GLOBAL LIVESTOCK CRSP

Changes in Land Cover and Soil Conditions for the Yabelo District of the Borana Plateau, 1973-2003

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It has been proposed that the Borana Plateau has markedly changed in terms of land cover and land use in recent decades, but no hard data have been available to critically assess this claim. In addition, systematic analysis of soil properties has been limited. Research was designed to measure changes in land cover/land use over 30 years in the 400-km² Yabelo District of southern Ethiopia using three satellite images taken at an average interval of 15 years. Samples were also collected to assess variation in the physical and chemical properties of dominant soils. Results indicated that Yabelo District has indeed changed greatly in terms of land use and land cover; dramatic declines were noted in the extent of grasslands, while croplands increased five-fold, and bushed-grasslands and bushlands both increased substantially. Bushland soils had less organic matter and were more compacted than grassland soils. These results all support the idea that the productive capacity of this landscape for grazing has been markedly reduced in 2003 as compared to that for 1973. Rehabilitating the grazing system would be difficult and require a comprehensive, inter-disciplinary approach. Central to such an approach would be devising a well-informed land use plan.

Background

It has been proposed that the livelihoods of pastoral people on the Borana Plateau have changed considerably in recent decades (Desta and Coppock, 2004.) The Boran pastoralists, in particular, have probably gradually shifted from a heavier dependence on livestock products to more dependence on crop cultivation in some locations. For example, maize has reportedly spread in recent decades along drainages on the plateau, and some investigators suspect that it may expand even more as the Boran try to cope with population pressure and food insecurity. Some published evidence suggests that cultivation may have increased on the Borana Plateau from five to 16 percent of the land area over the past 15 years, and this is based on simple calculations from previous rates of spread as limited by suitable farming sites. Other changes in land use or land cover are also reportedly occurring. These include privatization of formerly open-access grazing sites (kalo), bush encroachment, and general ecological degradation of the rangelands. These trends can all have a negative impact on the overall grazing capacity of the ecosystem and hence would be detrimental to traditional use of the resource such as livestock grazing. The Borana pastoralists will be less able to support themselves via livestock production, and be less able to supply livestock and livestock products to markets, if such trends continue. It is therefore important to document land use and land cover changes in support of appropriate land use planning (Coppock, 1994.) One objective of this research, therefore, was to measure land use/land cover change on a portion of the Borana Plateau from 1973 to 2003. Another important issue is the extent that changes have occurred in the productivity of soils. Top soil is a non-renewable resource and it must be managed carefully to promote the sustainability of forage, livestock, and crop production. The second objective of this research thus was to assess the physical and chemical properties of dominant soils to determine whether degradation was occurring. Work was conducted in the Yabelo District of the Borana Plateau. This is one of five districts that comprise the Borana Zone. Yabelo District is situated 570 km south of Addis Ababa and is about 400 km² in size.

Spatial and temporal changes in land use and land cover were quantified at three intervals over the period 1973 to 2003 using remotely sensed data. LandSat images were collected for 1973, 1986, and 2003. Preliminary image interpretation was checked and adjusted via ground truth methods. Data interpretation and analysis were conducted using GIS software. Temporal change patterns over time were automatically produced once the software was calibrated and results were expressed in terms of changes against a baseline reference map. This approach resulted in the analysis of four basic land uses/land cover types: (1) grassland; (2) bushed grassland; (3) bushland; and (4) cropland. The grasslands are typically used for livestock grazing. They tend to be open areas with good visibility on flat areas and hill slopes dominated by perennial herbaceous plants with scattered small shrubs and trees; another descriptive term would be mixed savanna. The bushed grasslands are former grassland sites where woody

shrubs and trees have increased in density to be co-dominant with herbaceous plants in terms of cover. The bushlands are those sites where woody cover is fully mature and herbaceous plants have been almost eliminated. The croplands tend to be drainage sites where moisture accumulates and crops of maize can be grown. Traditionally, such sites have produced perennial grasses for dry-season grazing.

Soil sampling was stratified across the four site types with three repetitions per type. Composite samples were taken according from the surface of certain landscape positions using a coring tool at a depth of 0-20 centimeters. The samples were transported in plastic bags and processed at the National Soils Laboratory in Addis Ababa. The samples were analyzed for standard physical and chemical properties.

Major Findings

Tables 1 and 2 illustrate land use/land cover trends for Yabello District between 1973 and 2003. Dramatic declines in the grassland type were observed, while cropland increased five-fold and both the bushed-grasslands and bushlands increased substantially. These results support the idea that grazing land has been lost to crop cultivation and bush encroachment, in general. The increase in cultivation is the result of several factors. First, recurrent droughts and major death losses of milking cows due to starvation create significant periods of food insecurity for pastoralists. Lack of milk forces them to cultivate to produce calories to fill the gap. Growing their own maize also means that the pastoralists do not have to sell what few stock they have left to buy food. Secondly, due to the gradual change in livelihoods, the Borana have probably become agro-pastoralists in some areas and plan to grow maize as a routine part of their production system. Third, increased access to seeds via local markets may facilitate cultivation as well. Bush encroachment is recognized as one of the biggest threats to the rangelands of the Borana Plateau. Lack of fire and heavy grazing on residual savanna are probably contributing factors to the increase in woody vegetation. The pastoralists reportedly have been unable to use managed fire to control bush since the 1970s. Reoccurring drought may also contribute to vegetation change. Another important indirect cause of bush encroachment is population pressure. The population of Boran was about 300,000 in the 1980s and has reportedly increased to over 500,000 in recent years. More people mean more livestock, more grazing pressure, and a downward spiral in resource condition.

Table 3 illustrates physical features of soils in the study area. In general, these data show how the bushed-grasslands and bushlands differ from grasslands and croplands. The trends for soil texture indicated that, compared to grassland sites, both the bushed sites tended to be sandier with less silt and clay. The bushed sites had significantly higher values for bulk density and soil compaction compared to that for grassland and cropland sites. The overall trend of bulk density and soil compaction is in the order of bushlands > bushed grasslands > croplands > grasslands. What this says is that the bushland sites had the most tightly packed soils.

Table 1. Change in land use/land cover for Yabello District between 1973 and 2003 as interpreted from satellite images.

Land Use/Land Cover Class	1973		1986		2003	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Bushlands	80.0	20.0	100.0	25.0	115.0	28.8
Bushed-grasslands	134.0	33.5	161.0	40.3	198.0	49.5
Grasslands	173.0	43.3	106.0	26.5	24.0	6.0
Croplands	13.0	3.3	33.0	8.3	63.0	15.8
Total	**400.0**	**100.0**	**400.0**	**100.0**	**400.0**	**100.0**

Table 2. Percentage change in land use/land cover for Yabello District between 1973 and 2003 as interpreted from satellite images.

Land use class	Area in 1973		Percent change in land use		
	(km^2)	%	1973-1986	1986-2003	1973-2003
Bushlands	80	20.0	+25.0	+15.0	+43.8
Bushed-grasslands	134	33.5	+20.1	+23.0	+47.8
Grasslands	173	43.3	-38.7	-77.4	-86.1
Croplands	13	3.3	+153.8	+84.8	+384.6

Table 3. Mean values of physical properties of soils as affected by land use/land cover.

Land use type	*Textural classes (%)			Tex. class	BD (g cm^{-3})*	COMP (kg cm^{-2})
	Sand	Silt	Clay			
Grasslands	39b	25a	36a	CL	1.37b	1.85d
Bushed-Grasslands	52ab	14b	34a	SCL	1.60a	3.11b
Bushlands	71a	9b	20a	SL	1.70a	4.35a
Croplands	40b	22a	38a	CL	1.42b	2.64c
LSD (0.05)	21.8	5.9	18.9	-	0.23	0.16
SEM (±)	8.92	2.42	7.70	-	0.09	0.07

**Means within a column followed by the same letter are not significantly different at P = 0.05. BD = Bulk density; COMP = Compaction; CL = Clay loam; SCL = Sandy clay loam; SL = Sandy Loam; LSD = Least significant difference; SEM = Standard error of the mean*

When the soil is tightly packed there is less opportunity for water and nutrients to infiltrate, thus contributing to lower plant productivity.

Table 4 illustrates chemical features of the soils. A key indicator is organic matter (OM), as OM can provide a beneficial production environment for plants. The loss of organic matter (OM) in bushlands and bushed-grasslands relative to the other sites is notable. Considering the grasslands as a reference point, the bushlands, bushed-grasslands, and croplands have lost 61%, 30% and 17%, respectively, of their top soil OM content. Croplands were higher in phosphorus and electrical conductivity (an indicator of salinity), which likely reflects their role as drainage sites. Croplands are often in the proximity to livestock holding areas laden with manure. Higher phosphorus levels in cropland soils are most likely due to run-off that transports nutrients from corrals to the fields. It is virtually certain that the Borana do not use any commercial fertilizers.

The soil physical data indicate that the bushed sites are degraded compared to the grassland and cropland sites. If it is assumed that the bushland and bushed-grassland sites were once grassland sites, the texture trends indicate that enhanced soil erosion has probably occurred with the increased prevalence of woody species. Woody species often out-compete herbaceous (grass, herb) species for light and water when grazing is heavy and fire absent. This can result in an under-story devoid of herbaceous vegetation. Sandy textures are heavier and would prevail in bushland and bushed-grassland sites as silt and clay is lost via erosion processes. Exposure of topsoil to rain and trampling by livestock can also lead to changes in bulk density and soil compaction as observed in the data. Compaction of soil surface produces crust which can severely hamper water infiltration and seedling emergence. The soil chemical data also indicate that the bushed sites are degraded compared to the grassland and cropland sites. A key indicator is the decline in soil OM. The loss of herbaceous biomass for nutrient recycling and loss of nutrient-rich top soil via erosion are probably the main contributing factors to changes in OM content.

Practical Implications

The changes in land use/land cover for Yabelo District are striking and support the idea that grazing lands are decreasing on the Borana Plateau. However, care must be taken in extrapolating the data too broadly in the region. Annual rainfall in Yabelo District tends to be at the high end (>650 mm per year) of records for the Borana Plateau, and this is largely because Yabelo District sits at higher elevations. This may predispose Yabelo District to more woody encroachment and cultivation compared to other districts of Borana Zone. These results also indicate that the changes in land use and land cover are associated with

Table 4. Mean values of some chemical properties of soils as affected by different land use types.

Land use type†	pH (H_2O)	*EC (dS m^{-1})	OM (%)	AvP (ppm)
Grasslands	6.40ab	0.07a	3.44c	0.78
Bushed-grasslands	6.40ab	0.08a	2.16b	2.37
Bushlands	5.70a	0.08a	1.36a	0.66
Croplands	7.00b	0.17b	2.85bc	13.85
LSD (0.05)	1.13	0.08	0.79	16.40
SEM (±)	0.46	0.03	0.32	6.70

*†Means within a column followed by the same letter are not significantly different at P = 0.05. *EC = Electrical conductivity; OM = Organic matter; AvP = Available (Olsen) P; ppm = Parts per million; LSD = Least significant difference; SEM = Standard error of the mean.*

fundamental changes in soil physical and chemical properties. The losses in soil OM and increases in soil compaction illustrate how difficult it could be to restore rangeland condition, even with renewal of prescribed burning regimes. The fundamental problems of heavy stocking would have to be corrected as well to have hope to improving herbaceous cover, and hence the physical and chemical properties of top soils.

An appropriate land-use policy is the first step in a process that promotes sustainable use of ecological resources. Efforts to promote lower stocking rates are important for the ecological health of the system, but the reality is that achieving lower stocking rates would be difficult given the pressures on the rangelands to yield livestock products. Assisting the pastoralists to diversify their livelihoods and connect with sustainable livestock markets could help reduce stocking rates in some cases. Degraded sites could be reclaimed using controlled fire and planting indigenous grass species, but it will involve a long process.

Further Reading

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The GL-CRSP Pastoral Risk Management Project (PARIMA) was established in 1997 and conducts research, training, and outreach in an effort to improve welfare of pastoral and agro-pastoral peoples with a focus on northern Kenya and southern Ethiopia. The project is led by Dr. D. Layne Coppock, Utah State University, Email contact: Lcoppock@cc.usu.edu.

The Global Livestock CRSP is comprised of multidisciplinary, collaborative projects focused on human nutrition, economic growth, environment and policy related to animal agriculture and linked by a global theme of risk in a changing environment. The program is active in East Africa, Central Asia and Latin America.

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