Effect of Manure on Grazing Lands in Ethiopia, East African Highlands

Authors: Girma Taddesse, Don Peden, Astatke Abiye, and Ayaleneh Wagnew

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Biomass productivity, botanical composition, and soil physical properties were studied under conditions with and without application of manure. The study was conducted at the Debre Zeit station of the International Livestock Research Institute, located 5 km from Addis Ababa in the Ethiopian highlands. The aim of the study was to assess the effect of manure on botanical composition, plant biomass, and water infiltration rates. There were 3 treatments: no grazing, moderate grazing (MDG = 1.8 animal unit months [AUM]/hectare), and heavy grazing (HVG = 4.2 AUM/hectare), each replicated 4 times. Removing cow dung from grazed plots decreased biomass production. Species richness was higher on manured plots than on nonmanured plots. The water infiltration rate was low on grazed and nongrazed plots with no manure when compared with the manured plots.

Keywords: *Grazing pressure; biomass productivity; afromontane grassland; species richness; infiltration rate; Ethiopia.*

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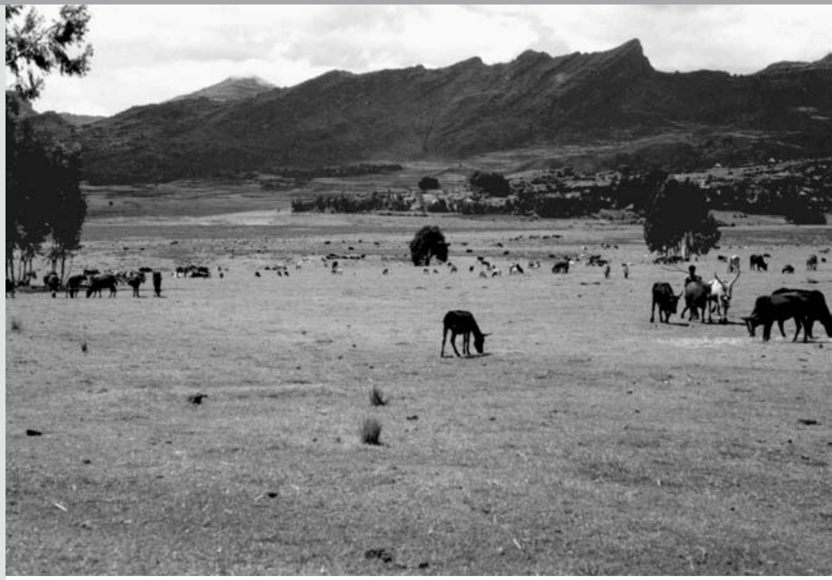

FIGURE 1 Valley floor with livestock. (Photo by Girma Taddesse)

Introduction

High stocking rates can lead to rapid change in botanical composition and pasture productivity, attributed to defoliation and dispersion of seeds (Woldu Zerihun 1986; Woldu Zerihun and Mohamed Saleem 2000; Girma Taddesse et al 2002a,b). The hoofs and bodies of grazing animals can disperse plant species from previous sites to new grazing land, thus fostering diversification of plant species. Inappropriate grazing practices can lead to heavy soil trampling, low water infiltration into the soil, heavy runoff, and high rates of soil erosion (Mwendera and Mohamed Saleem 1997; Girma Taddesse et al 2002c). The afromontane grasslands of East Africa are under enormous pressure as a result of uncontrolled grazing and heavy stocking. Farmers collect cow dung from barns and grazed fields to use as fuel; however, this common practice reduces soil fertility and nutrient recycling on grazing land (Girma Taddesse 2001). Though there is awareness of the environmental benefits of spreading livestock manure, alternative materials for fuelwood are becoming very scarce as a result of deforestation (Van den Bosh et al 1998). During the cropping season, livestock move from valley floors to the uplands, where high livestock density creates great pressure on vegetative cover and is responsible for denudation of plant cover in the mountainous region (Girma Taddesse et al 2002a,b).

Lack of adequate vegetative cover during heavy rains creates severe soil erosion and formation of wide gullies in agricultural fields on fragmented bottomland. During the dry season, livestock are concentrated on communal grazing land and allowed to graze freely on crop residues after agricultural fields have been harvested. Small streams running to the valley floor create favorable moisture conditions for grasses to rejuvenate (Figure 1). However, overgrazing, heavy stocking, and less livestock feed have resulted in degraded grazing land. Moreover, dung dropped during the rainy season is washed away by runoff. Recycling manure to the soil through a precise manure management plan is efficient and practical. This optimizes the nutrient value of the manure while minimizing potential environmental hazards. Manure is a valuable farm resource and should be treated as an asset. Thus, an understanding of nutrient cycling within soil–plant–animal grazing systems, change in herbage production, and infiltration rates is of great importance in grazing land ecosystems.

Site and methods

Study site

The study was conducted at the Debre Zeit station of the International Livestock Research Institute, located 50 km southeast of Addis Ababa at an altitude of 1850 m

FIGURE 2 Location of study area in Ethiopia. (Map by Andreas Brodbeck)

(8°44'N, 38°58'E; see Figure 2). The soil at the experimental site is an Alfisol (Kamara and Haque 1988), and the site receives unimodal rainfall, with a short rainy season between March and April and a long rainy season between June and mid-September.

Experimental design

Twelve fenced plots (20 m × 40 m) were established with 3 treatments and 2 subtreatments along a 0–10% slope in 1998. Two subtreatments were set on each main plot and invisibly demarcated into 2 equal halves. Dung was removed from the first subplot and left on the second subplot for nutrient recycling (Figure 3). The grazing experiment included 3 treatments: no animal grazing with permanent fencing, moderate grazing (MDG = 1.8 animal unit months [AUM]/hectare), and heavy grazing (HVG = 4.2 AUM/hectare). Each treatment was confined to a plot and replicated 4 times.

The animals were allowed to graze every day, and the fresh dung was collected immediately after grazing from each plot and weighed. Dry matter content was determined after drying at 68°C. The grazing regimes were converted to stocking density and stocking rate. Stocking rate was calculated on a monthly basis as AUM per hectare, which is defined as stocking density multiplied by the number of months of grazing. The animals used in the experiment were crossbred and local zebu cows. Normally, an AU is defined as a 450-kg steer at 30 months of age, whereas a tropical livestock unit is defined as a 250-kg mature zebu kept at maintenance (LeHouerou 1989). Stocking rate is defined as follows:

Stocking rate = mean stocking density (AU/hectare) × time (months)

Two mobile wooden cages (1 m × 1 m) were used for vegetation sampling for each subplot, and cages were moved randomly to a new location every month. The samples were clipped to ground level once a month within and outside the cages to measure regrowth, residual, and biomass consumed by the animals. The clipped samples were oven-dried at 70°C for 24 hours and weighed, and the biomass was calculated (in tons/hectare) (Edwards 1981).

Infiltration rate was measured on each subplot using a double-ring infiltrometer to measure the impact of livestock trampling on soils (Bower 1986).

Data analysis

Data were subjected to statistical analysis. Data were analyzed using general linear model multivariate and simple linear correlations. For the linear correlation, Pearson's parametric bivariate was used to examine interaction among the variables (SPSS 1999).

Results

The linear model for multivariate tests showed that the model was significant. Thus, species richness and infiltration rate varied significantly by year. Infiltration rate, biomass yield, species richness, soil moisture, and bulk density varied significantly with grazing pressure. Apart from the infiltration rate, all parameters measured were statistically significant with the treatments. Similar trends were observed when linear bivariate correlation statistical analysis was run (Table 1).

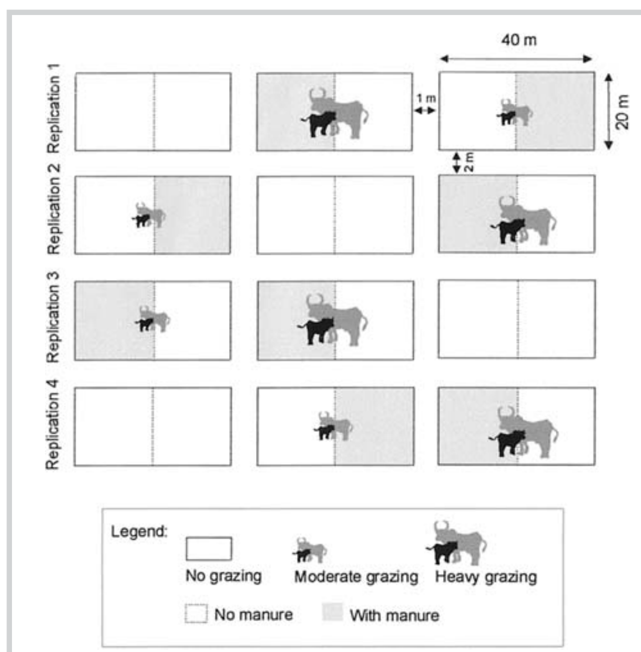

FIGURE 3 Experimental layout of plots.

TABLE 1 Parametric bivariate correlation according to Pearson, as influenced by grazing pressure and manure.

Source	Year	Treatment	Biomass (tons/hectare)	Species richness	Soil moisture (kg/kg)	Bulk density (g/cm^3)	Infiltration rate (cm/h)
Year				0.513**			–0.385*
Treatment			–0.691**		–0.639**	0.547**	
Biomass (tons/hectare)				0.521**	0.423**	0.631**	
Species richness (%)							
Soil moisture (%)						–0.358**	

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

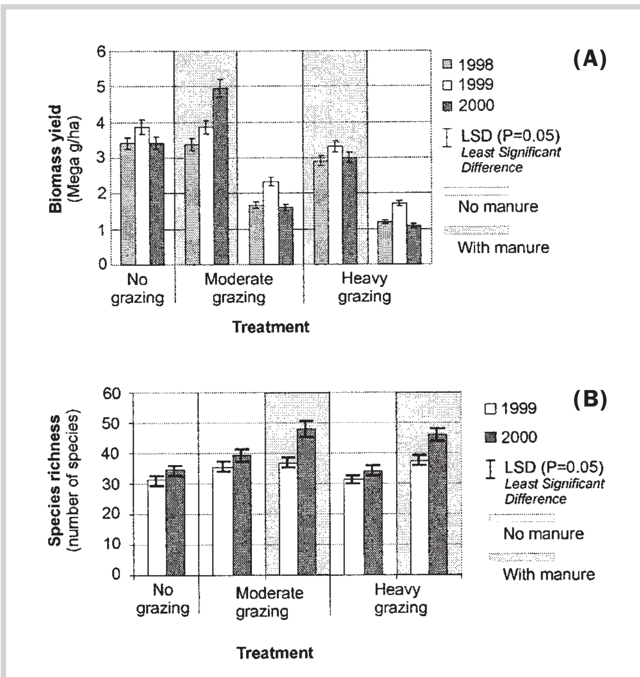

FIGURE 4 Effect of grazing and manure on (A) biomass yield (1998–2001) and (B) species richness (1999–2001).

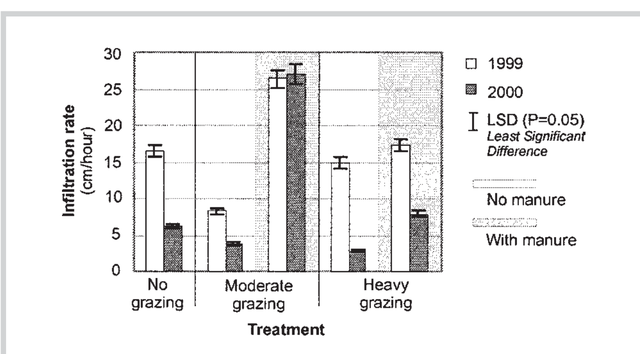

FIGURE 5 Effect of grazing and manure on infiltration rate, 1999–2001.

The results indicated that collecting manure from grazed plots resulted in reduced biomass production in comparison with manured plots. The biomass yield on manured plots that were moderately and heavily grazed was 23.6% and 23.2% higher, respectively, than on plots with no manure (Figure 4A). Species richness was greater on moderately grazed plots with manure than on plots with other treatments (Figure 4B).

The dominant species cover showed an increase on heavily grazed plots with manure when compared with nonmanured plots (Table 2). A similar trend was also obtained on moderately grazed plots with manure. On nongrazed plots, *Bothriochloa insculpta* and *Hyparrhenia hirta* were dominant. However, on the manured plots in both years, *Cynodon dactylon*, *B. insculpta*, and *H. hirta* were common. There was less species richness on non-grazed, nonmanured grazing plots and on heavily grazed manured plots, and plant species richness on nonmanured grazed plots was lower than on nongrazed manured plots.

Heavy trampling or high stocking rates and removal of cow dung from grazed plots reduced infiltration rates on heavily grazed plots. The results showed that livestock trampling and removal of cow dung from grazed plots reduced infiltration rates on heavily grazed plots (Figure 5). On nongrazed plots, infiltration rates were lower than on moderately grazed manured plots. This indicates the positive impact of manure on soil hydrological properties.

Discussion and conclusions

The effects of different grazing pressure and manure on grassland ecosystems requires careful assessment. Available research results and observations do not support the assertion that moderate livestock grazing is harmful to grazing lands (Girma Taddesse et al 2002a,b). Although we cannot generalize across the various mountainous regions, results indicate that moderate grazing facilitates greater plant species richness on grazing land than no grazing and very heavy grazing. Inappropriate grazing practices damage plant herbage and grass growth through trampling, browsing, and

TABLE 2 Effect of grazing pressure and manure on dominant species cover (species listed if cover is at least 5%). Individual species were counted and the percentage of each as a part of total vegetative cover per plot calculated. Species turnover rates were not calculated in this study.

		No manure			With manure	
Year	Dominant species	No grazing	Moderate grazing	Heavy grazing	Moderate grazing	Heavy grazing
1999	*Aristida adoensis*			5.0	–	–
	Bothriochloa insculpta		15.0	10.0	20.0	10.0
	Chloris gayana	10.0	10.0		–	–
	Cynodon dactylon	20.0	10.0		11.7	15.0
	Digitaria velutina		10.0		–	–
	Desmodium intortum	13.3		10.0		10.0
	Eragrostis tenuifolia	–	–	–		10.0
	Harpachne schimperi		11.0	10.0	7.5	
	Hyparrhenia hirta		10.0		15.5	7.5
	Hyparrhenia arrhenobasis	12.5	5.0	10.0	15.0	10.0
	Laggera pterodonta	5.0	10.0	10.0	15.0	
	Notonia abyssinica	10.0			10.0	
	Solanum incanum	15.0	5.0		5.0	
	Sporobolus africanus	5.0	0.0	5.0		12.5
	Vernonia leopoldii	–	–	–		5.0
	Total cover (% dominant species)	**90.8**	**86.0**	**60.0**	**99.2**	**80.0**
2000	*Bothriochloa insculpta*	17.5	22.5	25.0	22.4	20.0
	Chloris gayana			15.0	–	–
	Chloris pychnothrix	–	–	–		10.0
	Cynodon dactylon			13.8	10.0	8.0
	Digitaria scalarum		12.5		8.8	16.7
	Desmodium intortum	10.0	15.0		–	–
	Eragrostis tenuifolia			10.0	–	–
	Gynotroches axillaris	10.0			10.0	
	Harpachne schimperi		17.5			10.0
	Hyparrhenia hirta	38.3	17.5	15.0	30.0	29.2
	Hyparrhenia rufa	–	–	–	5.0	
	Medicago polymorpha	10.0			–	–
	Styloxanthus fruticosa			12.5	–	–
	Tagetes minuta	10.5			–	–
	Notonia abyssinica	–	–	–	8.0	
	Total cover (% dominant species)	**96.3**	**85.0**	**91.3**	**94.0**	**93.9**

damage to plant roots (Mwendera et al 1997). Uncontrolled grazing has negative effects in afromontane grassland ecosystems (Woldu Zerihun 1986; Woldu Zerihun and Mohamed Saleem 2000). Overgrazing compacts soils, leading to increased bulk densities, decreased infiltration rates, and increased surface runoff (Mwendera and Mohamed Saleem 1997; Girma Taddesse et al 2002c). In mountainous regions of East Africa, erosion caused by cattle trampling generally is found on certain road tracts frequently used for migration and at animal watering points (Raghavan et al 1990; Girma Taddesse 2001).

Fragmented agricultural land evolved under intensive crop production, competing with grazing land and driving it to marginal areas. Elimination of grazing land along with cropland therefore resulted in different species composition, poor soil fertility, and poor vegetation cover. In the absence of fertilizer or manure inputs, agricultural production appears to be impossible without grazing land, given the necessity of nutrient transfer from livestock to agricultural and grazing land (Girma Taddesse 2001). Therefore, livestock is still the key factor that makes it possible for farmers in East Africa to practice sustainable economic development in a relatively infertile mountain environment. Collecting cow dung dropped on grazing land for use as fuel—a common practice in the Ethiopian highlands—hampers plant nutrient cycling in livestock–crop-grazing land ecosystems. As communal and private grazing lands are converted to cropland production systems, rural households are giving up livestock production on bottomlands and moving into afromontane grasslands at higher elevations. There is a serious misconception that livestock grazing frequently causes severe land degradation. However, several studies have shown that proper management of grazing land improves nutrient recycling, plant attributes, and species richness (Powell et al 1995; Mohamed Saleem 1998; Van den Bosh et al 1998).

It must be emphasized that uncontrolled grazing with high animal population densities is harmful to grassland ecosystems (Turner et al 1993). Studies in East Africa and elsewhere have shown that the problems related to excessive use of these common resources can only be solved by involving rural populations in grazing land management, thus giving them a feeling of ownership (Girma Taddesse et al 2002a,b).

The following conclusions are significant in light of the results obtained here.

- Improper management of grazing land, such as high stocking density, resulted in low biomass yield. Heavy grazing degrades the herbage cover on grazing land.
- Moderate livestock grazing improves species richness, plant attributes, and cover.
- Allowing cow dung to recycle on the grazing field improves soil hydrological properties such as water infiltration.
- The practice of collecting cow dung from grazing fields and using it for fuel should be halted through the use of alternative fuel sources because this practice hinders nutrient transfer to grazing land.
- Crop and livestock production should be harmonized to avoid land degradation to diminish fragmentation of agricultural land in East African highland grazing areas.

AUTHORS

Girma Taddesse, Don Peden, Astatke Abiye, and Ayaleneh Wagnew
International Livestock Research Institute (ILRI), PO Box 5689, Addis Ababa, Ethiopia.
g.taddesse@cgiar.org (G.T.), d.peden@cgiar.org (D.P.), a.abiye@cgiar.org (A.A.), and a.wagnew@cgiar.org (W.A.)

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