The effects of physical environment on the condition of rangelands in Borana

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Abstract

This study was carried out to assess the effect of season, elevation, bush encroachment and location on the condition of the rangelands in Borana. A survey was conducted during the long and short rainy seasons of 1998 at a time when most grass species were at full flowering stage on a government ranch and 6 communal grazing areas. Each of the study areas covered 3 elevation zones: low (1250–1500 m), medium (1500–1650 m) and high (1650–2000 m). The assessment of range condition was based on the botanical composition of the herbaceous layer, basal cover, litter cover, relative number of seedlings, size distribution of dominant grasses and soil condition. The overall results showed that season, bush encroachment and location of the rangeland had significant effects on condition of the rangelands. Overall range condition scores were higher during the long rainy season than in the short rainy season and in range sites that were not affected by bush encroachment. Moreover, the total range condition score was higher on the ranch than in some communal grazing areas. Expansion of cultivation for crop production, establishment of permanent sources of water and permanent settlement were considered to be the main contributing factors to the relatively lower condition scores observed in the communal grazing areas because of increased grazing pressure.

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Introduction

Range condition analysis is an essential prerequisite for designing appropriate management practices. Range condition refers to the current ecological condition of the rangeland as compared with its ecological potential (Holechek *et al*. 2001). Range condition classification provides an indication of the necessary management inputs. Based on successional and community dynamics concepts, analysis of range condition is designed to assess whether or not range sites are at acceptable standards and capabilities for livestock production (Stoddart *et al.* 1975).

A few decades ago, the Borana rangelands in southern Ethiopia were considered among the best remaining pastoral lands in east Africa (AGROTEC/CRG/CEDES 1974). Hogg (1997) also noted that the Borana have continued to produce livestock with remarkable social organisation until recently and that the system has often been cited as a model of pastoralism in sub-Saharan Africa. Traditionally, the Borana pastoralists practised strategic management of herds and range resources to avoid local overstocking of the scarce dry season grazing areas. However, recent reviews of published research have indicated that the area is presently experiencing ecological and economic stress (Coppock 1994; Oba *et al.* 2000). Ecological pressure is manifested by proliferation of bush encroachment, a common cause of herbaceous vegetation loss in arid regions, plus a decline in range condition. Oba *et al.* (2000) showed that both external and internal factors promoted bush encroachment and deterioration in range condition, which are reflections of rangelands where the Borana pastoral production systems are under intensive pressure.

Range condition is described by means of range condition classes and is affected by environmental factors such as climate and seasonal variation in rainfall, elevation, soil type, intensity of grazing/browsing and bush encroachment. Assessing the effect of environmental factors on the condition of the rangeland may be a practical way of identifying possible management options for range development programs. Thus, this study was carried out to assess the effects of season, elevation, bush encroachment and location (site difference) on the condition of rangelands in Borana to elucidate the relative roles played by these factors in affecting the condition of the rangelands.

Materials and methods

The study area

The Borana rangelands are located in the southern part of the Ethiopian lowlands, occupying a total land area of approximately 95 000 km^2 ranging in elevation from 1000 to 1600 m above sea level (McCarthy *et al*. 2002), with peaks to 2000 m above sea level (Coppock 1994). The climate of the area is arid and semi-arid. Rainfall is bimodal, with the long rainy season in March–May and the short rains in September–November, followed by the long dry season. Rainfall is variable with strong effects on range productivity. Average annual rainfall varies from 353 to 873 mm (McCarthy *et al*. 2002). Droughts occur once every 5–10 years (Coppock 1994).

The terrain includes a central mountain range, with scattered volcanic cones and craters and gently undulating and flat plains. Soil and vegetation in lowland sites in valleys and depressions differs from that in upland sites with important implications for land use (Coppock 1994). Composition of the main soil types of the Borana rangelands is 53% sand, 30% clay and 17% silt. In most cases, the soil is well drained red sandy loam type. In valley bottoms with impeded drainage, cracking black clay soils and volcanic light coloured silty clays predominate, with relatively higher fertility (higher content of nitrogen, phosphorus and organic matter) and higher water holding capacity than the upland soils. Upland soils are shallower, well drained red sandy soils that are widespread on flat lands and hills with relatively lower fertility and lower ability to retain water and nutrients as compared with the Vertosols in the bottomlands (Coppock 1994).

The vegetation of the area is of 4 major types: (i) evergreen and semi-evergreen bushland and thickets; (ii) rangeland dominated by *Acacia* and *Commiphora* trees; (iii) rangeland dominated by *Acacia, Commiphora* and allied genera; and (iv) dwarf shrub grassland or shrub grassland (AGROTEC/CRG/CEDES 1974). The dominant herbaceous plants are perennial grasses. Bushes have encroached on large areas, which is one of the main causes of range deterioration, next to drought and overgrazing (Alemayehu 1998). Several species of *Acacia*, particularly *Acacia drepanolobium* and *A. brevispica,* are notorious invaders in the rangeland (Tamene 1990).

The study was conducted on a government ranch (Did-Tuyura) with a total area of 5550 ha and 6 communal grazing areas (Did-Yabello, Did-Hara, Dubluq, Madhacho, Melbana and Web). In the past, Did-Hara was used for wet season grazing, while the remaining communal grazing lands served as dry season rangelands because of the presence of permanent watering points. However, both Did-Hara and Did-Yabello are currently used for year-round grazing as a result of permanent pond development and subsequent human settlement. Dubluq, Madhacho, Melbana and Web are known as traditional well zones because of the presence of clusters of traditional deep wells that are used during the dry season, and the first three are situated 60, 80 and 140 km south of Yabello town (4°47′N, 38°12′E), respectively. Did-Yabello and Did-Tuyura are 15 and 17 km north-east of Yabello town, respectively, whereas Did-Hara and Web are 30 and 140 km east and south-east of Yabello town.

Assessment of range condition

A survey was conducted during both the long and short rainy seasons of 1998 when most grass species were at the full flowering stage, which is important for identification purposes. Twenty-one transects, 3–10 km in length, were established in the 6 communal grazing areas and on one Government ranch. Areas disturbed by cultivation were avoided. Each area, including the ranch, covered 3 elevation zones: low (1250–1500 m), medium (1500–1650 m) and high (1650–2000 m). One transect was selected in each elevation zone in all areas. An altimeter was used to measure the elevations of the sampling sites. The history of the rangelands indicated that the different elevation ranges had been subjected to differing grazing pressures, with the bottomlands considered as heavily grazed transects because of their proximity to watering points, whereas the medium and toplands were regarded as moderately and lightly grazed sites, respectively.

Each transect had 4 sample sites. Transects were selected in such a way that they covered: (i) 2 encroached and 2 non-encroached rangeland sites; and (ii) different distances from watering points within transects. The distance of the first sample site of the transects from water sources differed (2–15 km) according to elevation. When there were nil or scattered shrubs, bushes and trees, the rangeland was considered to be open or non-encroached, and when the shrubs, bushes and tree canopy were more than 40%, it was considered to be encroached (based on visual observation).

At each sample site, the range condition of the central site in a representative area was assessed by 4 observers who radiated out to about 100 m from the central site in a circular fashion for individual assessment and came together for a group assessment from the central position, resulting in a total of 5 assessments per sample site and an average of the 5 observations was taken. Grass composition, age distribution, soil erosion and soil compaction were determined in this manner within a 100 m radius from the central site.

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, size distribution of dominant grasses and soil condition (soil erosion and compaction), which were considered the critical criteria for describing condition of semi-arid rangelands in southern Africa (Ivy 1969; Tainton 1981; Baars *et al*. 1997). A maximum score of 10 points each was given for 3 of the factors (grass composition, basal cover and litter cover) and a maximum score of 5 points each for the remaining 4 factors (number of seedlings, size distribution, soil erosion and soil compaction), summing to a maximum possible score of 50 points. The total rating was interpreted as follows: very poor (≤ 10); poor (11–20); fair (21–30); good (31–40); and excellent (41–50 points).

Grass composition (1–10 points). The assessments were carried out late in the long and short rainy seasons of 1998, when most grasses were flowering. Plants with full flowering heads and other vegetative parts were used for identification. The identification of the species was carried out according to the guidelines developed by Fromman and Persson (1974), and by comparing with specimens in the herbarium. Classification of grasses according to succession theory (Dyksterhuis 1949) into desirable species likely to decrease with heavy grazing pressure (decreasers), intermediate species likely 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 rangelands of southern Africa (Ivy 1969; Tainton 1981). These were augmented by the opinions of Borana elders on the palatability of a particular species. Information was gathered from pastoralists and key informants (herdsmen) on vigour and palatability of a particular species. A species with high palatability was considered a decreaser, whereas a species with medium palatability, that is not affected by grazing pressure, was considered an increaser. Scores were based on visual estimation of percentage of decreasers or increasers at each sampling site (Table 1).

Table 1. Rating of range condition based on percentage of increasers or decreasers in the sward.

Percent of increasers or decreasers	Score
91–100% decreasers	10
81–90% decreasers	9
71–80% decreasers	8
61–70% decreasers	7
51–60% decreasers	6
41–50% decreasers	5
10–40% decreasers and ≥30% increasers	4
10–40% decreasers and <30% increasers	3
<10% decreasers and ≥50% increasers	2
<10% decreasers and <50% increasers	1
Bare ground	0

Basal cover (0–10 points) and litter cover (0–10 points). A representative area of 1 m^2 was selected at each sampling site for detailed assessments and divided into 2 halves. One half was further divided into quarters, one of which was divided into eighths. All plant basal cover in the selected 1 m^2 was cut, transferred while kept together, and drawn in the eighth segment to facilitate visual estimations of basal cover of living parts. Scores of 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 were given for basal covers of 0%, <1%, 1–3%, >3% composed mainly of annuals, >3% mainly perennials, >6% with bare spots, >6% and evenly distributed, >9% with occasional bare spots, >9% and evenly distributed, >12% with slightly bare spots and >12% with no bare spots, respectively. Similarly, litter cover was given scores of 0, 2, 4, 6, 8 and 10 when the cover was <3%, 3–10% with weeds or tree leaves, 3–10% composed mainly of grasses, 11–40% and unevenly distributed, 11–40% and evenly distributed and >40%, respectively (Baars *et al*. 1997). The rating for basal cover for tufted species was considered 'excellent' when the eighth was completely filled (12.5%) and 'very poor' when the cover was less than 3%. The rating for litter cover within the same area of 1 m^2 was considered 'excellent' when it exceeded 40% and 'poor' when less than 10%.

Number of seedlings (0–5 points). The number of seedlings at each sampling site was counted using 3 areas, 10 m apart, equal to the size of an A4 sheet of paper (30 cm x 21 cm) chosen at random. The sheet was dropped from a height of 2 m above the ground. Scores of 0, 1, 2, 3, 4 and 5 were given if the numbers of seedlings in the area outlined by the A4 paper were 0, 1, 2, 3, 4 and >4, respectively.

Size distribution (1–5 points). Size distribution, which was considered to reflect the age of the plants, was based on visual observation and estimation of the size of the grass tussocks within the 100 m radius in a circular form. When all size categories (small, medium and large plants of the dominant species) were present, the maximum score of 5 points was given. Small and medium-sized plants were defined as having approximately 20% and 50%, respectively, of the biomass of large mature plants of the dominant species. A score of 4 was given when both small and medium-size groups were present, while scores of 3 and 2 were given when only large and medium-size groups of plants, respectively, were present. When there were only small plants, the minimum score of 1 point was given.

Soil erosion (0–5 points) and soil compaction (1–5 points). Soil erosion was based on the amount of pedestals (higher part 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). If there was no sign of soil erosion (no soil movement), a maximum score of 5 was given and a minimum score of 0 was given in situations where gully formation was observed due to soil erosion. The occurrence of slight sand mulch, slope-sided pedestals, steep-sided pedestals and pavements coincided with scores of 4, 3, 2 and 1, respectively. Soil compaction was based on the amount of capping (crust formation). If there was no compaction, a maximum score of 5 was given and the scores decreased with increasing capping of the soil. Scores of 4, 3, 2 and 1 were given for soils with isolated capping, >50% capping, >75% capping and almost 100% capping, respectively.

Statistical analysis

Analysis of variance was carried out using the General Linear Models Procedure of the Statistical Analysis System (SAS 1993). The model included elevation, season, location and bush encroachment in a factorial arrangement. Differences were considered significant at $P < 0.05$. The statistical significance of the differences between means was tested using the Least Significant Difference (LSD) procedure.

Results

Seasonal variation

Table 2 shows the effect of season on condition of the rangelands in Borana. There were no significant differences between the long and short rainy seasons in grass composition, basal cover, litter cover and size distribution of the dominant grasses. However, values for the number of seedlings, soil condition and total score were significantly higher ($P < 0.05$) during the long rainy season than the short rainy season. Based on the total score, the overall condition of the rangeland was in the lower 'good' range condition class during the long rainy season, but had declined to the upper 'fair' range condition class during the short rainy season.

Table 2. The effect of season on the condition of rangelands in Borana (see text for scoring systems).

Parameter	Season		s.e.
	Long rainy season	Short rainy season	
Grass composition	5.9	6.1	±0.15
Basal cover	5.8	5.5	±0.18
Litter cover	4.5	4.0	±0.21
Number of seedlings	2.9a[1]	1.7b	±0.16
Size distribution	4.5	4.4	±0.07
Soil condition[2]	7.6a	7.2b	±0.08
Total score	31.3a	28.9b	±0.52

[1] Within rows, means followed by different letters are significantly different at $P = 0.05$.
[2] Soil condition = soil erosion + soil compaction.

Effect of elevation on range condition

There were no significant differences in ratings for grass composition, basal cover, litter cover, size distribution and total score among the 3 elevations, but there were more seedlings ($P < 0.05$) at higher elevation than at medium elevation (Table 3). On the other hand, soil condition declined as elevation increased ($P < 0.05$). The total score showed that the condition of the rangeland at all 3 elevations lies in the transition zone between 'fair' and 'good' range condition.

Table 3. The effect of elevation on the condition of rangelands in Borana (see text for scoring systems).

Parameter	Elevation			s.e.
	Topland	Medium	Bottomland	
Grass composition	5.8	6.0	6.3	±0.18
Basal cover	5.5	5.6	5.9	±0.22
Litter cover	4.3	4.4	4.1	±0.26
Number of seedlings	2.6a[1]	2.1b	2.3ab	±0.20
Size distribution	4.5	4.3	4.5	±0.08
Soil condition[2]	7.3b	7.4ab	7.6a	±0.10
Total score	29.9	29.7	30.7	±0.64

[1] Within rows, means followed by different letters are significantly different at P = 0.05.
[2] Soil condition = soil erosion + soil compaction.

Encroached vs non-encroached rangelands

Grass composition, basal cover, litter cover, number of seedlings, soil condition and total score were significantly lower ($P < 0.05$) in encroached rangelands than non-encroached rangelands (Table 4). However, size distribution of the dominant grasses showed no significant difference between encroached and non-encroached sites. The total scores showed that the bush-encroached rangelands are towards the top of the 'fair' condition range, whereas the non-encroached rangelands are in the lower part of the 'good' condition range.

Table 4. The effect of bush encroachment on condition of rangelands in Borana (see text for scoring systems).

Parameter	Non-encroached	Encroached	s.e.
Grass composition	6.6a[1]	5.4b	±0.15
Basal cover	6.5a	4.8b	±0.18
Litter cover	4.6a	3.9b	±0.21
Number of seedlings	2.6a	2.1b	±0.16
Size distribution	4.4	4.4	±0.07
Soil condition[2]	7.8a	7.0b	±0.09
Total score	32.5a	27.6b	±0.52

[1] Within rows, means followed by different letters are significantly different at P = 0.05.
[2] Soil condition = soil erosion + soil compaction.

The effect of location

Table 5 shows the effect of location on the condition of rangelands in Borana. There were significant differences between locations for all parameters measured. While these differences were somewhat inconsistent, the overall scores for rangelands at Did-Tuyura and Web were highest with the score for Did-Yabello lowest.

Discussion

The basic assumptions made in this study were that, if other variables influencing range condition were the same in most cases, any differences must be the result of seasonal variation, elevation, bush encroachment and site differences. The findings confirm that season, bush encroachment and location of the rangeland had significant effects

Table 5. The effect of location on the condition of rangelands in Borana (see text for scoring systems).

Parameter	Location[1]							s.e.
	DT	DY	DH	MDH	MEL	WEB	DBL	
Grass composition	6.7a[2]	5.3d	5.5cd	5.8cd	6.0bcd	6.8a	6.2abc	±0.27
Basal cover	5.9ab	4.5c	5.1bc	6.0ab	6.1a	6.2a	5.6ab	±0.33
Litter cover	4.9ab	3.5c	3.5c	5.1a	4.3abc	4.5abc	3.9bc	±0.39
Number of seedlings	4.0a	2.2bc	3.0b	0.6d	2.3bc	2.9b	1.5c	±0.31
Size distribution	4.9a	4.0d	4.4bcd	4.4bcd	4.3cd	4.7ab	4.4bc	±0.12
Soil condition[3]	7.6ab	6.7d	7.0cd	7.3bc	7.9a	7.6ab	7.8a	±0.16
Total score	33.9a	26.2d	28.4cd	29.1c	30.8bc	32.7ab	29.5c	±0.97

[1]DT = Did-Tuyura; DY = Did-Yabello; DH = Did-Hara; MDH = Madhacho; MEL = Melbana; WEB = Web; DBL = Dubluq.
[2] Within rows, means followed by different letters are significantly different at P = 0.05.
[3] Soil condition = soil erosion + soil compaction.

on the condition of the rangelands. The higher overall range condition scores during the long rainy season as compared with the short rainy season were probably due to more available moisture during the long rainy season leading to better soil condition and more seedlings. However, the availability of moisture in both seasons could contribute to the lack of significant differences between the two seasons in most parameters studied. Examining condition at the end of the long dry season might reveal a better picture of seasonal effects. The lower condition scores for encroached rangelands resulted from decreased grass cover and growth of grasses plus inferior pasture composition under encroached areas and replacement of former grassland by bushes and woodland (Oba *et al*. 2000). Similar results were reported by Ayana and Baars (2000). Bush encroachment resulted in a decline in range condition score due to changes in vegetation composition (loss of herbaceous species and invasion by woody and shrubby species) and significant decline in basal cover and litter cover. However, the difference in range condition among the different elevation categories was minimal and confounded by the differences in grazing pressure based on availability of water and grazing strategy of the pastoralists.

Grass composition was better in the traditional well complex areas and the ranch where both traditional and ranch management practices were relatively better than in the other communal land use types. Grass composition in these areas was better than in the remaining communal land use types where traditional grazing management is no longer practised. It was also observed that the total score for rangeland on the government ranch (Did-Tuyura) was higher than that of the communal grazing areas with the exception of Web. In general, the range condition of the communal grazing areas was better in Web ($P < 0.05$) and tended to be higher ($P > 0.05$) in the other traditional well zones such as Melbana, Dubluq and Madhacho as compared with the traditional wet season grazing area (Did-Hara).

Permanent settlement and encroachment of cropping in communal grazing areas appear to be the main factors contributing to the relatively lower total score attained in Did-Hara and Did-Yabello. Did-Hara was a wildlife sanctuary before 1960 and served as a wet season grazing land for livestock from Yabello, Arero and Dubluq localities. The area had two traditional ponds used for a short period of time (usually 3–4 months) during the wet season, after which the population shifted to the dry season grazing area (Oba 1998). These patterns of seasonal grazing left the rangelands less overgrazed and resilient. However, a large population of livestock and human settlements were attracted to Did-Hara following the establishment of permanent water sources in the 1970s. According to Oba (1998), the number of settlements in Did-Hara increased by 200% between 1974 and 1990. Accordingly, the grazing pattern was altered from wet season to year-round grazing because of availability of permanent water points in the traditional wet season rangelands. Similarly, the adoption of range enclosures and expansion of cultivation for crop production, following pond development and permanent settlement leading to year-round grazing, appear to be the main factors contributing to the relatively low condition score of the rangelands both in Did-Hara and Did-Yabello.

The areas used for assessments of basal cover, litter cover and number of seedlings were minimal. We would have preferred to sample much larger areas by examining many more quadrats but availability of resources was limited. However, our visual observations on a wider scale would suggest that the results obtained are indicative of the overall picture for each location and site. In general, the mean range condition of the study area varied from good to fair for the different parameters used in the assessment, which is higher than the range condition reported by Oba *et al*. (2000) for Borana rangelands. The mean values for condition score in our study tend to mask the range of scores recorded. A limited number of extreme total score values were recorded at some sample sites ranging from as low as 17.5 (poor) in Did-Yabello to as high as 42.9 (excellent) in Did-Tuyura. Considering individual sampling sites, 62% and 33% of the ratings per site fell in fair and good condition classes, respectively, whereas 3% and 2% of the sample sites fell in excellent and poor condition classes, respectively. According to Oba *et al.* (2000), 30% of the landscape patch types included in their assessment showed poor range condition, whereas 41%, 26% and 3% of the landscape patch types showed fair, good and excellent range condition, respectively. The spatial and temporal differences in sampling site and time of the year could be the main reasons for the different outcomes of the two studies.

Soil condition is the sum of soil erosion and soil compaction and the overall condition of the soil was good, which is in agreement with the findings of Oba *et al*. (2000), who reported that soil erosion was generally low. Soil condition was lowest in Did-Yabello, which could be due to many years of human settlement, year-round grazing and expansion of cultivation for crop production. Differences in range condition between seasons and encroached *vs* non-encroached, as well as among elevations and locations, may be the result of climatic variation (amount and distribution of rainfall) and management factors.

The overall condition of the rangelands varied from fair to the lower margin of good condition class. The mean total condition score varied within a narrow range of 26–34 with relatively small differences in magnitude between seasons, elevations, locations and bush-encroached and non-encroached sites in the rangelands. The Borana rangelands had the reputation of being well managed at least until the early 1980s and the decline in the condition of the rangelands is a fairly recent phenomenon, which could be one of the reasons for the relatively narrow range in the range condition classes among the different factors considered.

The observations made in this study support earlier reports (Alemayehu 1998; Oba 1998; Oba *et al*. 2000; Oba and Kotile 2001; Desta and Coppock 2004), indicating that the Borana rangelands are showing a gradual decline in condition due to increased pressure, shrinkage of grazing area, ethnic conflicts and displacement from large parts of grazing lands resulting from the demarcation of regional boundaries and loss of wet season grazing lands to cultivation and ranching, that further contributed to bush encroachment and loss of perennial grasses with the added complication of bans on use of fire. Thus, concerted efforts are needed to curb the increasing bush encroachment and the decline in the condition of the rangelands. To this end, a study on bush encroachment as a process of landscape change in Borana rangelands is currently underway to identify the underlying causes of bush encroachment as a basis for future range management. Expansion of cropping as a means of diversification of livelihoods in the pastoral areas should also be carried out with great caution. In general, due attention should be given to the traditional wisdom of the pastoralists in resource management in future pastoral development initiatives.

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