The effect of clearing bushes and shrubs on range condition in Borana, Ethiopia

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Abstract

The effect of bush encroachment and the responses of range condition to clearing were assessed at 2 locations in Borana rangeland at the end of the growing season on cleared and uncleared sites. The study was carried out in a communal grazing area (Medhecho) and a Government ranch (Dida-Tuyura) in bush and/or shrub-encroached and cleared areas to assess the effect of bush clearing on range condition. In each area, 3 elevation ranges were distinguished and in each range a single transect, covering both uncleared and cleared rangeland, away from water sources, was selected. The assessment was based on botanical composition of the herbaceous layer, basal cover, litter cover, relative number of seedlings, age distribution of grasses and soil condition. A total of 31 grasses, 4 legumes and 3 sedges were identified. The grasses *Bothriochloa radicans, Cenchrus ciliaris, Chrysopogon aucheri* and *Panicum coloratum* were common or dominant in both cleared and uncleared sites. *Pennisetum mezianum* was typically found in encroached vegetation. In general, the range condition was fair to good. The uncleared vegetation had a significantly lower score for range condition than the cleared vegetation for most parameters as well as for total score, although the differences were small. Differences based on elevation range were also significant for grass composition, soil condition and total score. Cleared areas contained more desirable species and more seedlings than the uncleared areas.

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Introduction

A few decades ago, the Borana rangelands in southern Ethiopia were considered amongst the best grazing lands in east Africa (AGROTEC 1974). The Borana pastoralists traditionally practised strategic grazing management to avoid local overstocking around the scarce dry season water sources. They used different grazing areas in the dry and wet seasons; lactating cows with their calves were herded separately from dry cows, bulls and young stock; and encampments were not allowed within 10 km from water sources used during the dry season (Coppock 1994). This management regime in combination with episodic climatic events and the planned use of fire maintained a relatively stable tree-grass balance. However, in the last few decades, increasing grazing pressure and the development of water ponds has resulted in more sedentary settlements and enhanced crop cultivation. In the mid 1980s, about 19% of the area was affected by erosion, and about 40% of the area had a woody cover exceeding 40% (Assefa *et al*. 1986). The high grazing pressure, the official bans on the use of fire and pond development (pond-construction program) promoted bush encroachment and a decline in range condition (Coppock 1994). Progressive bush encroachment is claimed to alter grass productivity and patterns of livestock grazing (Bille and Eshete 1983) and result in a decline in range condition (Smith 1988; Scholes and Walker 1993). The shift from grassland (<10% bush cover) to bush climax (*i.e*., >30% bush cover) is influenced by interactions of episodic rainfall, fire and heavy grazing (Harris 1980; Scholes and Archer 1996). Once established, bush encroachment accelerates the decline in grass cover, while the intensification of grazing pressure reduces the fuel load required for fire to burn the bush cover (Scholes and Archer 1996).

Clearing of bush-encroached areas may improve pasture productivity and range condition but little is known about the effects of bush clearing in this region. Therefore, this study was conducted with the objective of assessing the effect of bush clearing on the condition of the rangeland under different management systems in Borana.

Materials and methods

Study area

The rangelands of Ethiopia constitute 62% of the country's land area and account for 12–15% of the human population (Hogg 1997). The Borana rangelands account for 7–12% of the total land area of the country (Tamene 1990). The study was conducted in Dida-Tuyura ranch 17 km north-east of Yabello town (5°00'N, 38°00'E) and in Medhecho 80 km south of Yabello town (4°00'N, 38°00'E) in Borana. The Borana plateau covers approximately 95 000 km^2, is slightly undulating and ranges in elevation from 1000–1500 m with peaks up to 2000 m (Coppock 1994). The area has a bi-modal rainfall regime, with mean annual rainfall ranging from 400 mm in the south to 600 mm in the north. Droughts occur once every 5–10 years (Coppock 1994). There is no detailed information on the soils of Borana rangelands. However, the main soils of the region comprise 53% red sandy loam soil, 30% black clay and volcanic light coloured silty clay and 17% silt and vertisols (Coppock 1994). Four major vegetation types have been described (AGROTEC 1974): (i) Evergreen and semi-evergreen bush land and thickets, found north of Yabello, Arero and Negelle stretch; (ii) Rangeland dominated by *Acacia* and *Commiphora* trees, covering most of the rangeland area extending in central, south and west directions; (iii) Rangeland dominated by shrubby *Acacia, Commiphora* and allied genera, confined to water sources and depressions covering some portion of the western parts of the rangeland with barren land between; and (iv) Dwarf shrub grassland or shrub grassland, in the eastern parts of the rangeland where the soil is very shallow and sandy. According to Coppock (1994), woody plants contribute from 5–75% of total plant cover on the Borana plateau depending on location. The dominant herbaceous plants are perennial rather than annual grasses. The average stocking rate in the study area was approximately 15.6 TLU/km^2 (Cossins 1985), where TLU represents a Tropical Livestock Unit, a cow weighing 250 kg. Large parts of the vegetation are encroached by bushes (Coppock 1994). Based on indicator species, Borana elders ranked bush encroachment third, next to drought and overgrazing, as a cause of range deterioration (Alemayehu 1998). Several species of *Acacia*, particularly *A. drepanolobium* and *A. brevispica*, are notorious invaders (Tamene 1990).

Selection of transects and sample sites

The study was conducted in the late wet season of 1998 (April) when most grasses were in full flowering stage, which is important for identification. Six transects, from 5–10 km in length, were established in both a communal grazing area and a Government ranch. Sites disturbed by crop cultivation were avoided. Each area covered 3 ranges of elevation: low (1250–1500 m), medium (1500–1650 m) and high (1650–2000 m above sea level). One transect was selected in each altitude zone in both areas. High altitude was generally far from water sources while low altitude was nearest to water sources. An altimeter was used to measure elevation of the sampling sites. Each transect had 4 sampling sites. Transects were selected in such a way as to cover: (i) 2 encroached and 2 cleared rangeland sites; and (ii) different levels of grazing pressure, relatively nearby and far away from watering points within transects. The distance to water for the first sampling site on each transect differed according to elevation and ranged from 1.5–10 km. Areas where the shrub, bush and tree canopy was estimated visually as more than 40% were designated as encroached. When the shrubs and bushes were manually removed, the rangeland was considered as cleared. In both areas, bush or shrub clearing was done between 1994–1996 as an experimental treatment. Vegetation types that were not easily classified as cleared or encroached were avoided.

At each sampling site, the range condition of a central site in a representative area was assessed by 4 observers together, who then radiated out to about 100 m from the central site for individual assessments, resulting in a total of 5 assessments per sample site. Each site was assessed once.

Range condition factors

The assessment was based on the botanical composition of the herbaceous layer (referred to as grass composition), basal cover, litter cover, relative number of seedlings, age distribution of grasses, and soil condition (erosion and compaction). Since the major part of the Borana region is a semi-arid environment, the factors were based on the criteria developed for semi-arid rangelands in southern Africa (Ivy 1969; Tainton 1981; Baars *et al*. 1997), and are shown in Table 1. Scores for each of 7 criteria were summed and the maximum possible score was 50 points (Table 1). Three criteria had a maximum score of 10 points while the remaining 4 criteria had a maximum score of 5 points. The overall rating was interpreted as follows: very poor (0–10); poor (11–20); fair (21–30); good (31–40); and excellent (41–50 points).

Grass composition (1–10 points). At each sampling site, a 0.5 m × 0.5 m quadrat was cut. The fresh and dry weights of each individual species were determined. Three levels of species occurrence, based on dry matter yield, were distinguished: (i) present, <5% of the dry matter (DM) of the herbaceous biomass; (ii) common, 5–20%; and (iii) dominant, >20%. The assessments were carried out late in the long rainy season of 1998, when most grasses were in flower. Plants with a full flowering head and other vegetative parts were collected and identified at the National Herbarium of Addis Ababa University. The identification of the specimens was based on Fromann and Persson (1974) by comparing with specimens in the herbarium. Classification of grasses according to the succession theory (Dyksterhuis 1949) into desirable species likely to decrease with heavy grazing pressure (decreasers), intermediate species likely

Table 1. Criteria for the scoring of the different factors determining range factors.

Score	Grass composition	Basal cover	Litter cover	No. of seedlings[1]	Age distribution	Soil erosion	Soil compaction
10	91–100% decreasers	>12% no bare areas	>40%				
9	81–90% decreasers	—	—				
8	71–80% decreasers	>9% evenly distributed	11–40% evenly distributed				
7	61–70% decreasers	>9% occasional bare spots	—				
6	51–60% decreasers	>6% evenly distributed	11–40% unevenly distributed				
5	41–50% decreasers	>6% bare spots	—	>4 seedlings	young, medium and old	no soil movement	no compaction
4	10–40% decr 30% incr	>3% mainly perennials	3–10% mainly grasses	4 seedlings	2 size categories present	slight sand mulch	isolated capping
3	10–40% decr <30% incr	>3% mainly annuals	—	3 seedlings	only old	slope-sided pedestals	50% capping
2	<10% decr 50% incr	1–3%	3–10% weeds/ tree leaves	2 seedlings	only medium	steep-sided pedestals	>75% capping
1	<10% decr <50% incr	<1%	—	1 seedling	only young	pavements	almost 100% capping
0		0%	<3%	no seedlings		gullies	

Source: Baars *et al*. (1997).
[1]Number of seedlings on an A4 page area.

to increase with heavy grazing pressure (increasers), and undesirable species likely to increase or invade with heavy grazing pressure (pioneers), was based on information from arid to semi-arid southern Africa (Ivy 1969; Tainton 1981). In case of doubt, the opinions of herdsmen on vigour and palatability of a particular species were considered.

Basal cover (0–10 points) and litter cover (0–10 points). A representative sampling area of 1 m^2 was selected for detailed assessment, and divided into halves. One of these was further divided into quarters, one of which divided into eighths. All plant basal cover in the selected 1m^2 per sample site was cut, transferred while kept together, and drawn in the eighth segment to facilitate visual estimations of basal covers of living parts. The rating of basal cover for tufted species was considered 'excellent' when the eighth was completely filled (12.5%) or 'very poor' when the cover was less than 3%. In this study, *Cynodon dactylon*, a creeping grass, was encountered twice. No other system was developed for this grass, but it was given the maximum score because of abundance of cover. The rating for litter cover within the same 1 m^2 was considered 'excellent' when it exceeded 40% and 'poor' at less than 10% litter cover.

Number of seedlings (0–5 points). The number of seedlings was counted using 3 areas, with a distance of approximately 10 m between the areas for each sampling site. Each area sampled was equal to the size of an A4 sheet of paper (30 × 21 cm) and was chosen at random. The sheet was dropped from a height of 2 m above the ground. The category 'no seedling' was given 0 points and more than 4 seedlings was given the maximum score of 5 points.

Age distribution (1–5 points). When all age categories (young, medium age and old plants) of the dominant species were present, the maximum score of 5 points was given. Young and medium-aged plants were defined as having approximately 20% and 50%, respectively, of the biomass of old and mature plants of the dominant species. When only young plants were present, a score of 1 point was applied.

Soil erosion (0–5 points) and soil compaction (1–5 points). Soil erosion was based on the amount of pedestals (higher parts of soils, held together by plant roots, with eroded soil around the tuft) and in severe cases, the presence of pavements (terraces of flat soil, normally without basal cover, with a line of tufts between pavements). Soil compaction was based on the amount of capping (crust formation).

Statistical analysis

A General Linear Model (GLM) was used for all range condition factors (SAS 1990) for the effect of encroachment versus the effect of bush or shrub clearing and elevation range. Interactions were not significant. Differences were considered significant when $P < 0.05$.

Results

Grass species composition

A total of 31 species of grasses, 4 legumes and 3 species of sedges were identified. The grasses *Bothriochloa radicans, Cenchrus ciliaris, Chrysopogon aucheri* and *Panicum coloratum* were common or dominant in both cleared and uncleared sites (Table 2). In addition, *Bothriochloa radicans* and *Panicum coloratum* were common in both high and medium elevation zones, whereas *Heteropogon contortus* was common in the high zone, and *Panicum maximum* in the low zone. *Pennisetum mezianum* was common in the uncleared rangeland sites. The 4 legumes together took up about 13% of the DM of the total biomass. Sedges were, in terms of DM, insignificant.

The percentages of decreasers, increasers and pioneer grasses were 29, 45 and 26%, respectively. The average score for grass composition was 6.1 out of 10 (fair) and ranged from 3.0–9.0 points per sample site. Grass composition differed significantly between the uncleared sample sites, mean 5.2 (fair) and the cleared sample sites, mean 7.1 (good) (Table 3).

Range condition factors

The effect of elevation on range condition factors showed no significant differences, except for grass composition, soil condition and total score (Table 4). No significant differences were observed between communal grazing and Government ranch areas, except for grass composition and the relative number of seedlings (Table 5).

The average score for basal cover was 6.6 out of 10 (good) and ranged from 2.0–10 points per

Table 2. Botanical composition (% of DM) of the sampled areas in Borana rangeland, Ethiopia.

	Category[1]	Elevation			Cleared	
		High	Medium	Low	Yes	No
Grasses						
Aristida adoensis	P	1	1	—[2]	0.8	0.7
Aristida adscensionis	P	3	2	4	4	2
Aristida conjesta	P	—	1	—	0.5	0.3
Bothriochloa radicans	D	7	15	2	9	6
Brachiaria dactyoneura	D	1	—	—	0.8	—
Brachiaria serrata var. *Gossypina*	D	—	—	1	0.3	0.5
Cenchrus ciliaris	D	11	13	39	19	23
Chloris roxburghiana	I	—	1	*[3]	0.7	0.2
Chrysopogon aucheri	D	18	17	24	19	20
Cynodon dactylon	I	0.2	1	1	0.5	1
Digitaria milanjiana	D	1	3	—	1	1
Enneapogon lophotrichus	I	2	2	0.1	0.7	1
Enteropogon macrostachyus	P	—	0.2	—	—	0.1
Enteropogon somalensis	I	—	*	—	—	*
Eragrostis papposa	I	0.4	4	0.3	2	1
Harpachnae schimperi	I	0.2	0.6	—	0.1	0.5
Heteropogon contortus	I	12	3	—	6	5
Hyparrhenia hirta	I	6	—	—	4	0.2
Leptothrium senegalense	D	0.2	2	—	1	0.3
Lintonia nutans	I	0.7	0.2	2	0.3	2
Microchloa kunthii	I	—	0.2	—	0.2	—
Panicum coloratum	D	12	10	—	7	7
Panicum maximum	D	1	2	8	3	4
Panicum turgidum	I	0.3	—	—	0.2	—
Pennisetum mezianum	P	3	0.6	3	—	5
Pennisetum stramineum	P	—	2	4	—	4
Rhynchelytrum roseum	I	0.2	—	—	—	0.2
Sporobolus pellucidus	P	3	—	—	2	0.1
Sporobolus pyramidalis	P	—	0.4	2	0.7	0.7
Tetrapogon cenchriformis	I	1	2	0.4	0.8	2
Themeda triandra	I	2	4	—	3	1
Legumes						
Endostemon tereticaulis	I	6	5	3	4	6
Indigofera spinosa	P	2	3	0.8	2	2
Vigna vexillata	D	3	2	1	2	2
Zornia glochidiata	I	3	3	4	5	2
Sedges						
Cyperus bulbosus	P	*	0.1	0.2	0.1	0.1
Cyperus obstusiflorus	P	—	—	*	—	0.1
Cyperus rubicundus	P	—	*	0.2	0.2	*

[1]P = Pioneer, I = Increaser, D = Descreaser, according to the succession theory (Dyksterhuis 1949).
[2]Not present.
[3]Present, but < 0.05% of the total herbaceous dry matter biomass.

Table 3. Means ± s.e. of cleared versus uncleared rangeland sites for the criteria used to score range condition.

	Grass composition	Basal cover	Litter cover	No. of seedlings	Age distribution	Soil condition	Total score	N
Cleared	7.1±0.28a[1]	7.8±0.44a	6.3±0.58a	2.3±0.31a	4.8±0.13a	8.3±0.18a	36.5±1.34a	12
Uncleared	5.2 ±0.28b	5.4±0.44b	5.1±0.58a	1.5±0.31a	4.8±0.13a	7.4±0.18b	29.4±1.34b	12
Average	6.5±0.28	6.6±0.44	5.7±0.58	1.9±0.31	4.8±0.13	7.9±0.18	33±1.34	

[1]Within columns, values followed by different letters differ at P < 0.05.

Table 4. Means ± s.e. for the criteria used to score range condition at different elevations in Borana, Ethiopia.

Elevation	GC[1]	BC[2]	LC[3]	NS[4]	AD[5]	SC[6]	TS[7]
High	5.8±0.35a[8]	6.3±0.54a	6.3±0.71a	1.6±0.39a	4.9±0.16a	7.8±0.22ab	32.5±1.64ab
Medium	5.6±0.35a	6.0±0.54a	5.0±0.71a	1.2±0.39a	4.8±0.16a	7.5±0.22b	30.8±1.64b
Low	7±0.35b	7.5±0.54a	5.9±0.71a	2.3±0.39a	4.8±0.16a	8.3±0.22a	35.6±1.64a

[1]Grass composition, [2]Basal cover, [3]Litter cover, [4]No. of seedlings, [5]Age distribution of grasses, [6]Soil condition, [7]Total score.
[8]Within columns, values followed by different letters differ at $P < 0.05$.

Table 5. Means ± s.e. for the communal grazing area (Medhecho) and government ranch (Dida-Tuyura) in Borana, Ethiopia.

	GC[1]	BC[2]	LC[3]	NS[4]	AD[5]	SC[6]	TS[7]
Medhecho	5.7±0.28b[8]	6.5±0.44a	6.3±0.58a	1.2±0.31b	4.8±0.13a	7.6±0.18a	31.9±1.34a
Dida-Tuyura	6.6±0.28a	6.7±0.44a	5.2±0.58a	2.7±0.31a	4.8±0.13a	8.1±0.18a	34±1.34a

[1]Grass composition, [2]Basal cover, [3]Litter cover, [4]No. of seedlings, [5]Age distribution of grasses, [6]Soil condition, [7]Total score.
[8]Within columns, values followed by different letters differ at $P < 0.05$.

sample site. Basal cover was significantly higher ($P<0.05$) in cleared areas than in encroached areas. The average score for litter cover was 5.8 out of 10 points (fair) and ranged from 1.0–8.0 points per sample site. There was no significant difference for litter cover between the uncleared and cleared sample sites. The average score for the number of seedlings was 1.9 out of 5 (poor) and ranged from 1.0–5.0 points per sample site. The number of seedlings showed no significant difference between the uncleared and cleared sample sites. However, low elevation showed a slightly higher number of seedlings than the high and medium elevations although these differences were not significant. The average score for age distribution was 4.8 out of 5 (excellent) and ranged from 4.0–5.0 points per sample site. For age distribution, there was no significant difference between the uncleared and cleared sample sites. The average score for soil condition was 7.9 out of 10 (good) and ranged from 6.0–9.0 points per sample site. There was a significant difference between the uncleared and cleared sample sites.

Overall condition

The average total score was 33 out of 50 (good) and ranged from 19–43 points per sample site. The majority of the ratings per sample site fell in the categories ‘fair’ and ‘good’, with 12% and 75%, respectively. The categories ‘poor’ and ‘excellent’ had 8% and 4% of the ratings, respectively. However, none of the sample sites was in a ‘very poor’ condition. The total score was significantly higher for the cleared sample sites compared with uncleared sample sites (Table 3). The total score was significantly lower ($P<0.05$) at medium elevation than at the higher and lower elevations, which were not significantly different (Table 4). The different elevations have variable bush cover and those highly encroached have reduced grass cover and increased bare soil and were more prone to erosion than those with more grass cover. There were no significant differences between the communal grazing area and the Government ranch for the total score (Table 5).

Discussion

Grass species composition

The observations on grass species composition made in this study correspond with that reported earlier (Jenkins *et al.* 1974; Coppock 1994). *Pennisetum mezianum and Pennisetum stramineum* were common on uncleared land and *Pennisetum mezianum* appears to be associated with shrub encroachment on dark clay soils (Pratt and Gwynne 1977). The species is relatively unpalatable but cattle eat it during periods of feed deficits. The contribution of highly palatable species was considerable. The three palatable species, *Cenchrus ciliaris, Bothriochloa radicans* and *Chrysopogon aucheri*, together made up 47% and 49% of the total dry matter of the herbaceous layer in cleared and uncleared vegetation, respectively. These native grasses are important for calf feeding (Coppock 1994) and are key forage species in Borana rangeland.

Clearing has been found to result in marked changes in grass species composition. It is significant that not all changes in species composition with clearing are favourable (Walker 1979). There was a marked decrease in certain desirable species, notably *Cenchrus ciliaris*. However, there was also an increase in certain unpalatable species such as *P. mezianum* and *P. stramineum* on uncleared areas.

Various studies in different parts of the world have indicated that the response in terms of herbage mass per unit area of "clearing unit" increases progressively with progressive degrees of clearing (Walker *et al.* 1972; Walker 1979). Walker (1979) reported that yields of grass increased exponentially as the number of mature plants per unit area decreased from 119 kg per ha with a density of 1071 woody plants per ha to 1071 kg per ha with complete clearing.

Range condition

In contrast to the description of vegetation, little research has been done in the rangelands of Borana with respect to the other factors of range condition. Basal and litter cover play an important role in the dissipation of raindrop energy and thus in the control of erosion. Based on the results of the present study, there is a clear relationship between basal cover (good) and soil condition (good) but there is no clear relationship between litter cover (fair) and soil condition (good). However, in some cases, particularly at low elevations, natural features of the landscape favoured soil condition. Erosion is more closely related to bare soil and the patchy nature of landscapes. In southern Ethiopia, formation of bare soil may be a result of centuries-old environmental processes. In contrast to the present findings, Assefa *et al.* (1986) examined aerial photos and concluded that 19% of the Borana rangeland was affected by erosion of which 4% was severely affected and 15% was moderately affected. Some of the moderately eroded areas coincided with the areas selected in the present study. Severe erosion was related to cultivation and overgrazing, and these areas were avoided in the present study.

I concluded that, in general, the sampled sites were in good condition and soil erosion was not a severe problem in these rangelands. Clearing of bush improved range condition by increasing basal cover of perennial grasses and improving soil condition.

In terms of dry matter production, uncleared areas will certainly yield less forage. The use of bush or shrub clearing may, therefore, be important in the management and improvement (condition and productivity) of the rangelands. On the other hand, Borana pastoralists are increasingly including camels in their herds, and a bushy environment forms a good habitat for camels. Cattle, because they rely on grass production, are adversely affected by bush encroachment.

Communal grazing areas are often considered to be in worse condition than government or private ranches but the results of this study indicate both areas to be in good condition despite high grazing pressures in communal grazing areas in recent years.

In summary, the results of the present study show that the Borana rangelands are not deteriorated. This is probably due to the sound traditional grazing management in the past, which maintained the resilience of the range. However, as a result of increased grazing pressure and water pond development, in recent decades patterns of traditional grazing have deteriorated. It is possible that the Borana rangelands are in a stage of transition towards deterioration. Therefore, it is essential to monitor the rangelands in an endeavour to minimise woody encroachment and deterioration or to develop a state-and-transition model (Westoby, Walker & Noy-Meir 1989) for the Borana rangelands to better understand vegetation dynamics as a result of bush clearing.

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