elder pastoralists' assessments; they categorized forage plants into 'highly desirable', 'desirable', 'partly or less desirable' and 'not desirable' (Table 3). The 'highly desirable' forages are highly selected by livestock and given preference during grazing. 'Desirable' forages are those which occur in rangeland in good condition and increase with moderate overgrazing. 'Less desirable' forages are those which increase with severe overgrazing. 'Not desirable' forages are those which are not preferred/edible completely by livestock species. According to the elder pastoralists' assessments, the existence of highly desirable and desirable forages indicates good rangeland quality while the existence of less desirable and not desirable forages indicates poor quality. Results in the study site were that 56.25%, 37.5%, 6.25% and 0% of the grass species were highly desirable, desirable, less desirable and not desirable by livestock species, respectively (Table 3). Forbs (non-grass species) varied in abundance from as low as 0.4% to as high as 11.6%. In addition, 6.25%, 18.75%, 56.25% and 18.75% of the non-grass species were assessed as highly desirable, desirable, less desirable and not desirable by livestock species, respectively.

Basal cover was significantly increased from 41.8% before the control actions to 57.7 ± 4.1 after the control actions (Tables 1 and 2). The high basal cover in the study area could be associated with reduced soil erosion by 3.3% and reduced encroaching tree species densities which created a conducive environment for recruiting new grass species. Furthermore, canopy gaps created by tree/shrub removal are expected to result in increased herbaceous cover, diversity and abundance due to reduced competition for water and nutrients as well as increased availability of light (Casado et al. 2004). In line with this finding, Karuaera (2011) found that non-encroached sites had a higher grass cover than the bush-encroached sites.

Litter cover was increased from 22.2% ± 3.7% before the control actions to 30.6% ± 3.8% after the control actions that might be attributed to the increment in basal cover percentage and the newly introduced grasses after the control actions specially *Digitaria naghellensis*, *Sporobolus pellucidus*, *Bothriochloa insculpta* and *Heteropogon contortus*. These grasses are very important livestock

Table 2 Mean difference value of parameters between before and after the control actions

Parameters	Mean differences across treatments					Overall mean difference
	1	2	3	4	5	
Basal cover (%)	13.3^a	10.3^a	20^a	16.6^a	19.4^a	15.9^a
Litter cover (%)	6.4^a	4.7^a	18.7^a	7.6^a	4.6^a	8.4^a
Soil erosion (%)	2.4^b	3.0^b	5.7^b	4.0^b	1.4^b	3.3^b
Soil compaction (%)	9.7^b	12.3^b	7.3^b	11.7^b	3^b	8.8^b
Number of nymph-stage tick/ha	15,000^b	7,222.2^b	10,555.5^b	12,777.8^b	6,666.7^b	10,444.5^b
Number of adult-stage tick/ha	1,666.6^b	2,222.2^b	1,111.1^b	2,777.8^b	1,111.1^a	1,333.3^b

Key: [a]Increased mean value when after treatment application mean value was subtracted from before treatment application mean value. [b]Decreased mean value when after treatment application mean value was subtracted from before treatment application mean value.

Table 3 Overall grass and non-grass species recorded in the study district

Scientific name	Vernacular name	Growth form	Desirability	Life form	Frequency (%)
Dyschoriste hildebrandtii	Gurbii gaalaa	Non-grass	Less desirable	Perennial	11.6
Cenchrus ciliaris	Mata guddeessa	Grass	Highly desirable	Perennial	8.9
Heteropogon contortus	Seerricha	Grass	Highly desirable	Perennial	8.5
Dactyloctenium species	Qabattee	Grass	Highly desirable	Perennial	6.9
Chrysopogon aucheri	Alaloo	Grass	Highly desirable	Perennial	6.2
Pennisetum mezianum	Ogondhichoo	Grass	Desirable	Perennial	6.2
Eragrostis papposa	Saamphilee	Grass	Desirable	Annual	5.4
Solanum schimperianum	Hiddii qixii	Non-grass	Less desirable	Perennial	3.9
Cynodon dactylon	Saardoo	Grass	Highly desirable	Perennial	3.5
Abutilon hirtum	Gurbii daalattii	Non-grass	Less desirable	Perennial	3.1
Tagetes minuta	Sunkii	Non-grass	Less desirable	Annual	2.7
Chloris roxburghiana	Hiddoo luucolee	Grass	Highly desirable	Perennial	2.7
Oxygonum sinuatum	Mogorree	Non-grass	Desirable	Annual	2.3
Digitaria naghellensis	Ilmoo gorrii	Grass	Highly desirable	Perennial	2.3
Sporobolus pellucidus	Salaqoo	Grass	Desirable	Perennial	2.3
Digitaria milanjiana	Hiddoo	Grass	Highly desirable	Perennial	2.3
Xerophyta humilis	Areedoo	Grass	Desirable	Perennial	1.9
Helichrysum glumaceum	Darguu	Non-grass	Not desirable	Perennial	1.9
Commelina africana	Qaayyoo	Non-grass	Highly desirable	Annual	1.9
Chlorophytum gallabatense	Miirtuu	Non-grass	Not desirable	Annual	1.9
Indigofera volkensii	Gurbii hoolaa	Non-grass	Less desirable	Perennial	1.6
Pupalia lappacea	Hanqarree	Grass	Less desirable	Annual	1.6
Eragrostis capitulifera	Biilaa	Grass	Desirable	Perennial	1.6
Rhynchosia ferruginea	Kalaalaa	Non-grass	Desirable	Annual	1.2
Cyperus species	Saattuu	Grass	Desirable	Annual	1.2
Bothriochloa insculpta	Luuccolee	Grass	Highly desirable	Perennial	0.8
Alakuu ajoo (not known)	Alakuu ajoo	Non-grass	Not desirable	Annual	0.4
Psydrax schimperiana	Gaalee	Non-grass	Less desirable	Perennial	0.4
Abutilon species	Gurbii re'ee	Non-grass	Less desirable	Perennial	0.4
Solanum somalense	Hiddii gaagee	Non-grass	Less desirable	Perennial	0.4
Lantana rhodesiensis	Midhaan durbaa	Non-grass	Less desirable	Perennial	0.4
Mixixiqaa (not known)	Mixixiqaa	Non-grass	Desirable	Perennial	0.4

feed resources in the rangeland ecosystem. This finding indicated that grass diversity is negatively correlated with woody plant density which is in accordance with Abule et al. (2007). The increase in density of woody plants beyond a critical density suppresses herbaceous growth and its production in semi-arid ecosystems (Richter et al. 2001).

A significant difference ($p < 0.05$) among treatments was noticed for the mean number of nymph-stage tick population per hectare. Accordingly, nymph-stage tick population per hectare was reduced significantly from 22,666.7 pre-control to 12,222.2 after control actions (Table 1). Likewise, the number of adult-stage tick population per hectare was reduced from 22,666.7 before the control actions to 2,888.9 after the control actions. The highest reduction in number of nymph-stage tick per hectare was noticed for T1 (cutting at 0.5 m above ground and applying kerosene) that reduced by 15,000 ha^{-1}. This might be due to the inability of the nymph-stage ticks to withstand the unpleasant odour of kerosene gas over the plot. The study results suggest that *A. mellifera* and *A. drepanolobium* encroachment provides a conducive environment for the survival of ticks which is in line with Bertrand and Wilson (1996) who reported that ticks in open fields suffered higher mortality rates than those in canopied habitats. A previous study by Scott and Jeffrey (2010) found that adult tick density was positively correlated with percent coverage of live Japanese barberry. Adult-stage tick density was increased by 1,111.1 ha^{-1} after the control actions only in the control plot (T5) probably due to their ability to escape from the plots that were cleared off encroaching trees/shrubs species to the plots that were untouched, i.e. T5 (no treatment application) (Table 1). Overall, the density of nymph- and adult-stage tick population per hectare was decreased by 30% and 18.8%, respectively, due to the control actions. This implies that controlling encroaching tree/shrub species has also contributed in the reduction of tick density which had a negative impact on the milk yield by the livestock species via closing off teats.

Conclusion and recommendation

The study aimed to test controls for bush encroachment, an important factor hampering livestock production and improved living standards of the Borana pastoralist community. The grazing system of the Borana plateau has become increasingly unsuitable in recent decades due to range degradation in the form of woody plant encroachment. The widespread use of different bush control techniques would serve to stabilize forage supply in these semi-arid rangelands by improving overall forage production in drought years. According to our results, T2 and T4 were effective in controlling *A. drepanolobium* and *A. mellifera*, respectively. Changes in vegetation structure from thicket-forming bush encroachment to open grasslands have recruited herbaceous biomass and plant biodiversity and reduced the tick population, which has a positive impact on the rangeland ecosystem, livestock production and livelihoods of the pastoral communities. This agrees with studies by Richter et al. (2001), Briske et al. (2003) and Abule et al. (2007).

Responses of individual encroaching woody species to the different control methods have important implications for management, conservation policy and public education, which in the future should be promoted through pastoralist participatory research and extension. Controlling encroaching tree/shrub species also contributed in the reduction of tick density which has a negative impact on the milk yield by the livestock species via closing off teats. The management of bush encroachment, if sustained, will contribute in stabilizing rangelands, livestock productivity and pastoralist livelihoods and help minimize the negative effects of feed and food crises in the future.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
BN carried out the field data collection, analysed the data and wrote the paper. BE was involved in the data collection and revised and edited the manuscript. ST revised and edited the manuscript. BB carried out the data collection and revised and edited the manuscript. JD was involved in the data collection. NH was involved in the data collection. All authors read and approved the final manuscript.

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