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VEGETATION CHANGE IN THE CENTRAL BORANA PLATEAU REGION OF SOUTHERN ETHIOPIA

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Abstract: Vegetation composition was studied in a semi-arid region of southern Ethiopia where bush fires have been banned for the past 25 years. The area is used by the pastoral Borana people and their livestock. Seven vegetation types are described using a hierarchical classificatory technique. Vegetation types that are new to the landscape have developed as a result of bush fire banning and other forms of human interference. Floristic gradients revealed by numerical ordination technique were not strongly related to measured environmental factors, although variation was partially related to soil texture, soil phosphorus levels, and terrain slope. Fire suppression has favoured the invasion of woody plants, resulting in increased cover of communities dominated by *Acacia drepanolobium*, *A. seyal* and *Tarchonanthus camphoratus*. By contrast, the grassland community that formerly dominated the central plateau is shrinking, and a community dominated by *Juniperus procera* and *Olea europea* is facing local extirpation. Removal of invasive woody species, and extraction of livestock through participatory development programs, are suggested as initial management steps to help rehabilitate vegetation diversity and productivity to the conditions existing prior to fire suppression.

Introduction

The environmental impact of forest destruction in Ethiopia has long been recognized (Almeida 1954; Alvares 1961). However, until recently few attempts were made to formulate a long-term policy to protect Ethiopian forests and other natural ecosystems. The first officially declared policies were stated in proclamations by the Imperial Ethiopian Government in 1965 (Proclamations No. 225, 226 and 227). One objective of these proclamations was to promote rational use of all forests in order to maintain their protective character and productivity, and to attain maximum economic benefit taking into account the interests of present and future generations. A prohibition on forest burning was part of this policy. The Democratic Republic of Ethiopia (1974-90) has also passed a circular to all Districts and Peasant Associations forbidding forest fires. A proclamation to provide for the conservation, development and utilization of forests was given by the Transitional Government of Ethiopia in 1994. This proclamation emphasized the objective of forest policy stated by the Imperial Ethiopian Government. In this proclamation, the burning of forests was considered a serious offense that could result in a two-year prison sentence and/or a fine of Birr 5,000.00 (Ethiopian currency), depending on the severity of the offense.

Although the long-term forest policies mentioned above emphasise the protection, rehabilitation and utilization of forest resources, clear policy guidelines regarding ownership and use rights of forest resources are lacking. A clear definition of responsibilities and rights of the Federal and Regional governments, communities and individual citizens of Ethiopia is also lacking. The most glaring drawback of these documents is that little or no concern has been shown for lowland plains and river basins, where the majority of pastoralists and hunter-gatherer peoples of Ethiopia live (Hogg 1996).

Traditionally, Ethiopian pastoralists generally used management systems in which their grazing areas were regularly burned, in order to promote lush new growth for livestock, to reduce populations of ticks and other pests residing in the vegetation, and to discourage intruders and their livestock from using their grazing areas. Invading livestock populations compete for the scarce resources and may carry contagious diseases. From an ecological viewpoint, regular burning controls bush encroachment while maintaining the composition and structure of vegetation, since fire suppresses woody vegetation while enhancing grass production (Walker 1981).

The Borana are a group of lowland pastoralists who managed their rangelands using various traditional methods, including bush fire. Growth of the Borana human and livestock populations, coupled with a steady immigration of other ethnic groups into the area, has increased the pressure on pastoral resources. The suppression of bush fire over the past 25 years has resulted in bush encroachment, aggravating resource depletion. Between 15,000 and 20,000 ha of grazing land in Liben district has been invaded by bush since the cessation of fire, affecting about 120,000 pastoralists (Save the Children 1997).

Until the first decade of the 20th century, the Borana pastoralists occupied most of the Borana plateau (Asmarom

1973). However, the Arsi, Gugi, Marihan and Digola pastoral ethnic groups have claimed access to these pastoral resources, especially during times of severe drought. This has often lead to armed conflicts and breaches of ethnic territoriality.

Past vegetation studies in the area include Pichi-Sermoli (1957), Friis et al. (1982), Coppock (1994), and Torstein (1992). However, none of these studies attempted a quantitative analysis of the vegetation in relation to environmental, edaphic, and anthropogenic factors. This study complements the findings of these previous works, and examines vegetation dynamics in southern Ethiopia. Vegetation physiognomy and regional climate suggest that the region has been experiencing low-intensity fires. It has previously been notes that fires often occur in areas where primary productivity is limited by water and/or nutrients (Christensen 1985).

The specific objective of this study are to quantify vegetation composition of the central plateau of Borana, and to assess vegetation changes resulting from human and livestock population pressures and the cessation of fire management. In addition, we develop recommendations for improving the carrying capacity of these grazing lands by reintroducing controlled burning as a management practice.

Materials and Methods

Study Area

The central Borana plateau consists of rolling plains sloping towards the south and southeast (Fig. 1). Elevation ranges from 900 to 1700 m. The rainfall pattern is bimodal, with the major rainfall period occurring between March and May with a secondary period between September and November (Fig. 2). The average annual rainfall ranges between 500 and 700 mm. The major occupation of the Borana people is pastoralism: they keep cattle, camels, sheep, goats, and some equines. There is some settled agricultural land near Negelle, which is currently the capital of the Zonal Administration.

Plant communities on the flat and undulating plains of the central Borana plateau consist of various mixtures of woody and herbaceous vegetation. The typical physiognomy of the vegetation is suggestive of tropical savanna (Pichi-Sermoli 1957, Pratt & Gwayne 1977). Climatic conditions and soil nutrient status are also typical of tropical savanna (Coppock 1994).

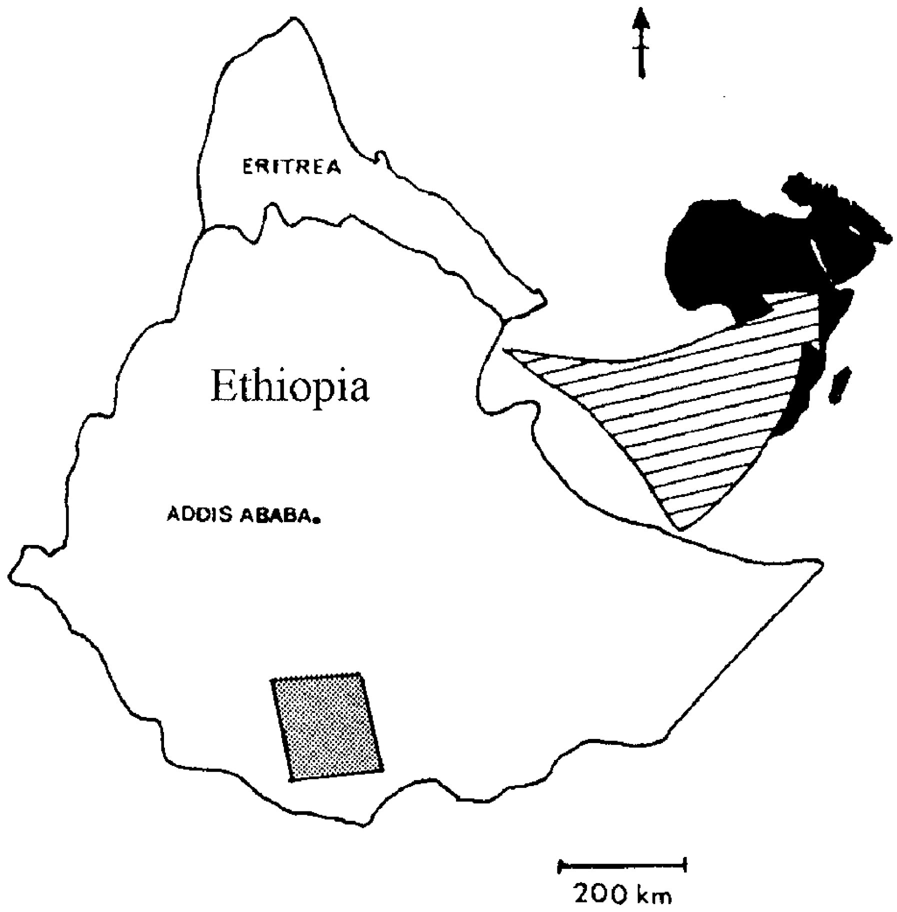

Figure 1. The general location of the study area.

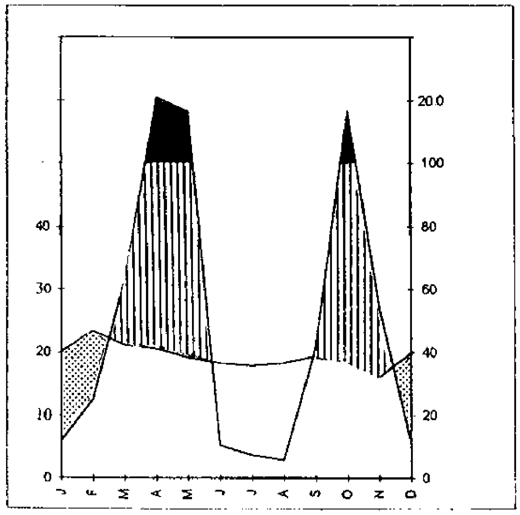

Figure 2. Climate Diagram of Negele, 1430 m.a.s.l, 44 years of observation. Y axis, precipitation in mm and Temperature ^{O}C * 2.

Vegetation and Environmental Data

A reconnaissance survey of the study area was conducted in May 1997, shortly following the long rains in the area. Most plant species were either flowering or fruiting during this time. Discussions were held with the southern Rangeland Development Unit, Borana elders, the Zonal Office of Agriculture, and non-governmental organizations to learn more about the extent of the depletion of pastoral resources, bush encroachment, and other factors contributing to environmental degradation. This reconnaissance survey was useful in obtaining a visual description of general vegetation patterns, and in establishing the apparent vegetation-environment relationships.

Plots were then selected to cover all the physiognomic vegetation types recognized during the reconnaissance survey. Preferential sampling (Orlóci 1978) was followed in selecting 52 relevés. Percent cover of each vascular plant species was recorded in each 20 x 20 m relevé. A total of 221 species were encountered. Botanical nomenclature follows Cufodontis (1953-1972), Hedberg & Edwards (1989,1995), Edwards et al. (1995), and Edwards et al. (1997). Voucher specimens have been deposited in the National Herbarium of Addis Ababa University.

Environmental variables measured or estimated at each relevé included slope (degrees) and edaphic factors. Five soil cores were randomly collected from each relevé at a depth of 0-10 cm. The samples were analyzed for pH (1:1 soil/water ratio), organic matter (Wakley-Black method), available phosphorus (Olsen's method), and texture (hydrometer method) following the procedures outlined in Jou (1978).

Vegetation data were entered into a spreadsheet. Cover values were converted to the modified Braun-Blanquet scale (van der Maarel 1979) prior to multivariate analysis. The vegetation data were converted to Cornell condensed format using the utility programs in the TWINSPAN Package (Hill 1994), and later converted into table format using the utility program in SYNTAX (Podani 1988).

Aerial photographs of the study area were obtained for the years 1964 and 1984, from which were extracted a map showing land-use changes over this twenty year period. Human population data for these dates were obtained from the Central Statistical Office.

Data Analysis: Classification

Studies of vegetation characteristics and processes require methods for classifying and identifying units of internal homogeneity, since the type, intensity and timing of many ecosystem processes may be determined in part by the vegetation (and vice versa). Hierarchical agglomerate clustering was performed on the vegetation matrix using SYNTAX (Podani 1988). The similarity ratio was chosen as the resemblance measure, and average linkage clustering was used to construct the dendrogram (Fig. 3). All vascular species encountered were considered in the analysis. Shannon's diversity index (Shannon & Weaver 1949) was computed separately for each community types, and were tested for significant difference among types.

Ordination

Canonical correspondence analysis (CCA) of the vegetation and environmental data was performed using CANOCO (ter Braak 1987, 1990).

Results

Classification and Analysis of Diversity

Seven distinct community types were recognized from the classification of the floristic data. These types are named using a combination of the dominant species found in each. The maximum cover values of species occurring in the seven community types are summarized in Table 1. Shannon diversity index and species richness values are summarized in Table 2. The community types are significantly different in H' ($P < 0.01$).

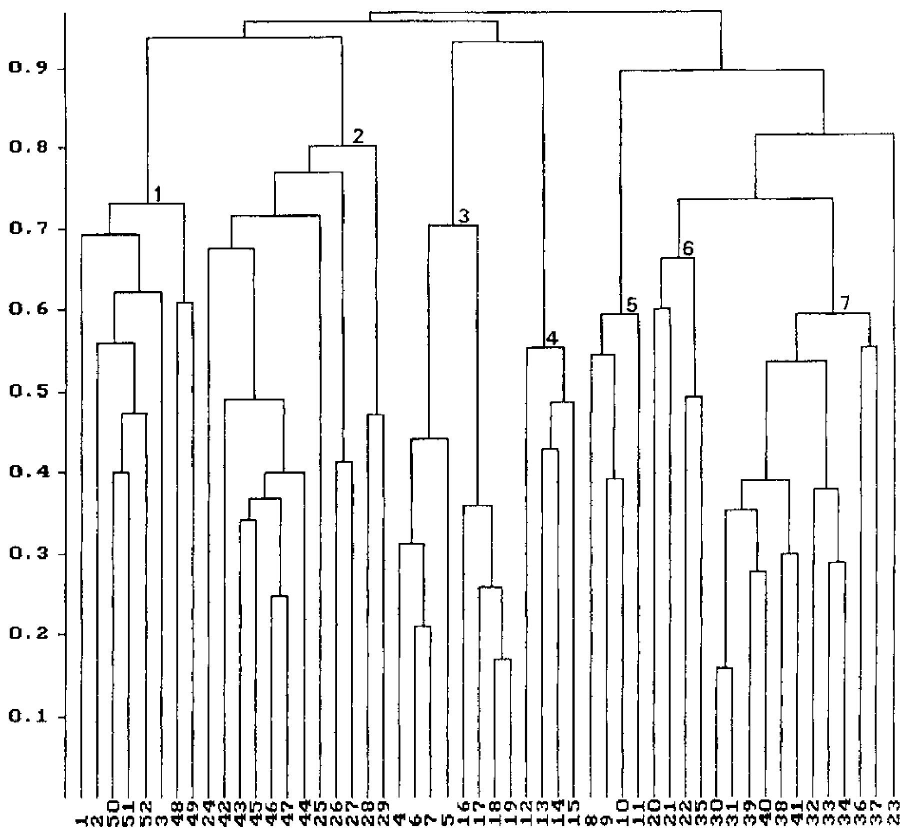

Figure 3. Dendrogram of the relevés, where horizontal axis shows relevés and vertical axis shows the dissimilarity index.

The seven vegetation types are described below.

Type 1. Tarconanthus camphoratus woodland (n = 8). This community is characterized by a high cover of *Tarconanthus camphoratus*, with *Combretum molle* in the shrub layer and *Dischoriste radicans*, *Hypoestes forskali* in the herb layer. *T. camphoratus* occurs in dense clumps. The leaves of this plant have a strong aromatic odour that can be repulsive to browsing animals. This community is the poorest with respect to tree-shrub species composition and the most uneven in overall species representation (Table 2). The herbaceous layer is impoverished as a result of overgrazing. This type is found in the northwestern part of the study area.

Type 2. Commiphora woodland (n = 12). The canopy layer of this type is dominated by *Commiphora africana* and *Commiphora boranensis*. The herbaceous layer is dominated by *Bidens pilosa*, *Setaria pumila* and *Sansevieria forskaliana*. This type occurs at the southern and northeastern edge of the study area.

Type 3. Acacia drepanolobium - Acacia seyal woodland (n = 8). This type occurs in depressions that may be waterlogged during the rainy seasons. *Acacia drepanolobium* occupies the central and the more moist part of the depressions, whereas Acacia seyal occupies the drier fringes. *Setaria pumila*, *Sorghum purpureum*, and *Commelina* spp. are among the important species of the herbaceous layer. Although the species richness is not the lowest of the seven types identified, it has the lowest Shannon diversity index (Table 2) indicating the dominance of the two invading shrubs. This type occurs in the central part of the plateau interspersed in the grassland.

Type 4. Chrysopogon plumulosus grassland (n = 4). This type is entirely dominated by a herbaceous layer that includes *Chrysompogon plumulosus*, *Indigofera* spp., *Becium flavilosum*, *Plectranthus* spp. and *Bothriochloa insculpta* on flat or undulating plains. This community has the lowest species richness, and has the second lowest Shannon diversity index (Table 2). It occurs in the central part of the plateau where the *Acacia drepanolobium* and *Acacia seyal* communities are interspersed.

Type 5. Barbeya oleoides - Combretum molle woodland (n = 4). This type is characterized by *Barbeya oleoides* and *Combretum molle* in the shrub layer, and by *Plectranthus* spp. and *Baleria eranthemoides* in the herbaceous layer. The vegetation cover is very open. The rock substratum, which is mainly limestone, is exposed in most places. This type occurs only in the far eastern portion of the study area.

Type 6. Clausena anisata - Panicum arundinacea woodland (n = 4). This type is dominated by *Clausena anisata*, *Carrisa edulis*, and *Dodenea angustifolia* in the tree and shrub layer, and by *Panicum arundinacea* in the herb layer. There are also some old stands of *Olea europea* and *Terminalia brownei* trees. It occurs mainly between the *Commiphora* forest in the south and east, and the *Juniperus procera* forest in the north and west.

Table 1. Species and their maximum per cent cover in the seven vegtation types identified. Species occurring only once in the whole data set are not included.

No.	Species	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
1	*Abutilon fruticosum*	0	1	15	5	0	0	0
2	*Acacia brevispica*	1	5	0	0	0	0	0
3	*Acacia bussei*	0	20	0	0	0	0	0
4	*Acacia drepanolobium*	0	0	60	0	0	0	5
5	*Acacia mellifera*	0	5	0	0	1	0	0
6	*Acacia oerfota*	0	5	0	0	0	0	0
7	*Acacia reciniformis*	0	0	0	0	2	0	0
8	*Acacia senegal*	1	5	0	0	0	0	0
9	*Acacia seyal*	10	10	45	5	0	1	1
10	*Acacia sieberiana*	20	0	0	0	5	1	1
11	*Acacia tortilis*	1	5	0	0	0	0	0
12	*Acalypha fruticosa*	1	20	0	0	0	0	0
13	*Achyranthes aspera*	0	10	0	0	0	0	0
14	*Achyrocline glumacea*	5	1	1	2	5	1	5
15	*Acokanthera schimperi*	0	0	0	0	0	5	10
16	*Actinopteris radiata*	0	1	0	0	0	0	0
17	*Adenia venenata*	1	1	0	0	0	0	0
18	*Aeluropus lagopoides*	1	0	0	1	0	0	0
19	*Andropogon abyssnicus*	0	0	5	0	0	0	1
20	*Arginia sp.*	0	0	0	0	0	1	0
21	*Aristida adescensionis*	1	0	1	0	0	0	0
22	*Aristida adoensis*	1	0	1	20	20	0	1
23	*Aristida kenyensis*	0	0	0	5	0	0	0
24	*Arthraxon prionodes*	0	0	0	0	0	5	5
25	*Asparagus africanus*	1	1	1	0	1	1	0
26	*Asparagus scaberulus*	1	1	0	0	1	1	1
27	*Aspilia mozambquensis*	0	1	5	1	1	1	1
28	*Asystasia charmain*	0	0	1	0	0	1	0
29	*Asystasia ganggetica*	1	0	1	0	0	0	1
30	*Balanites aegyptica*	1	0	1	0	0	0	1
31	*Barbeya oleoides*	0	0	0	0	5	1	15
32	*Barleriaeria acanthoides*	0	1	5	0	0	0	0
33	*Barleria eranthemoides*	10	1	0	0	10	0	0
34	*Barleria lachnantha*	1	1	0	0	0	0	0
35	*Becium filamentosum*	0	0	5	20	1	0	0
36	*Bidens pilosa*	10	40	10	0	0	1	1
37	*Blepherispermum villosum*	0	0	2	0	0	0	0
38	*Bothrichloa insculpta*	0	1	1	20	0	1	1
39	*Cadaba farinosa*	0	1	1	0	1	0	0
40	*Canthium lactescens*	0	0	0	0	0	1	1
41	*Capparis tomentosa*	0	0	0	0	0	0	1
42	*Carissa edulis*	5	0	0	0	0	5	10
43	*Caucalis sp.*	1	0	2	0	0	1	1
44	*Celtis africana*	1	0	0	0	0	0	0
45	*Chinothrix latifolia*	0	0	1	0	1	1	1
46	*Chloris gayana*	1	0	5	5	0	1	0
47	*Chloris mensense*	0	0	5	1	1	5	5
48	*Chlorophytum neghellense*	1	10	0	0	0	0	0
49	*Chloris phynotrix*	0	0	0	0	0	0	1
50	*Chlorophytum somalensis*	1	0	0	5	0	1	0
51	*Chrysopogon plumulosus*	0	0	0	20	0	0	0
52	*Cissis quadriangula*	1	1	0	0	0	0	0
53	*Clausena anisata*	1	0	0	0	2	50	40
54	*Clerodendrum myricoides*	0	1	0	0	1	1	1
55	*Cissus petaiolata*	1	1	0	0	0	5	0
56	*Combretum mollle*	20	20	0	0	5	5	0

57	*Commiphora africana*	1	20	0	0	1	0	1
58	*Commiphora albiflora*	0	1	0	0	0	0	0
59	*Commiphora boranensis*	5	20	0	0	5	1	0
60	*Commiphora ciliata*	0	0	0	0	0	1	1
61	*Commiphora confusa*	1	5	0	0	0	0	2
62	*Commiphora corrugata*	0	0	0	5	5	0	0
63	*Commiphora helenae*	2	0	5	0	1	0	0
64	*Commiphora pedunculosus*	0	0	1	0	0	0	0
65	*Commelina species*	0	1	20	0	0	5	1
66	*Cotula abyssinica*	1	0	0	0	0	1	1
67	*Crassula vaginata*	2	0	0	0	0	0	0
68	*Craterostigma plentagineum*	10	20	0	5	0	0	0
69	*Crosandra mucronata*	0	1	1	5	0	1	1
70	*Crosandra spinosa*	0	0	0	0	2	0	0
71	*Croton macrostachys*	1	0	0	0	0	0	0
72	*Cucumis species*	0	1	1	0	1	0	0
73	*Cyathula cylinderica*	0	10	0	0	0	0	0
74	*Cyperus costatus*	1	0	0	0	0	0	0
75	*Dactyloctenium aegyptium*	1	1	0	0	0	0	0
76	*Desmodium species*	5	5	5	0	0	1	5
77	*Dichrostachys cinerea*	1	1	0	0	0	0	0
78	*Digitaria scalarum*	1	1	1	0	0	0	0
79	*Discoriste radicans*	20	0	1	0	0	1	0
80	*Dodonea angustifolia*	0	0	0	0	10	10	10
81	*Entropogon macrostachys*	1	1	0	0	1	0	0
82	*Eragrostis capitulifera*	1	0	0	0	0	0	0
83	*Erythrochlamys cufodontii*	0	1	0	0	1	1	1
84	*Euclea divinorum*	5	1	0	0	5	5	20
85	*Euclea like*	0	0	0	0	5	0	0
86	*Euphorbia fruiting*	0	0	1	0	0	0	0
87	*Eustachys paspaloides*	1	0	0	0	0	0	1
88	*Gardenia lutea*	1	0	0	0	0	0	0
89	*Gloriosa simplex*	0	1	0	0	0	1	0
90	*Gnidia glauca*	10	0	0	0	1	0	0
91	*Grewia bicolor*	0	20	0	0	1	0	1
92	*Grewia villosa*	1	10	0	0	1	0	0
93	*Gynura pseudochina*	0	0	1	0	0	0	0
94	*Harpachne schimperi*	1	0	0	1	0	1	1
95	*Heliotropium cinerascens*	0	0	0	0	1	0	0
96	*Heliotropium simile*	0	0	0	1	1	0	0
97	*Hibiscus sp.*	0	1	1	0	0	1	0
98	*Hyparrhenia hirta*	0	0	0	1	1	1	1
99	*Hypoestes forskali*	20	1	1	0	0	1	0
100	*Hypoestes triflora*	0	0	0	0	0	0	40
101	*Indigofera sp.*	0	0	1	0	0	1	0
102	*Indigofera saveolens*	0	1	0	20	1	1	1
103	*Ipomea carica*	0	1	2	0	0	5	0
104	*Jasminium floribundum*	1	0	0	0	0	1	1
105	*Juniperus procera*	0	0	0	0	0	20	40
106	*Juncus capitatus*	0	0	0	0	1	0	0
107	*Kalanchoe densiflora*	0	1	0	0	0	0	0
108	*Kohautia caespitosa*	0	0	1	0	0	0	0
109	*Kohautia coccinea*	2	0	1	1	0	0	0
110	*Leucas glabrata*	0	0	1	0	0	0	0
111	*Leucas marticinesis*	1	5	1	0	0	0	0
112	*Lintonia nutans*	0	0	10	0	0	0	0
113	*Lippia triflora*	1	0	0	0	1	1	0
114	*Maerua angolensis*	1	1	0	0	1	0	0
115	*Maytenus arbutifolia*	0	0	0	0	0	1	30
116	*Maytenus senegalensis*	0	0	0	0	1	2	0

117	*Monsonia angustifolia*	0	0	1	5	0	0	0
118	*Myrica salicifolia*	5	0	0	0	0	5	1
119	*Nernilia kotschyi*	1	1	0	0	0	0	0
120	*Notonia abyssinica*	2	0	1	0	0	1	1
121	*Ocimum sauve*	1	0	0	1	0	0	0
122	*Olea europea ssp. africana*	5	0	0	0	0	1	20
123	*Ormocapum tricarpum*	2	1	0	0	1	0	0
124	*Osyris abyssinica*	0	0	0	0	0	1	1
125	*Oxalis sp.*	1	0	0	0	0	0	0
126	*Ozoroa insignis*	1	1	0	0	0	1	0
127	*Panicum arundinaria*	0	20	0	0	0	1	20
128	*Panicum maximum*	0	0	1	0	0	0	0
129	*Panicum ruspoli*	0	0	0	0	0	0	5
130	*Paspalum sp.*	0	1	0	0	0	0	0
131	*Pentanisia ourgogyne*	0	20	0	0	0	0	0
132	*Phyllanthus maderaspatensis*	0	0	0	1	0	0	0
133	*Pimpinella hirtella*	1	0	0	0	0	0	0
134	*Pittosporium viridiflorium*	0	0	0	0	0	5	5
135	*Plectranthus laxiflora*	10	20	0	0	0	1	1
136	*Plectranthus sp.*	10	1	5	20	20	1	1
137	*Plectranthus woody*	0	5	0	0	10	0	0
138	*Polygala sp.*	1	0	0	1	0	0	0
139	*Pulicaria crispa*	0	0	0	1	0	0	0
140	*Rhoicissus sp.*	1	0	1	1	0	0	0
141	*Rhus glutinosa*	0	0	0	0	0	5	0
142	*Rhus natalensis*	1	1	0	0	5	5	1
143	*Rhus ruspoli*	0	0	0	0	0	1	5
144	*Rhynchosia malacophylla*	10	0	0	0	1	5	1
145	*Ruellia Patula*	1	0	0	1	0	0	0
146	*Ruellias pecies2*	0	1	0	0	1	5	5
147	*Ruellia species*	0	0	0	0	1	0	0
148	*Sansevieria forskaliana*	0	50	0	0	0	0	0
149	*Sarcstemma venenata*	1	1	0	0	0	0	0
150	*Satanocrater somalensis*	0	0	1	0	1	0	0
151	*Senna singuana*	2	0	0	0	0	0	0
152	*Setaria pumila*	5	20	30	5	0	5	0
153	*Sida alba*	0	1	0	0	0	0	0
154	*Sida ovata*	1	0	1	10	0	1	0
155	*Solanum incanum*	3	1	0	0	1	0	1
156	*Solanum peduriforme*	0	0	0	0	1	1	0
157	*Solanum schimperiana*	0	0	5	1	0	0	0
158	*Sorghum purpreo-sericeum*	0	0	50	0	0	5	0
159	*Spermacoce species*	5	1	0	0	0	5	0
160	*Sporobolus africana*	5	10	0	5	0	1	1
161	*Steganotaenia araliacea*	0	1	0	0	0	1	1
162	*Sterculia africana*	0	20	0	0	0	0	0
163	*Striga hormonthica*	0	0	2	0	0	1	0
164	*Tagetes minuta*	1	1	1	0	0	1	0
165	*Tarconanthus camphoratus*	60	0	0	0	0	0	0
166	*Teclea salicifolia*	0	0	0	0	0	1	10
167	*Terminalia brownii*	1	10	0	0	1	1	10
168	*Tetrapogon villosus*	0	0	1	0	1	1	1
169	*Themda triandria*	1	0	1	10	0	1	0
170	*Toddalia asiatica*	0	5	0	0	0	0	0
171	*Usterreospermum vattliantii*	0	0	10	0	0	0	0
172	*Vernonia leopoldii*	1	1	1	1	0	1	1
173	*Vigna menbranacea*	1	1	0	0	1	0	1
174	*Volutaria boranensis*	0	0	10	0	0	0	0
175	*Xideroxylon gilletti*	0	0	0	0	0	1	10
176	*Zhernia species*	0	0	1	0	0	0	0
177	*Zornia apiculata*	1	0	0	1	0	0	0

Table 2. Species richness (number of species in the vegetation type), H' (Shannon Diversity Index), Maximum possible H' assuming equal evenness and evenness (low evenness indicates dominance of a few species) of the seven vegetation types.

Relevé groups	Species richness	H'	Maximum possible H'	Evenness
1	100	3.085	4.605	.670
2	88	3.414	4.477	.763
3	65	2.843	4.174	.681
4	37	2.956	3.611	.819
5	52	3.211	3.951	.813
6	79	3.138	4.369	.718
7	81	3.062	4.394	.697

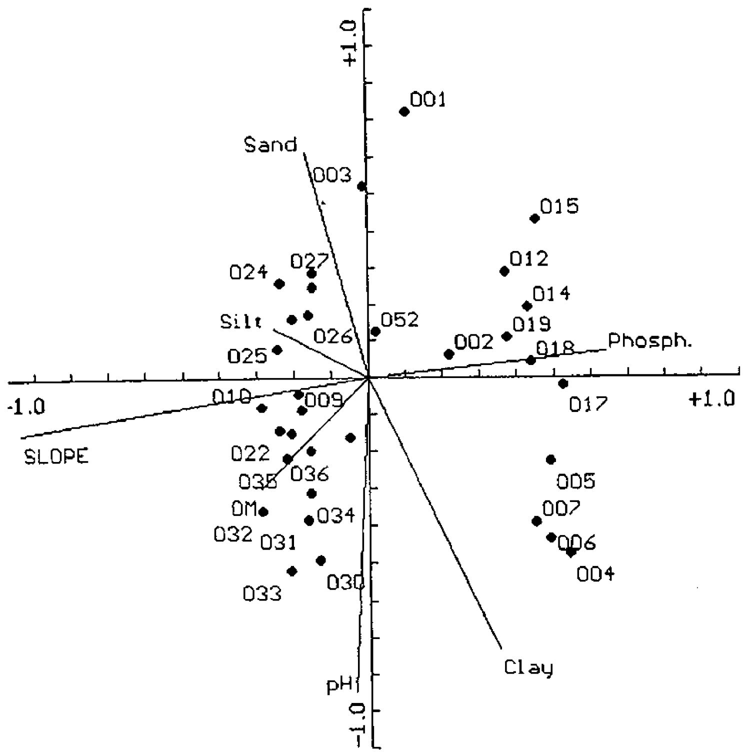

Figure 4. Canonical Correspondence Analysis of the relevés and the environmental factors measured . The dark circular dots the positions of the numbers representing the relevés. The direction of the lines connecting the origin of the figure with the environmental variables measured indicate the relationship of the group of relevés with that variable. Phosph = phosphorus.

Type 7. Juniperus procera - Clausena anisata forest (n = 12). This is a forest dominated by *Juniperus procera, Clausena anisata, Olea europea, Euclea divinorum* and *Maytenus arbutifolia* in the tree layer, and by *Hypoestes trifolia* and *Panicum arundinacea* in the herbaceous layer. *Juniperus procera* seedlings are not present, and most of the trees have been girdled by poachers. The herbaceous layer is impoverished by heavy overgrazing and trampling.

Ordination

The floristic gradient in the CCA ordination did not show any clear relationship with the environmental factors measured. However, those relevés on level ground or slight slopes tend to have clayey soils that are somewhat richer in phosphorus. Relevés on steeper slopes occur on soils richer in organic matter and higher in silt and sand content (Fig. 4). The vegetation types identified using classification are not clearly identified in the CCA, indicating low correspondence between the vegetation and measured environmental variables.

Discussion

Community Dynamics

Fire has been the major factor influencing the vegetation of the area. The vegetation of the area has been described as *Acacia-Commiphora* woodland interspersed with grasslands (Pichi-Sermoli 1957). The fact that there are seven community types currently suggests that the vegetation has changed over the last 40 years as a result of both anthropogenic and natural factors.

The recurrent drought in Ethiopia that peaked in 1976 induced positive attitudes towards protection of natural resources and rehabilitation of degraded areas, both by biological means such tree planting and area closure and physical means such as terracing and construction bands to slow the rate of erosion. Any interference with natural resources was either consciously or inadvertently condemned. While this attitude benefitted the settled agricultural region of the country, the pastoralists whose survival is closely tied to the availability of grazing lands at the right place during the right season suffered from such rules and regulations. The pastoralists in Borana would traditionally burn the grassland on the central plains between December and February, moving east to the Genale river basin or west to the Dawa river basin for dry period grazing. The plains in the interior were used for rainy season grazing. The structure and productivity of the area were maintained in this traditional management system for years in the past until burning was totally banned about 25 years ago. Fire suppression has allowed trees such as *Acacia drepanolobium* and *Acacia seyal*, which were once restricted to the centers of depressions in the plains, to invade onto a considerable portion of the plains. These plains were once capable of sustaining the livestock population during the wet season. According to some elder informants and the Zonal Office of Agriculture, more than 50% of the plains have been lost to *Acacia drepanolobium*, which forms dense impenetrable tickets. The galls at the base of the spines harbour stinging ants which make grazing in the ticket even more difficult.

The area around Negelle receives more precipitation, and the soil is black clay which is capable of conserving moisture. As a result, crop cultivation in the area has increased to meet part of the demand of a growing urban population. The population of Negelle town has grown from 4,365 in 1964 to 11,997 in 1984, and the area under crop cultivation has increased by 173% over the same period (Fig. 5). The Mankubsa *Juniperus* forest, which is currently restricted to a small

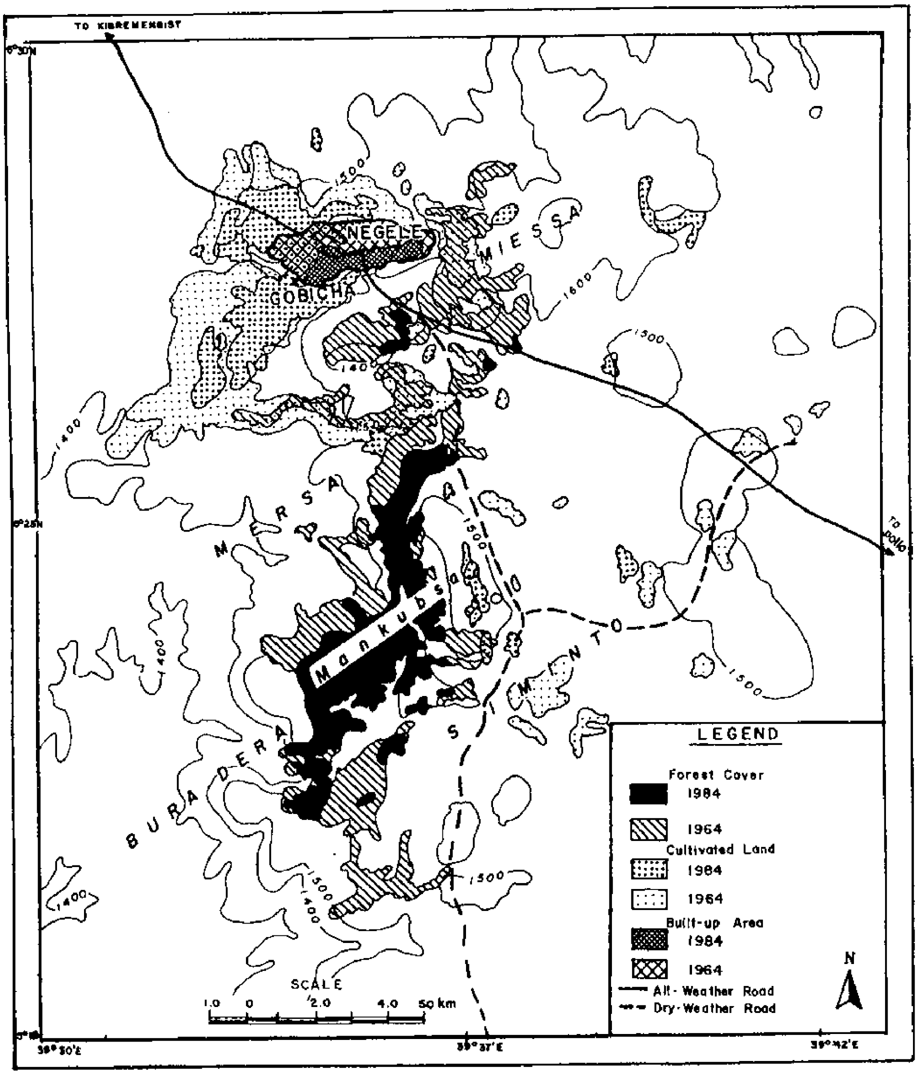

Figure 5. Map showing the changes in the land use around Negelle between 1964 and 1984.

patch 6 km south of the Negelle, was only 2 km south of the town in 1964. Logging of *Olea* and *Juniperus* trees for timber has decimated this forest, and illegal logging of trees is still occurring. As a result, the area under *Juniperus pocera* forest has decreased by 65.15% and this forest type can be considered for all practical purposes to have been lost. There are no seedlings of *Juniperus procera* and *Olea europea* in the forest since the few trees in the forest are all girdled and do not bear fruit. A forest fire which lasted for a week in 1976 has left an indelible mark on the trees. *Clausena anisata*, a short and highly branched tree not useful for timber, actively regenerates into these degraded stands. It can therefore be argued that community type 6 (dominated by *Clausena anisata*) has come into existence largely as result of the selective felling of *Juniperus procea* and *Olea europea* since the founding of Negelle in 1930 as a military garrison during the brief period of colonial occupation.

In the south where *Commiphora* species dominate the vegetation, *C. boranensis* is being selectively felled for its straight and long boles and transported to urban centers including Negelle since the supply of *Juniperus* and *Olea* timbers have dwindled. It seems that the pastoralists have turned to other ways of exploiting some non-pastoral resources such as selling wood and charcoal to the urban centers. This is a direct result of a shortage of grazing resources due to population pressures (both by livestock and humans), as well as fire suppression and the resultant encroachment of woody vegetation.

On the uplands in the northwestern part of the study area, *Tarconanthus camphoratus* forms dense clumps with its horizontally spreading branches, manifesting the characteristics of plants with the ability to sprout from below-ground parts following fire (Scott 1986; Frost and Roberston 1987). The closed canopy between adjacent clumps discourages the establishment of herbaceous plants, particularly grasses. As a result, the understory cover is low. The dominance of *Tarconanthus camphoratus* may in this area is probably attributable to fire suppression practices over the past 25 years. Although high densities result in a reduction in the fuel load of the herbaceous layer, shrublands are flammable relative to other ecosystems (Mutch 1970).

The prohibition of forest burning seems to have increased the landscape diversity by creating new areas that are still in the process of succeeding to other vegetation types. In this respect the creation and/or the expansion of *Acacia drepanolobium*, *Acacia seyal* and *Tarconanthus camphoratus*, and the increasing abundance of *Clausena anisata* which is gradually replacing *Juniperus procera*, are new features of the landscape.

Fragmentation

Fragmentation of vegetation should not be conceived as simply the creation of habitat islands. Fragmentation is essentially the disruption of continuity in pattern or processes. There can be various stages to the fragmentation process. Fragmentation may begin with gap formation in the vegetation matrix. In this respect, the illegal logging of timber resources that has decimated *Juniperus procera* and *Olea europea* populations may be considered as an example of forest fragmentation that has changed the patch occupancy of species. The *Juniperus procera* forest, which is surrounded by *Acacia-Commiphora* woodland on southern and western sides and by *Clausena anisata* in the northern and eastern sides, is isolated from the nearest patch of *Juniperus procera* forest north of it by about 40 km. This degenerate forest patch may therefore be considered as an island in which propagules may not easily get there for re-establishment. The continued fragmentation of this forest patch will eventually lead to the local extirpation of *Juniperus procera* and *Olea europea*.

Conclusions and Recommendations

Human pressures on the ecosystem, through the combined effects of population pressure, the growth of urban centers, illegal logging, and fire suppression for a long period of time have resulted in three concomitant processes, namely invasion, diminishing biodiversity, and local extirpation.

Fire suppression has altered the mix of habitat types by increasing the dominance of one type over the other, thereby diminishing landscape biodiversity. One effect of the preponderance of the *Tarconanthus camphoratus* community, which covers a large part of the northern edge of the study, is the impoverishment of the tree-shrub component. The small patches of *Acacia drepanolobium* and *Acacia seyal* which were restricted to isolated depressions have invaded the relatively dry grasslands. The disappearance of the *Juniperus procera* has reached its terminal stage as result of illegal logging and intense fires in the past.

This scenario of resource degradation suggests that the pastoral system in Borana is in jeopardy, undermining the long-held view that it is an exemplary model of sustainable pastoral management (Pratt 1987). It must therefore receive priority attention for urgent action to maintain the dynamics that created the mosaics in the region, so that patch diversity and productivity may be allowed to rehabilitate over the long term. In particular, fire should again be considered as a management tool in these pastoral systems. This needs to be reinforced by a relevant decision support system.

In woodlands and shrublands where there is a lower grass biomass and a more uneven distribution of fuel fires tend to be less intense and burn more patchily (Frost and Roberston 1987). Since the herbaceous component of the vegetation of the area has been largely removed by overgrazing, or discouraged by the closed canopy of *Tarconanthus camphoratus*, *Acacia drepanolobium* and *Acacia seyal*, it will now be difficult to introduce the traditional practice of burning. In addition, the increase in human population has resulted in heterogeneous settlement pattern and there are huts almost everywhere. Any attempt to reintroduce forest fire could easily get out of hand and burn the huts, causing extensive damage to the agroecosystem.

As alluded to earlier, the traditional practice of burning can be introduced only if the herbaceous layer can be rehabilitated. This may be possible if the invading woody species, which have produced a more closed canopy, are removed. This would require the clearing of encroaching species such as *Acacia seyal*, *Acacia drepanolobium* and *Tarconanthus camphoratus*. Grazing pressure should also be relaxed to achieve more sustainable levels. This would have to be accomplished by involving the Borana people in participatory discussions and developments.

The frequency and intensity of fire for sustainable management should be determined after establishing the balance between the production required for adequate fuel load and the level of aridity, which influences flammability. Short term effects of fires will be the production of structural and floristic changes in the vegetation, which will provide parallel changes in the animal populations that depend on them. The long-term effects will be those that are compounded over time, resulting in changes in plant communities of the region that produce or accentuate characters that promote quality forage and good pastoral resources. The long held view that the Borana pastoral system is an exemplary model of sustainable pastoral system can be realized only when the dynamics that created the mosaics in the region are rehabilitated through appropriate interventions. These include the use or development of indigenous strategies and solutions to the commonly perceived problems related to range management, and the encouragement of local communities to participate in these activities.

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