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VEGETATION OF CHENCHA HIGHLANDS IN SOUTHERN ETHIOPIA

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ABSTRACT: The relationship between environmental factors and plant communities identified using multivariate numerical analyses were investigated in the highlands of southern Ethiopia. Vegetation data were obtained from relevés placed in belt transects along altitudinal gradients on the mountain slopes following the Arbaminch-Chancha road. The relevés were placed in the two transects which ran for about 30 km from 1180 m to 2250 m along the slope representing a 25 m vertical distance between each relevés. The relationship among plant communities and environmental factors were established using one way Analysis of Variance (ANOVA). Community transition and species diversity are affected, inter alia, by environmental factors including soil properties, slope and aspect which varied significantly ($P < 0.05$). The Communities changed along altitudinal gradients as indicated by the high community coefficients of 0.52, 0.53 and 0.16 in between adjacent communities. Species diversity and richness were high in communities between 1250–1800 m. The high species diversity and richness is explained partly by the variations in the environmental factors, which are associated with the effect of altitude.

Key words/phrases: Community transitions, environmental factors, species diversity/richness

Nomenclature follows: Hedberg and Edwards (1989; 1995), Edwards *et al*. (1995; 1997).

INTRODUCTION

The distribution, abundance and diversity patterns of species can result from the interaction between the abiotic and biotic factors at different spatial and temporal scales (Brown, 2001). Mountains exhibit great complexity in environmental conditions primarily due to changes in temperature, precipitation and air pressure associated with altitude (Palmer and van Staden, 1992). In the tropics temperature is negatively correlated with altitude while precipitation maintains a nonlinear-relationship with increasing altitude below the cloud level (Walter, 1985). The abundance and diversity of plant species is influenced by the interaction of these two complex gradients and a mid-altitudinal pattern of species diversity can be manifested (Brown and Lomolino, 1998; O'Brien, 1998).

Natural vegetation may respond to gradients in many different ways (Curtis, 1959; Whittaker, 1967). Temperature and moisture gradients along altitude, the nature of substrates, and topographic features such as aspect and their configuration can result in distinct or fuzzy units (Zerihun Woldu *et al*., 1989; Parker and Bendix, 1996). Huston (1994) has shown that the nature of substrate (*e.g*., texture) and availability of nutrients, which are mainly the result of geologic processes, influence the pattern of plant communities and diversity. Parker and Bendix (1996) have also pointed out that these features can influence the distribution pattern of individual plants or communities indirectly by regulating microclimatic and hydrological processes in the site. Distinct patches in natural vegetation may be produced through a variety of mechanisms such as anthropogenic influences including the effect of grazing, selective felling, and clearing of the vegetation for cultivation (Forman and Gordon, 1986). Patches may simply interlace and may not show distinct boundaries in areas where there are gradual environmental changes.

Zonal patterns of plant communities are common occurrences in Ethiopia and elsewhere in East African Mountains (Beals, 1969; Zerihun Woldu *et al*., 1989; Friis, 1992; Tamrat Bekele, 1994; Kebrom Tekle *et al*., 1997; Weshe, 1999). There is little published work on the south and southwestern part of Ethiopia which could provide information for comparative analyses. The purpose of this study is to investigate the transition of plant communities along altitudinal gradient and the relationships between vegetation and environmental factors on the western escarpment of the Rift Valley in the southern part of Ethiopia and make comparisons of the results with those observed in other parts of the country.

MATERIALS AND METHODS

The study area

This study was conducted on the western escarpment of the southern part of the Rift Valley in Ethiopia, between 6°05´N to 6°12´N and 37°33´E to 37°45´E (Fig. 1). Altitude ranges from 1180 m to 2250 m. The topography is rugged and ranges from steep slopes on the escarpment of the Rift Valley to nearly flat surface around the shores of L. Abaya. The geology of the lower part of the study area is of recent quaternary volcanic rocks (Mohr, 1971). Volcanic tuffs and effusive basic rocks on the surface are common in the lower course of Hare River (Vukasinovic, 1969). Basalts form the greater part of the trap series and more silicic lavas occur lying above the basalt on the highlands of Chencha (Mohr, 1971). The soils are derived from alluvial and lacustrine deposits of different origins (Vukasinovic, 1969; Mohr, 1971; FAO, 1984) along the Rift Valley and Lake Abaya. Vitric and Mollic Andosols are dominant around Lake Abaya while groups of Nitosols, Cambisols and Vertisols are found along the escarpment and highlands of Chencha (FAO, 1984).

The study area receives bimodal rainfall (Anon, 1988). The two wet seasons are interrupted by two dry seasons in the area. The total annual rainfall recorded around Arbaminch is 800 mm at 1200 m. and the mean annual temperature is above 26°C. The mean annual rainfall and temperature of Chencha at the top end of the gradient (2700 m.a.s.l) are 1520 mm and 15.7°C, respectively. The vegetation of the area lies within the Somalia-Masai regional centre of endemism as described by White (1983).

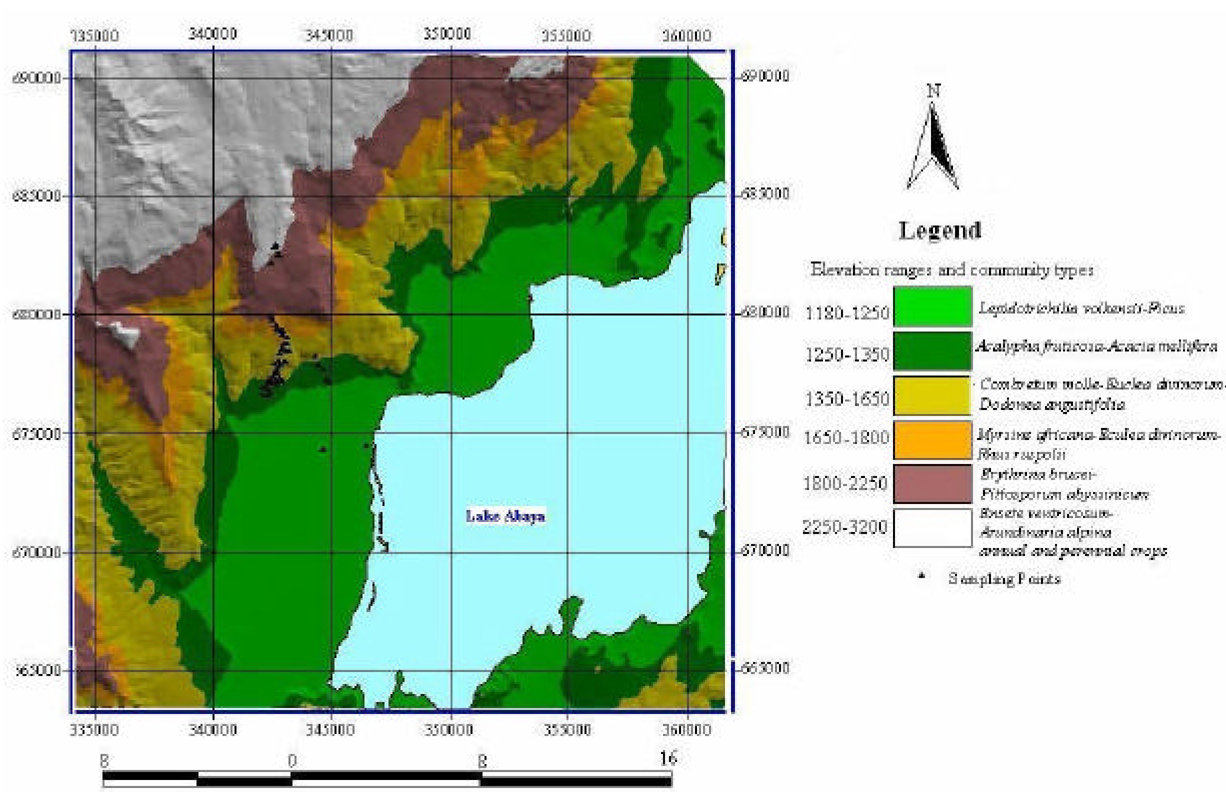

Fig. 1. Map of the study area.

Vegetation sampling

Vegetation data were collected in relevés placed in belt transects on the mountain slopes following the altitudinal gradient. A total of 50 relevés were sampled. Relevés were placed in the two transects which ran for about 30 km from 1180 m to 2250 m representing a 25 m vertical distance (ascent) between each relevés. Forty eight relevés of 20 m x 20 m were laid on the slopes and while 2 relevés of 40 m x 40 m were placed in the forest at the lakeshore. The percent cover values were visually estimated in the field and later converted into 1-9 modified Braun Blanquet scale (van der Maarel, 1979). Plant specimens encountered in the relevés were collected and brought to the National Herbarium of Addis Ababa University for verification and identification. Data collection was conducted between Nov. and Dec. 2001, which was the period marking the end of the big rainy season in the area (Daniel Gamachu, 1977).

Environmental data

Slope of each relevé was measured using a Clinometer. Aspect was codified following Zerihun Woldu *et al*. (1989). Soil samples were collected from each corner and centre of the relevés at 0-30 cm depth. These were mixed to make a composite sample for each relevé. The soil samples were analyzed for texture, pH, CEC, Total N, Available P, Percent Organic Matter, in the Ethiopian Agricultural Research Organization (EARO) soil laboratory at Debre Zeit following standard methods (Jou, 1978).

Vegetation classification and definition of communities

The Program Package SYNTAX 2000 for windows (Podani, 2000) was used to obtain hierarchical clustering of the data matrix using group average linkage with similarity ratio and correlation coefficient as resemblance indices for the relevés and for the species, respectively. Communities were recognized based on groups of relevés and the associated groups of species. Relevés with similarity level of 0.75 were grouped into the same community (Fig. 2). Principal Component Analysis (PCA) was then used to depict the relationship among communities along the altitudinal gradients (Fig. 3).

Statistical analysis

The environmental variables of the communities were tested for variation between the means using one-way analysis of variance (ANOVA). Species richness and diversity were measured using Shannon and Wiener (1949) diversity index. Jacquard's coefficient of similarity was used to test for turn over of species composition among successive communities.

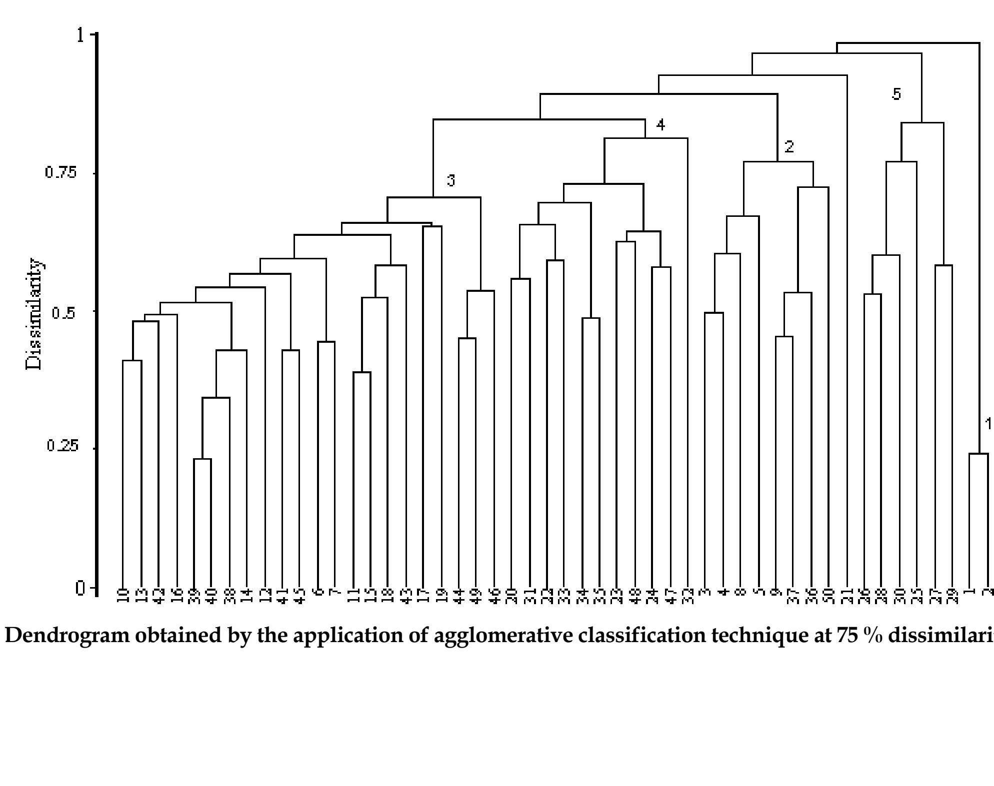

Fig. 2. Dendrogram obtained by the application of agglomerative classification technique at 75 % dissimilarity level.

RESULTS AND DISCUSSION

One hundred and seventy four species representing 56 families were encountered in the 50 relevés sampled: 105 tree/shrub, 47 herb, 14 grass, 7 climber and 1 fern species. Eight major families Fabaceae, Poaceae, Asteraceae, Acanthaceae, Euphorbiaceae, Lamaceae, Rubiaceae and Combretaceae accounted for 49.9% of the total number of species. The five communities identified are described below.

Vegetation communities

1. *Lepidotrichilia volkensii-Isoglossa somalensis-Achyranthus aspera-Ficus sur - Commicarpus plumbiagineus* community: This community is located at lower altitudes in between 1180 m and 1250 m.a.s.l. *Lepidotrichilia volkensii* and *Ficus sur,* attaining a height range of 30 m to 40 m, dominate the tree layer while the herb layer is dominated by *Isoglossa somalensis* and *Achyranthus aspera* with relatively lower cover of *Ruellia patula* and *Hoslundia opposita*. The climber *Commicarpus plumbiagineus* is common species with fairly high cover value in this community. There were as many as 58 seedlings of *Prunus africana* species in a relevé while there were only few mature trees.
2. *Acalypha fruticosa-Acacia mellifera* community: This community was found between 1250 m and 1350 m.a.s.l. *Acacia mellifera, Acacia tortilis, Rhus natalensis, Balanites aegyptiaca* and *Acalypha fruticosa* were dominant in the tree-shrub layer while *Barleria eranthemoides, Melhania ovata, plectheranthus barbatus, Sansieviera sp*. and *Asparagus flagellaris* were dominant in the herb layer. A succulent climber *Cissus quadrangularis* occurred abundantly in this community. The grass species in this community included *Sporobolus pyramidalis, Panicum atrosanguineum* and *Heteropogon contortus.*
3. *Combretum molle-Euclea devinorum-Dodonea angustifolia* community. This community was found between 1300 m and 1650 m.a.s.l. *Combretum molle, Euclea devinorum, Dodonea angustifolia* and *Terminalia brownii* were dominant species in the tree-shrub layer, while *Satureja abyssinica*, *Justicia calyculata* and *Barleria eranthemoides* were the dominant species in the herb layer. The grass species in this community included *Hetropogon contortus, Enteropogon macrostachyus* and *hyparrhenia hirta* in respective order of abundance. Zerihun Woldu *et al*. (1989) have indicated that *Combretum molle* dominantly occurred between 1470–1510 m in the Bale highlands in the tree-shrub layers.
4. *Myrsine africana-Euclea devinorum-Rhus ruspolii* community. This community was found between 1600 m and 1800 m.a.s.l. The dominant species in the tree-shrub layer were *Myrsine africana, Euclea devinorum, Rhus ruspolii, Combretum collinum* and *Terminalia brownii* while the dominant grass species in this community were *Hyparrhenia diplandra, Sporobolus pyramidalis* and *Hyparrhenia filipendula*. *Justicia calyculata* and *Ocimum canum* were the dominant species in the herb layer. Climbers including *Jasminum grandiflorum, Hippocratea africana* and *Vigna membranacea* were abundant. *Jasminum grandiflorum* occurred between 1470 and 1820 m.a.s.l in the herb layer in Bale highlands (Zerihun Woldu *et al*., 1989).

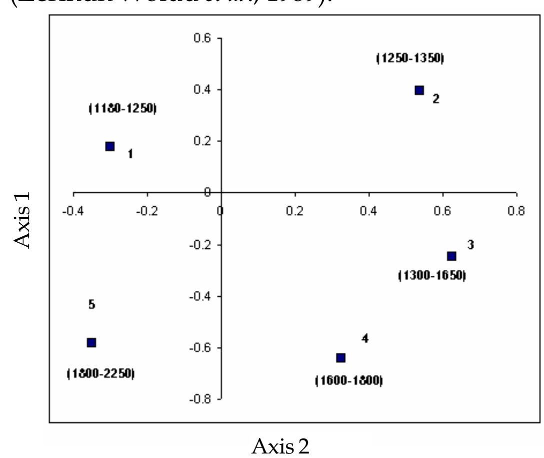

Fig. 3. A PCA scatterplot of the 1st and 2nd axes of the five communities and the Corresponding Altitudinal Ranges.

5. *Erythrina brucii-Pittosporum abyssinicum* community: This community was found between 1800 m and 2250 m. The dominant species in the tree-shrub layer were *Erythrina brucii, Pittosporum abyssinicum, Bersama abyssinica and Maesa lanceolata*. However, species such as *Galineria saxifraga, Hagenia abyssinica* and *Hypericum quartinianum* were also abundant in the tree-shrub layer. *Rubus stuedneri*, a woody scrambler occupied the area between the tree-shrub species. The dominant species in the herb layer were *Acanthus eminens* and *Acanthus pubescens*. Moist sites were occupied by *Arundinaria alpina*. Grass species were not common in this community. *Hagenia abyssinica* and *Arundinaria alpina* make part of

the tree-shrub layer in the Bale highlands at the height of 2350–2800 m while *Acanthus eminens* occurred in between 1900 and 2200 m in the herb layer (Zerihun Woldu *et al*., 1989).

A synoptic description of the five community types with families, growth forms, life forms and mean species percent cover is given in Table 1.

Table 1. A Synoptic description of the five vegetation types of patches obtained by cluster analysis. Average species percentage cover in each community, families and growth form and life form of each species are indicated as follows:-Growth forms:-AC = annual climbers, AG = annual grasses, AH = annual herb, C = climbers, HS = high shrubs, LS = low shrubs, PC = perennial climbers, PG = perennial grasses, PH= perennial herbs, T = Trees. Life forms:-Phanerophytes (Meso: 8–30 m, Micro: 2–8 m, Nano: 0.25–2 m) are referred to as MEP, MIP, NAP, respectively. CHP = Chamaephytes (0–0.25 m), HEC = Hemicryptophytes (perennating parts at the soil surface), SUC = Succulent and L: Lianas. Cryptophytes have not been encountered. Life forms were characterized following Raunkaier (1934).

SPECIES	Voucher No.	Alt.	FAMILY	Growth Forms	Life forms	Cluster of Relevés				
						1	2	3	4	5
Lepidotrichilia volkensii	-	1200	MELIACEAE	T	MEP	7.5	0	0	0	0
Isoglossa somalensis Lindau	281	1200	ACANTHACEAE	PH	CHP	7.0	0	0	0	0
Achyranthes aspera L.	42	1200	AMARANTACEAE	PH	CHP	6.5	0	0	0	0
Commicarpus plumbiagineus (Cav.) Standley	24	1200	NYCTAGINACEAE	PC	CHP	6.0	0	0	0	0
Ficus sur Forssk.	-	1200	MORACEAE	T	MEP	6.0	0	0	2.727	0
Prunus Africana (Hook.f.) Kalkm.	-	1200	ROSACEAE	T	MEP	5.0	0	0	0	0
Croton macrostachyus Del.	80	1200	EUPHORBIACEAE	T	MEP	4.5	0	0	0.727	1.5
Ocimum canum Sims	260	370	LAMIACEAE	PH	CHP	3.5	0	0.182	1.091	0
Cordia Africana Lam.	105	1800	BORAGINACEAE	T	MEP	2.0	0	0	0	0.833
Solanum incanum L.	39	1400	SOLANACEAE	LS	NAP	1.5	0	0.091	0.273	1.333
Ehertia cymosa Thonn.	296	1200	BORAGINACEAE	T	MIP	1.5	0	0	0	0.333
Ruellia patula Jacq	307	1250	ACANTHACEAE	PH	CHP	5.0	0.75	0.045	0	0
Hoslundia opposita Vahl	02	1250	LAMIACEAE	LS	NAP	2.5	0.38	0.091	0.455	1
Grewia villosa Willd.	36	1250	TILIACEAE	LS	MIP	0	1.25	0.045	0	0
Acacia tortilis (Forssk.) Hayne	37	1300	FABACEAE	T	MEP	0	3.5	0	0	0
Balanites aegyptiaca (L.) Del.	-	1250	BALANITACEAE	T	MEP	0	3	0	0	0
Sansevieria sp.	43	1300	AGAVACEAE	PH	SUC	0	1.375	0	0	0
Jasmnium abyssinicus Hochst. ex DC.	255	1400	OLEACEAE	PC	CHP	0	1.25	0	0	0
Panicum atrosanguineum A. Rich.	267	1300	POACEAE	PG	HEC	0	1.125	0	0	0
Hibiscus micranthus L.f.	188	1750	MALVACEAE	PH	CHP	0	0.25	0	0	0
Flueggea virosa (Willd.) Voigt.	83	1350	EUPHORBIACEAE	LS	NAP	0	0.25	0	0	0
Combretum sp.	03	1250	COMBRETACEAE	T	MIP	0	0.25	0	0	0
Commiphora africana (A. Rich.) Engl.	14	1300	BURSERACEAE	T	MIP	0	1	0	0	0
Acalypha fruticosa Forssk.	17	1250	EUPHORBIACEAE	LS	NAP	0	5.25	0.273	0	0
Acacia mellifera (Vahl) Benth.	23	1300	FABACEAE	T	MIP	0	5.13	0.182	0	0
Barleria eranthemoides R. Br. ex C.B.Cl.	38	1250	ACANTHACEAE	PH	CHP	0	3.75	0.455	0	0
Acacia senegal (L.) Willd.	21	375	FABACEAE	T	MEP	0	2.875	0.091	0	0
Rhus natalensis Krauss	262	400	ANACARDIACEAE	LS	NAP	0	2.875	2.318	1.091	0
Canthium psudosetiflorum	76	1250	RUBIACEAE	LS	NAP	0	2.75	1.454	0	0
Sporobolus pyramidalis P. Beauv.	28	1250	POACEAE	PG	HEC	0	2.25	0.273	1	0
Becium grandiflorium (Lam.) Pichi-Serm.	90	1350	LAMIACEAE	LS	CHP	0	2.13	0.591	0	0
Boscia angustifolia A. Rich.	82	1350	CAPPARIDACEAE	LS	NAP	0	2.25	0.318	0	0
Melhania ovata (Cav.) Spreng.	29	1250	STERCULIACEAE	PH	CHP	0	2	0.091	0	0
Cissus quadrangularies L.	-	1250	VITACEAE	PC	SUC	0	1.88	0.045	0	0
Bothriochloa insculpta (Hochst. ex A. Rich.) A. Camus	41	1300	POACEAE	PG	HEC	0	1.75	0.682	0	0
Plechtranthus barbatus Andr.	10	1250	LAMIACEAE	PH	CHP	0	1.75	0.091	0	0
Commiphora habessinica (Berg) Engl.	47	1250	BURSERACEAE	HS	MIP	0	1.5	0.091	0	0
Abutilon fruticosum Guill. & Perr.	23	1250	MALVACEAE	LS	CHP	0	1.5	0.364	0	0
Asparagus flagellaries (Kunth) Baker	04	1250	ASPARAGACEAE	PH	CHP	0	1.63	0.455	0	0
Acacia brevispica Harms	315	1250	FABACEAE	LS	MIP	0	1.38	0	0.545	0
Commiphora terebinthina Vollesen	310	1300	BURSERACEAE	T	MIP	0	1.38	0.136	0	0
Aloe sp.	19	1250	ALOACEAE	PH	SUC	0	1.375	0.045	0	0
Aristida adscensionis L.	40	1250	POACEAE	AG	HEC	0	1	0.136	0	0
Hyparrhenia diplandra (Hack.) Stapf.	133	1600	POACEAE	PG	HEC	0	1	0.455	0.727	0
Acokanthera shimperi (A. DC.) Schweinf	25	1250	APOCYNACEAE	LS	MIP	0	0.875	0.091	0.455	0
Jasmnium grandiflorum L. subsp. *floribundum* (R.Br. ex Fressen.) P.S. Green Hochst. ex DC.	89	1350	OLEACEAE	PC	nap	0	0.875	0.773	0.364	0
Enteropogon macrostachyus (Hochst. ex A. Rich.) Benth.	124	1550	POACEAE	PG	HEC	0	0.375	0.227	0	0
Calpurnia aurea (Ait.) Benth.	178	1700	FABACEAE	LS	MEP	0	0.625	0.136	0.909	0.667
Grewia bicolor Juss.	13	1250	TILIACEAE	LS	NAP	0	0.625	0.136	0	0
Kalanchoe crenata (Andr.) Haw.	03	1300	CRASSULACEAE	AH	SUC	0	0.625	0.045	0	0
Ficus platyphylla Del.	44	1300	MORACEAE	T	MEP	0	0.125	0.045	0	0

Table 1. (Contd).

SPECIES	Voucher No.	Alt.	FAMILY	Growth Forms	Life forms	Cluster of Relevés 1	2	3	4	5
Acacia nilotica (L.) Willd. ex Del.	31	1300	FABACEAE	T	MEP	0	375	0.136	0.273	0
Acacia hockii De Wild.	11	1350	FABACEAE	T	MIP	0	0.375	0.136	0	0
Cadaba farinosa Forssk.	30	1550	CAPPARIDACEAE	LS	NAP	0	0.25	0.091	0	0
Dodonea angustifolia L.f.	53	1300	SAPINDACEAE	LS	MIP	0	0.875	5.5	1	0
Setaria sphacelata (Schumach.) Moss	315	1450	POACEAE	PG	HEC	0	2.875	5.227	4.545	0.5
Olea europea L.ssp. Cuspidate (Wall. Ex G. Don) Cif.	52	1400	OLEACEAE	T	MEP	0	0	4.273	0.182	0
Harrisonia abyssinica Oliv.	60	1300	SIMAROUBACEAE	HS	NAP	0	3.25	3.273	1.636	0
Combretum aculeatum Vent.	35	1300	COMBRETACEAE	T	MIP	0	2.5	3.773	2.454	0.833
Combretum molle R. Br. Ex G. Don	54	1450	COMBRETACEAE	T	MIP	0	2	3.546	0	0
Carisa spinarum L.	22	1300	APOCYNACEAE	LS	MIP	0	0	3.046	1	0.5
Hyparrhenia hirta (L.) Stapf.	46	1300	POACEAE	PG	HEC	0	1.5	2.454	0.455	0
Heteropogon contortus (L.) Roem. & Schult	72	1350	POACEAE	PG	HEC	0	0.875	2.318	0.545	0
Euclea divinorum Hiern	01	1250	EBENACEAE	LS	MIP	0	1.25	2.318	0.273	0
Papea capensis Eckl. & Zeyh.	96	1450	SAPINDACEAE	T	MIP	0	0.75	2.364	0	0
Terminalia brownii Fresen.	74	1350	COMBRETACEAE	T	MEP	0	0.125	2.273	0.818	0
Dichrostachys cinerea (L.) Wight & Arn.	118	1550	FABACEAE	HS	MIP	0	0.75	2.091	0	0
Ozoroa insignis Del.	71	1350	ANACARDIACEAE	T	MIP	0	0	1.454	0.545	0
Leucas stachydiformis (Benth.) Briq.	121	1550	LAMIACEAE	LS	NAP	0	0.125	1.364	0.636	0.5
Myrica salicifolia A. Rich.	106	1450	MYRICACEAE	T	MIP	0	0.375	1.227	1.182	0
Crotalaria laburnifolia L.	86	1350	FABACEAE	LS	NAP	0	1.25	1.273	0	0
Maytenus senegalensis (Lam.) Exell	69	1350	CELASTERACEAE	T	MIP	0	0	0.909	0.545	0.833
Ximenia americana L.	80	1300	OLACACEAE	HS	MIP	0	0	0.5	0.091	0
Lantana camara L.	187	1750	VERBENACEAE	LS	NAP	0	0	0.591	0	0
Tephrosia emeroides A. Rich.	*79*	*1350*	FABACEAE	LS	NAP	0	0	0.545	0.091	0
Gomphocarpus fruticosus (L.) Ait.f.	*86*	*1350*	ASCLEPIADACEAE	PH	CHP	0	0	0.727	0.455	0
Manilkara butugi Chiov.	88	1350	SAPOTACEAE	T	MRP	0	0	0.318	0	0
Gardenia ternifolia Schumach. & Thonn	105	550	RUBIACEAE	HS	MIP	0	0	0.955	0.364	0
Osyris quadripartita Decn.	77	1650	SANTALACEAE	LS	NAP	0	0	0.318	0.273	0
Bridelia micrantha (Hochst.) Baill.	108	1575	EUPHORBIACEAE	T	MIP	0	0	0.318	0.273	0
Ziziphus mucronata Willd.	303	1350	RHAMNACEAE	HS	MEP	0	0	0.091	0	0
Pavetta sp.	317	1575	RUBIACEAE	LS	MIP	0	0.125	0.136	0.091	0
Justicia calyculata Defl.	16	1250	ACANTHACEAE	PH	CHP	0	0	0.045	0.091	0
Desmodium velutinum (Willd.) DC.	117	1550	FABACEAE	LS	CHP	0	0	0.545	0.545	0
Maytenus arbutifolia (A. Rich.) Wilczek	129	1600	CELASTERACEAE	T	MIP	0	1	0.773	5.091	1
Indigofera atriceps Hook.f.	115	1650	FABACEAE	LS	NAP	0	0	0.318	3.546	0
Helichrysum odoratissium	185	1750	ASTERACEAE	PH	CHP	0	0	0.045	2.546	0
Rhus ruspolii Engl.	103	1550	ANACARDIACEAE	HS	MIP	0	0	0.864	2.727	0.667
Myrsine africana L.	131	1600	MYRSINACEAE	LS	NAP	0	0	1.182	4.273	0.833
Clutia abyssinica Jaub. & Spach.	119	1550	EUPHORBIACEAE	LS	NAP	0	0	0.136	2.091	0
Combretum collinum Fresen.	111	1550	COMBRETACEAE	T	MIP	0	0	0.273	1.091	0.333
Allophyllus rubifolis (A. Rich) Engl.	100	1500	SAPINDACEAE	LS	NAP	0	0	0	1.909	0.333
Hippocratea Africana (Willd.) Loes.	110	1575	CELASTERACEAE	PC	L	0	0	0.409	2.091	1.5
Pluchea disioscoridis (L.) DC.	125	1600	ASTERACEAE	PH	CHP	0	0	0.091	1.091	0
Hyparrhenia filipendula (Hochst.) Stapf	65	1300	POACEAE	PG	HEC	0	0.5	1.227	1.273	0
Flacourtia indica (Burm.f.) Merr.	107	1500	FLACOURTIACEAE	HS	MIP	0	0	0.591	0.818	0
Albizia gummifera (J.F.Gmel.) C.A.Sm.	299	1750	FABACEAE	T	MEP	0	0	0	0.818	0.5
Hyparrhenia collina (Pilg) Stapf.	45	1300	POACEAE	PG	HEC	0	0	0	0.455	0.167
Acanthus eminens C.B.Clarke	252	2250	ACANTHACEAE	LS	NAP	0	0	0	0.455	0
Clausena anisata (Willd.) Benth.	288	1750	RUTACEAE	LS	MIP	0	0	0.136	0.636	0.5
Rhamnus staddo A. Rich.	183	1750	RHAMNACEAE	T	MIP	0	0	0	0.364	0
Vigna membranacea A. Rich.	184	1750	FABACEAE	PC	L	0	0	0.045	0.455	0
Terminalia laxiflora Engl. & Diels	144	1350	COMBRETACEAE	T	MEP	0	0	0	0.818	0.333
Eucalyptus globulus Labill.	207	1900	MYRTHACEAE	T	MEP	0	0	0	0.545	0
Crotalaria incana L.	190	750	FABACEAE	LS	NAP	0	0	0	0.636	0
Dissotis senegambiensis (Guill. & Perr.) Triana	287	1750	MELASTOMATACEAI	PH	CHP	0	0	0.318	0.364	0
Acacia etbiaca Schweinf.	64	1300	FABACEAE	T	MEP	0	0	0.136	0.364	0
Setureja abyssinica (Benth.) Briq.	112	1550	LAMIACEAE	H	CHP	0	0	0.364	0.545	0
Cussonia holstii Harms ex Engl.	319	1250	ARALIACEAE	T	MIP	0	0	0.091	0.364	0
Aeschynomene abyssinica (A. Rich.) Vatke	95	1550	FABACEAE	LS	MIP	0	0.25	0.091	0.455	0
Syzygium guineense (Willd.) DC.	138	1650	MYRTACEAE	T	MEP	0	0	0.455	0.364	5
Allophyllus abyssinicus (Hochst.) Radlkofer	45	1750	SAPINDACEAE	T	MEP	0	0	0.136	0.364	4.333
Conyza schimperi Sch. Bip. ex A. Rich.	209	1950	ASTERACEAE	LS	CHP	0	0	0	0.545	3.5
Maesa lanceolata Forssk.	192	1800	MYRSINACEAE	T	MEP	0	0	0	1	3.5
Bersama abyssinica Fresen.	176	1700	MELIANTHACEAE	T	MEP	0	0	0	0	3.167
Pittosporum abyssinicum Del	221	2250	PITTOSPORACEAE	LS	MIP	0	0	0	0	2.833
Galiniera saxifraga (Hochst.) Bridson.	222	2150	RUBEACEA	T	MEP	0	0	0	0	2.333
Albizia schimperiana Oliv.	132	1600	FABACEAE	T	MEP	0	0	0	0	2.667

Table 1. (Contd).

SPECIES	Voucher No.	Alt.	FAMILY	Growth Forms	Life forms	Cluster of Relevés				
						1	2	3	4	5
Aspilia mossambicensis (Oliv.) Wild.	8	1250	ASTERACEAE	PH	CHP	0	0	0	0.818	2.5
Asplenium bugoiense Hieron	230	2150	ASPLENIACEAE	AH	CHP	0	0	0.091	0.182	1.5
Arundinaria alpina K. Schum.	240	2200	POACEAE	PG	HEC	0	0	0	0.636	1.833
Erythrina brucei Schweinf.	102	1500	FABACEAE	T	MEP	0	0	0	0	1.833
Euphorbia ampliphylla Pax	251	2200	EUPHORBIACEAE	T	MIP	0	0	0	0	1.667
Hagenia abyssinica (Bruce) J.F. Gmel.	280	2250	ROSACEAE	T	MEP	0	0	0	0	1
Ocimum urticifolium Roth.	291	2200	LAMIACEAE	LS	CHP	0	0	0	0.273	1.333
Hallea rubrostipulata (K. Schum.) J.-F. Leroy	291	1600	RUBIACEAE	T	MIP	0	0	0	0	1.333
Rubus steudneri Schweinf.	196	1800	ROSACEAE	PC	L	0	0	0.045	0.545	1
Acanthus pubescens (Thoms.) Engl.	175	2250	ACANTHACEAE	LS	NAP	0	0	0	0.273	1
Hibiscus crassinervius Hochst. ex A. Rich.	177	1750	MALVACEAE	LS	NAP	0	0	0	0	0.833
Ficus glumosa Del.	173	1650	MORACEAE	T	MEP	0	0	0	0.182	0.833
Rhamnus prinoides	198	1700	RHAMNACEAE	LS	NAP	0	0	0	0	0.833
Hypericum quartinianum A. Rich.	182	1750	HYPRERICACEAE	LS	NAP	0	0	0	0.091	0.5
Pavetta oliveriana Hiern	317	1575	RUBIACEAE	LS	MIP	0	0.125	0	0	0.5

-Species identified on the spot

Altitudinal gradient of communities and diversity

The distribution of plant communities on the mountain slope of the study area clearly signifies the influence of altitude and the associated environmental factors. Even though communities were identified on the basis of dominant species, the species composition and diversity changed gradually along the altitude. This is indicated by the high Jaccard's coefficient of similarity among communities, eg. community 3 shared high number of species with communities 2, 4 and 5. On the other hand, communities 3 and 1 shared only a few species. Community 1 had the lowest similarity with all other communities apparently because of its location at the lakeshore (Table 2) where the terrain is flat and the OM composition of the soil is high (Table 5).

Table 2. Jaccard's community coefficient among 5 communities.

Communities	1	2	3	4	5
1	1.00				
2	0.04	1.00			
3	0.05	0.53	1.00		
4	0.07	0.20	0.52	1.00	
5	0.11	0.07	0.16	0.36	1.00

There was abrupt transition between communities 1 and 2 with only 4% of species occurring between them (Table 3). The transition between community 2 and community 3 was not as abrupt as between communities 1 and 2 with 53% of species being common to both communities. Communities 3 and 4 also had 52% of the species in common. The share of species between community 4 and 5 was only 36 %.

Table 3. Jaccard's community coefficient among adjacent communities/altitudinal ranges.

Altitudinal Ranges	Similarity coefficient	Communities
1180–1250/1250–1350	4 %	1,2
1250–1350/1300–1650	53 %	2,3
1300–1650/1600–1800	52 %	3,4
1600–1800/1800–2250	36 %	4,5

The pattern observed in this study indicated that community composition turnover was gradual as exhibited by high similarity coefficients among altitudinal ranges (Table 3). Even though continuity of vegetation composition was widely observed in the study area, there was discontinuity of vegetation composition between communities 1 and 2 at an altitude of 1250 m and between communities 4 and 5 at an altitude of 1800 m. The difference in the nature of the substrate could be important in causing breaks in community transitions at 1250 m. The geology on the highlands of Chencha is mainly composed of tertiary basalt while that of the Rift Valley floor is recent volcanic and tuffs of the quaternary (Vukasinovic, 1969; Mohr, 1971). In this connection, Beals (1969) had observed the effect of substrate discontinuity on the community patterns along the escarpment of the Rift Valley in Bati, Wello. The relative abruptness in the transition of communities at 1800 m could be attributed to the disturbances accounted by the activities of exotic tree plantations.

The diversity of species also showed gradual change among communities as altitude increases (Table 4). Community 3 had the highest species richness while community 5 exhibited the least species richness. The species richness showed bell-shaped pattern along altitudinal gradients, with the peak at the intermediate elevation and declining pattern at the lower and upper altitudes.

Table 4. Shannon-Wiener Diversity Index (using H= -sum pi ln pi).

Communities	Richness	Diversity Index(H)	Evenness (H/HMAX)
1	45	3.527	0.927
2	63	3.826	0.923
3	89	3.75	0.835
4	76	3.891	0.898
5	16	2.478	0.894

On the other hand, communities 1 and 2 had more even representation of the species followed by communities 4 and 5. Community 3 had high richness and lowest evenness. Community 4 and community 2 had the highest species diversity (3.89 and 3.82) followed by community 3 and 1. Community 5 had the lowest species diversity and richness than others (Table 4).

The relationship between communities and environmental variables

The test for variance of soil physical and chemical properties shown in Table 5 reveals that the differentiation of communities can be partly explained by the variations of soil texture and chemical properties at 5% probability, except cation exchange capacity, which was not significant (Table 5).

The mean values for soil particle size distribution were highly variable. The proportion of sand can be related to the degree of steepness since it was highest in community 2 and lowest in community 1 (Table 5). The proportion of clay particle size was highest in community 4 while it was lowest in community 2. The test for significance of variation of soils physical properties exhibited that soil particle size distribution appears to explain some variation among communities. The mean pH values in the five communities ranged between 5.83 and 7.4. Communities 5, 4 and 3 were found in slightly acidic soils while communities 2 and 1 were found in neutral to slightly basic soils at lower elevations. Similar result was reported by Beals (1969) regarding the increase of soil acidity with altitude.

Organic matter content and total nitrogen also varied among communities with out significant interaction between themselves. The communities could be arranged in decreasing order of: (i) soil organic matter as 1, 5, 3, 4 and 2 (ii) while total nitrogen as 2, 5, 4, 3 and 1. The communities can be arranged in decreasing order of available phosphorous (Ppm) as 1, 5, 2, 4, and 3 indicating a significant positive correlation with soil organic matter content (P=0.037). The highest organic matter content (5.52%) in community 1 at lower elevation (1180–1250 m) appears to be the effect of poor drainage (Haynes, 1986) along the lakeside.

Community 5 had low diversity and richness apparently due to the higher total nitrogen and available Phosphorous content of the soil apart from the obvious effect of temperature decline with increasing altitude. This agrees with the generally held view that highly nutrient rich soils would tend to support low species diversity (Hall and Swaine, 1976; Huston, 1994).

Table 5. Mean values of Soil Physical/Chemical properties, slope and aspect (ANOVA, F ratio at P<0.05 df= 4 and 44).

Environmental Variables	Community 1 1180–1250m	Community 2 1250–1350m	Community 3 1300–1650	Community 4 1600–1800m	Community 5 1800–2250m	F ratio (P<0.05)
%Sand	19.98	50.50	34.39	30.21	33.07	4.87*
% Silt	40.02	32.65	25.60	24.72	31.20	2.67*
% Clay	40.06	16.84	40.62	45.05	35.72	6.62*
pH	7.40	7.23	6.63	6.33	5.83	6.41*
CEC	35.30	46.51	44.55	39.64	40.53	1.03**
%Organic Matter	5.52	2.03	2.90	2.84	3.72	3.59*
%Total Nitrogen	0.25	2.97	2.53	2.59	2.83	4.45*
Pppm	96.63	3.14	1.25	2.83	4.43	854.46*
Slope (°)	1	8.5	5.91	8.36	6.83	4.28*
Aspect	-1	2.01	1.72	2.34	2.42	4.81*

* Significant   ** not significant

The overall pattern of the vegetation on the Arbaminch-Chencha mountain slope owes partly to the relatively low disturbance as a result of reduced population of the livestock which is checked by the occurrence of trypanosomiasis. The current effort to eradicate the tsetse flies and hence the disease could in due course affect the composition of the vegetation. It is therefore necessary to consider the possible scenario of tsetse eradication in conserving the environment in the area.

CONCLUSION

The distribution, abundance and diversity of species along altitudinal gradient on the slopes of Arbaminch-Chencha highlands are influenced by the variation of environmental factors across the landscape. The variability in topographic and edaphic conditions along slopes have resulted in spatial variations in environmental factors and influence the vegetation attributes such as composition, distribution and diversity of species. Aspect and soil physical and chemical properties appear to be the most highly influential factors on the distribution and diversity of species along the altitude. The study showed that the distribution of community types, species composition and diversity are better understood through investigation of environmental factors along altitudinal gradients on mountain slopes.

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