SINET: *Ethiop. J. Sci.*, 24(2):213–228, 2001

ISSN: 0379-2897

AN ECOLOGICAL STUDY OF THE VEGETATION OF GAMBELLA REGION, SOUTHWESTERN ETHIOPIA

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ABSTRACT: The vegetation of Gambella Region, southwestern Ethiopia, has been studied through five field trips made between October 14, 1995 and October 10, 1996. Systematic sampling method was used to select homogenous vegetation stands. Cover/abundance data was recorded for all plants from a total of 58 relevès. For each relevè, environmental data on topographic factors (altitude and slope), and soil from a depth of 0–10 cm (topsoil) and 40–50 cm (subsoil) were collected. The soil samples were analyzed for pH, texture, cation exchange capacity, organic carbon, total nitrogen, available phosphorus, exchangeable potassium and sodium. The species and relevès were classified using a FORTRAN computer program TWINSPAN and seven major plant communities were described. Five plant communities were found to have phytogeographical affinity to the Sudanian vegetation type while two are affiliated to the Guineo-Congolian vegetation type of Africa. Comparison of the community types was made using ANOVA to find whether there are statistically significant variations in environmental factors.

Key words/phrases: Ethiopia, Gambella Region, phytogeographic affinity, phytosociology, plant communities

INTRODUCTION

Ethiopia is recognized as one of the countries with a rich biological diversity (Tewolde Berhan Gebre Egziabher, 1991; WCMC, 1992). The floristic diversity in the country is being documented and hopefully will come to completion when the writing of the Ethiopian Flora is completed (see Hedberg and Edwards, 1989; 1995; Edwards *et al.*, 1995; 1997).

There has been a lack of a unified approach to the description and identification of plant communities in the country so far. Vegetation types in Ethiopia have been described and classified based on physiognomic criteria

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by Pichi-Sermolli (1957), Breitenbach (1963), Mesfin Wolde Mariam (1972), Daniel Gamachu (1977), Wilson (1977), Friis *et al.* (1982), Tewolde Berhan Gebre Egziabher (1986), Friis (1992) and Bonnefille *et al.* (1993).

Few vegetation studies have also been based on floristic composition. These include: vegetation of the Erer-Gota plain, Harar (Beals, 1969), Menagesha-Suba State forest, Shewa (Sebsibe Demissew, 1980) Jemjem forest, Sidamo (Hailu Sharew, 1982), grassland vegetation on the central plateau of Shewa (Zerihun Woldu, 1985), Harena forest, Bale (Lissanework Nigatu, 1987), forests of the Central plateau of Shewa (Tamrat Bekele, 1993), and Afroalpine vegetation of the Senatti plateau, Bale (Menassie Gashaw and Masresha Fetene, 1996).

Prior to the present study, many plant collection expeditions have been carried out in the Gambella Region with subsequent publications that have described the flora of the region (Senni, 1940, Chaffey, 1979; Friis *et al.*, 1982; Ensermu Kelbessa *et al.*, 1992; Friis, 1992; Mesfin Tadesse, 1992). However, apart from earlier works carried out to identify the plant associations in the western flood plain of Gambella (TAMS-Agricultural Development Group, 1976), there has been no thorough study yet that has attempted to describe the plant communities in Gambella Region.

The exercise in vegetation descriptions and classifications in Africa todate had mainly relied on physiognomic features (White, 1983). However, the merits of having to ascribe floristic elements to the phytogeographical areas in which they occur have also been emphasized. There has been no significant effort made to this end with regard to vegetation studies so far in Ethiopia.

The present study was carried out with the following main objective in mind: to identify the plant communities of the vegetation of the Gambella Region and to describe the ecological relationship between the plant communities and their physical environment. The result of this study will hopefully add to our understanding of the vegetation of the region. It will also provide a basis for further ecological studies, which would contribute towards conservation of the vegetation in the region.

THE STUDY AREA

The study was carried out in Gambella People's National Regional State, in southwestern Ethiopia between latitudes 6° 30' and 8° 30' N and longitudes 33° 00' and 35° 45' E, with an area of 26,000 km² (Fig. 1). Oromia Regional State to the north, Southern Peoples' Nations and Nationalities Regional State to the east and the Republic of Sudan to the south and west border

Gambella Region. The northern and eastern parts of Gambella Region have an elevation of about 2000 meters above sea level. The central part is between 500 and 600 m. The elevation decreases gradually to an altitude of 300 m towards the border of the Sudan.

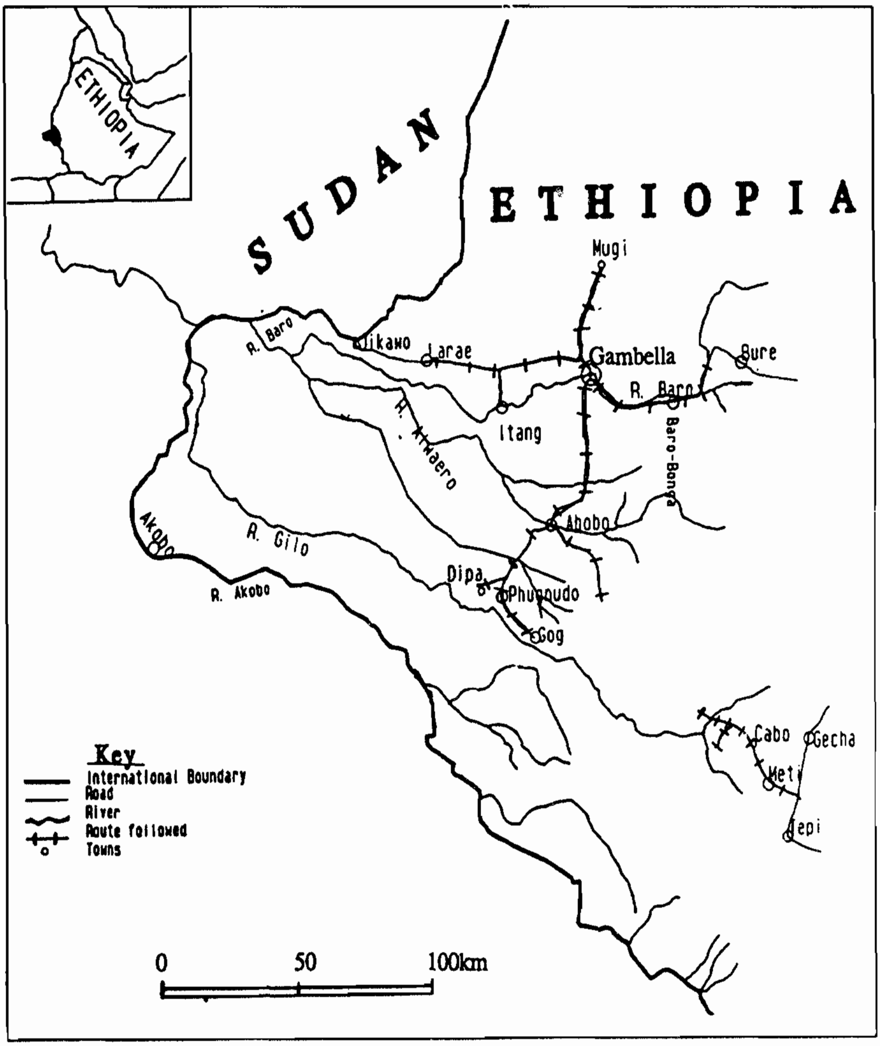

Fig. 1. **Map of Gambella Region: Modified from 1:1,000,000 scale map (EMA, 1994), using computer-digitizing techniques.**

Geology

The pre-cambrian rocks that underlie all the other rocks in Ethiopia are covered by extensive Late Tertiary and Quaternary deposits in the lowlands of Gambella (Mohr, 1971; Davidson *et al.*, 1976). Old crystalline rocks overlay the pre-cambrian rocks in the adjacent relief (Mesfin Wolde Mariam, 1969), and valleys are largely composed of Phyllite with uncommon Chlorite Schist (Mohr, 1971).

Soil

The soils in the Gambella plain are mainly Chromic and Pellic Vertisols, with Eutric Glysols and Eutric Histosols in areas that experience extreme seasonal flooding (FAO, 1984; EMA, 1988). There is also Eutric Fluvisols on the alluvial plains of Baro river and its tributaries (FAO, 1984). The soils in the forest of eastern Gambella are reddish or brown Ferrisols derived from volcanic material (Friis *et al.*, 1982).

Climate

The climatic zones of Ethiopia are divided into three distinct zones (NMSA, 1996), namley: dry climate, tropical rainy climate and temperate rainy climate. Among these, the tropical rainy climate occurs in the Gambella Region. The escarpments of eastern Gambella face the humid air currents coming from the Atlantic Ocean and receive high rainfall compared to the lowlands in western Gambella. A single maximum rainfall that runs from February/March to October/November characterizes the rainfall in this region. The second highest mean maximum temperature for the country was recorded in the lowlands of Gambella (35–40° C), next only to that of the Afar Depression (40° C) (NMSA, 1996). The escarpments in eastern Gambella on the other hand, have a mean maximum temperature between 27–32° C.

MATERIALS AND METHODS

Vegetation sampling

A reconnaissance survey was made in October 1995 to identify vegetation types in relatively undisturbed areas of Gambella Region. Five subsequent study trips, October 14 to November 6, 1995; November 20 to December 13, 1995; April 1-19, 1996; May 22 to June 1, 1996; and September 21 to October 10, 1996 were conducted. The sampling sites were selected along the following roads: Gambella-Itang-Larae, Gambella-Mugi, Gambella-Bure, Gambella-Abobo-Phugnudo-Gog and the Tepi-Meti-Cabo (Fig. 1).

Fifty-eight relevès were sampled following the Braun-Blanquet approach (Braun-Blanquet, 1965). A systematic sampling method was used to select homogenous vegetation stands (relevès). Each relevè was sampled using a square plot of 400 m^2 (20 m by 20 m). The cover/abundance values of all plants in each plot were estimated according to a 1-9 modified Braun-Blanquet scale (van der Maarel, 1979). Plants in the vicinity but absent in the sample plots were noted. Plant specimens were collected and identified as described in Tesfaye Awas *et al.* (1997). Nomenclature follows Cufodontis (1953-1972), Hedberg and Edwards (1989 and 1995) and Edwards *et al.* (1995 and 1997).

Environmental data

Environmental data on topographic and soil factors were gathered for each relevè. Everest Altimeter and Clinometer were used to measure altitude and slope, respectively. Soil auger was used to collect soil samples to depths of 0–10 cm (topsoil) and at 40–50 cm (subsoil). Soil was sampled from five spots (four from the corners and one from the center) within the sample plot and mixed to obtain a composite sample. Only topsoil was collected from grasslands and from very shallow soils with rocky substrates.

Soil analysis

Soil samples were analyzed in the soil laboratory of the Department of Biology, Addis Ababa University, following Juo (1978), and Chopra and Kanwar (1982). Soil samples were air dried, passed through 2 mm sieve for pH, texture, potassium, cation exchange capacity and phosphorous and through 0.5 mm sieve for nitrogen and organic carbon determination.

The pH was measured using pH-Meter in suspension at 1:1, distilled water to soil ratio. Hydrometer Method was followed to determine soil texture by using sodium hexametaphosphate as dispersing agent. Following Walklay-Black's Titration Method and Kjeldahl Method, the percentage of organic carbon and total nitrogen were determined, respectively. Available phosphorus was determined spectrophotometrically at 660 nm and exchangeable potassium and sodium by Flame Photometer.

Data analysis

Vegetation data were analyzed and classified using a FORTRAN Computer Program TWINSPAN, TWo-way INdicator SPecies ANalysis, Version 1.0 (Hill, 1994). TWINSPAN is a divisive polythetic method of vegetation classification. It classifies both samples and species. The resulting groups are recognized as community types. Community-environment interrelationships were tested using ANOVA (analysis of variance) to find out if there are significant differences between the derived plant communities in terms of environmental variables. The statistical analysis was performed using the computer program STATISTICA for windows, Release 4.5-A.

Table 1. Plant communities of the vegetation of Gambella Region.

Species	Relevès							
	44	1	111111112222445555	1222255	2552	3333333	344443344	
	67	890	235671234567823458923458	49017867	16019	1534067	223458910	
52 *Chlorophytum gallabatense*	21	---	------------------------	--------	----	-------	---------	0011
73 *Commelina zambesica*	32	---	------------------------	--------	----	-------	---------	0011
95 *Echinochloa rotundiflora*	3-	---	------------------------	--------	-----	-------	---------	0011
117 *Hygrophilia auriculata*	23	---	------------------------	--------	-----	-------	---------	0011
164 *Pennisetum thunbergii*	--	233	------------------------	--------	-----	-------	---------	0011
187 *Sorghum purpureo-sericeum*	--	444	------------------------	--------	-----	-------	---------	0011
17 *Andropogon schirensis*	--	-3-	442222-4-33-----------2-	--------	-----	-------	---------	0000
70 *Combretum collinum*	--	---	--122-1-1----121222-----	--------	-----	-------	---------	0000
97 *Entada africana*	--	---	-----------------1-12--2	--------	-----	-------	---------	0000
118 *Hyparrhenia filipendula*	--	---	---2-3---3--2--32-------	--------	-----	-------	---------	0000
119 *Hyparrhenia pilgeriana*	--	---	--33123-3-32-31333333323	-333-33-	-----	-------	---------	0000
145 *Loudetia arundinacea*	--	---	333--32-3324311232-23233	-----2--	-----	-------	---------	0000
189 *Sterculia africana*	--	---	-----------------2112-2-	--------	-----	-------	---------	0000
198 *Terminalia macroptera*	--	---	-------------223--------	--------	-----	-------	---------	0000
69 *Combretum adenogonium*	--	---	------------------------	-31-31--	-----	-------	---------	0001
107 *Flueggea virosa*	--	---	------------------------	--22-2--	-----	-------	---------	0001
109 *Grewia mollis*	--	---	------12------2--------1	1-21-1--	-----	-------	---------	0001
133 *Justicia ladanoides*	--	---	-----------------------1	-----22	-----	-------	---------	0001
144 *Lonchocarpus laxiflorus*	--	---	--111--11----1111---1---	2-33---1	-----	-------	---------	0001
161 *Panicum maximum*	--	---	----3--2---------------1	3-----3	-----	-------	---------	0001
174 *Pterocarpus lucens*	--	---	231---1----------2221222	--2-3233	---2-	-------	---------	0001
179 *Rottboellia cochinchinensis*	--	---	--------2---------2--3-1	2-----2-	-----	-------	---------	0001
197 *Terminalia laxiflora*	--	---	------------------------	21--21--	-----	-------	---------	0001
218 *Ziziphus abysisinica*	--	---	------------------------	---221--	-----	-------	---------	0001
8 *Acalypha ornata*	--	---	------------------------	--------	-22--	-------	---------	0010
10 *Achyranthus aspera*	--	---	------------------------	--------	-2-1-	-------	---------	0010
23 *Anogeissus leiocarpa*	--	---	-------------2--2----1--	-2222322	33332	-------	---------	0010
31 *Asystasia gangaetica*	--	---	------------------------	----2---	3-2--	-------	---------	0010
48 *Celtis toka*	--	---	------------------------	--------	---23	-------	---------	0010
111 *Hibiscus calyphyllus*	-1	---	-----1------------------	--------	--22-	-------	---------	0010
194 *Tamarindus indica*	--	---	----------------3----2--	--------	2233-	-------	---------	0010
219 *Ziziphus pubescens*	--	---	----------------2-------	--------	23--2	-------	---------	0010
99 *Erythroxylum fischeri*	--	---	------------------------	--------	2-113	--31---	---------	01
44 *Capparis erythrocarpus*	--	---	------------------------	--------	--2-3	22-----	---------	10
139 *Lepidotrichilia volkensii*	--	---	------------------------	--------	-112-	--222-1	---------	10
209 *Vepris dainellii*	--	---	------------------------	--------	----2	--21---	--------2	10
34 *Baphia abyssinica*	--	---	------------------------	--------	-----	1333333	-------3-	1100
147 *Malacantha alnifolia*	--	---	------------------------	--------	-----	3--1---	---------	1100
150 *Milicia excelsa*	--	---	------------------------	--------	-----	22-----	---------	1100
195 *Tapura fischeri*	--	---	------------------------	--------	-----	13-2-11	--------2	1100
217 *Zanthoxylum lepreurii*	--	---	------------------------	--------	-----	1---2-1	---------	1100
86 *Diospyros abyssinica*	--	---	------------------------	--------	-----	--21-2-	-22------	1101
7 *Acalypha acrogyna*	--	---	------------------------	--------	-----	2---113	22-----2	1110
49 *Celtis zenkeri*	--	---	------------------------	--------	-----	2---113	3--12232-	1110
213 *Whitfieldia elongata*	--	---	------------------------	--------	-----	-2-2-23	2-3331---	1110
12 *Justicia schimperiana*	--	---	------------------------	--------	-----	-------	-3232----	1111
14 *Alchornea laxiflora*	--	---	------------------------	--------	-----	-------	-------2-2	1111
21 *Pouteria altissima*	--	---	------------------------	--------	-----	-------	-----1323	1111
26 *Argomuellera macrophylla*	--	---	------------------------	--------	-----	---122-	332222332	1111
76 *Cordia africana*	--	---	------------------------	--------	-----	----2--	-21233323	1111
92 *Dracaena fragrans*	--	---	------------------------	--------	-----	-------	-22-234-2	1111
148 *Manilkara butugi*	--	---	------------------------	--------	-----	-------	-44441121	1111
152 *Mimusops kummel*	--	---	------------------------	--------	-----	-------	---12-23-	1111
	00	000	000000000000000000000000	00000000	00000	1111111	111111111	
	00	000	111111111111111111111111	11111111	11111	0000000	111111111	
	00	111	000000000000000000000000	00000000	11111	0011111	000000001	
			000000000000000000000000	11111111	00001	00111	00000111	
Cluster codes or Communities	1	2	3	4	5	6	7	

Communities: 1, *Commelina zambesica-Hygrophila auriculata*; 2, *Sorghum purpureo-sericeum-Pennisetum thunbergii*; 3, *Loudetia arundinacea-Hyparrhenia pilgeriana*; 4, *Combretum adenogonium-Anogeissus leiocarpa*; 5, *Tamarindus indica-Anogeissus leiocarpa*; 6, *Baphia abyssinica-Tapura fischeri* and 7, *Manilkara butugi-Cordia africana*.

RESULT AND DISCUSSION

Vegetation classification

The vegetation of Gambella Region was classified into seven major clusters or plant communities. The community types are designated as 1,2,3,4,5,6 and 7 (Table 1). The plant communities were named by the species that have the highest cover/abundance values. The seven major plant communities are described as follows.

1: *Commelina zambesica-Hygrophila auriculata* community: *Commelina zambesica* C. B. Clarke. and *Hygrophila auriculata* (Scum.) Heine. are the character species in this community. The herbaceous species were found to be dominant over grass species like *Echinochloa rotundiflora* Clayton. because the sample was taken at the beginning of the rainy season, in May. In addition to herbaceous and grass species, the occurrence of scattered trees of *Balanites aegyptiaca* (L.) Del. and shrubs of *Combretum collinum* Fresen. and *Maerua triphylla* A. Rich. are noted in the community. This community occurs in the western plain of Gambella at an average altitude of 535 m.

2: *Sorghum purpureo-sericeum-Pennisetum thunbergii* community: *Sorghum purpureo-sericeum* (Hochst. ex A. Rich.) Aschers. & Schweinf. and *Pennisetum thunbergii* Kunth are the character species in the community. Scattered individuals of the tree *Balanites aegyptiaca* and shrubs of *Acacia polyacantha* Willd. and *A. seyal* Del. are noted in the community. This community is confined to the vicinity of Itang at an altitude of 580 m.

3: *Loudetia arundinacea-Hyparrhenia pilgeriana* community: *Loudetia arundinacea* (Hochst. ex A. Rich.) Steud. and *Hyparrhenia pilgeriana* C. E. Hub. are important species of this community. Other grass species in this community include: *H. filipendula* (Hochst.) Stapf, *Andropogon schirensis* Hochst. ex A. Rich., *Rottboellia cochinchinensis* (Lour.) Clayton. and *Panicum maximum* Jacq. This community is characterized also by the presence of deciduous fire resistant woodland trees such as *Combretum collinum*, *Lonchocarpus laxiflorus* Guill. & Perr. and *Pterocarpus lucens* Guill. & Perr. *Sterculia africana* (Lour.) Fiori and *Entada africana* Guill. & Perr. are noted as tree species occurring in this community particularly on the hilly areas, and on the escarpments and ridges towards the lowlands of western Gambella. The community was found to occur along the road from Abobo to Phugnudo, Gambella to Itang and Gambella to Bure at an average altitude of 635 m.

4: *Combretum adenogonium-Anogeissus leiocarpa* community: *Combretum adenogonium* Steud. ex A. Rich. and *Anogeissus leiocarpa* (A. DC.) Guill. & Perr. are the character species in this community. The community is dominated and characterized by deciduous woodland trees. These include *Lonchocarpus laxiflorus, Pterocarpus lucens, Terminalia laxiflora* Engl. & Diels and *Ziziphus abyssinica* Hochst. ex A. Rich. Shrubs like *Flueggea virosa* (Willd.) Voigt. and *Grewia mollis* A. Juss., and lianas like *Cissus populnea* Guill. & Perr. and *Opilia amentacea* Roxb. are also found in this community. Herbaceous species such as *Justicia ladanoides* Lam. and *Asystasia gangetica* (L.) T. Anderss. grow under the canopy of trees. Tall grass species such as *Hyparrhenia pilgeriana, Rottboellia cochinchinensis* and *Panicum maximum* occur in open area. This community is confined to the road from Gambella to Abobo and to a certain extent along the road from Gambella to Bure. The average altitude at which the community occurs is 686 m.

5: *Tamarindus indica-Anogeissus leiocarpa* community: This community occurs along riverbanks, and represents riverine forest. It is characterized by *Tamarindus indica* L. and *Anogeissus leiocarpa* at tree layer. Other trees present include: *Celtis toka* (Forssk.) Hepper & Wood and *Ziziphus pubescens* Oliv. The shrub layer is characterized by *Acalypha ornata* A. Rich., *Erythroxylum fischeri* Engl. and *Lepidotrichilia volkensii* (Gurke.) Leroy. Herbaceous species like *Asystasia gangetica* and *Hibiscus calyphyllus* Cavan. are common in the field layer. The average altitude at which the community occurs is 617 m.

6: *Baphia abyssinica-Tapura fischeri* community: *Baphia abyssinica* Brummitt and *Tapura fischeri* Engl. are the characteristic species in this community. *Malacantha alnifolia* (Bak.) Pierre., *Zanthoxylum lepreurii* Guill. & Perr., *Vepris dainellii* (Pichi-Serm.) Kokwaro., *Diospyros abyssinica* (Hiern.) F. White., *Milicia excelsa* (Welw.) C. C. Berg and *Celtis zenkeri* Engl. are important species in the tree layer. *Whitfieldia elongata* (P. Beauv.) C. B. Cl., *Argomuellera macrophylla* Pax. and *Acalypha acrogyna* Pax. are common species in the shrub layer. Lianas like *Hippocratea africana* (Willd.) Loes. ex Engl. and *H. pallens* Oliv. have been noted in this type. This community is restricted to the lowlands of the eastern Gambella at an average altitude of 714 m.

7: *Manilkara butugi-Cordia africana* community: This community is characterized by *Manilkara butugi* Chiov. and *Cordia africana* Lam in the tree layer. Other important trees include *Mimusops kummel* Bruce. ex A. DC., *Pouteria altissima* (A Chev.) Baehni, *Alchornea laxiflora* (Benth.) Pax. & K. Hoffm. and *Celtis zenkeri*. Lianas noted in this community include: *Celtis philippensis* Blanco., *Hippocratea africana* and *H. pallens*. *Justicia schimperiana* Nees., *Dracaena fragrans* (L.) Kor-Grawal., *Whitfieldia elongata, Argomuellera* *macrophylla* and *Acalypha acrogyna* are very common species in the shrub layer. Epiphytic mosses and ferns noted in this community include *Selaginella abyssinica* Spring., *Leptogramma pozoi* (Lagasca.) Heywood. and *Drynaria volkensii* Hieron. This community occurs on the escarpments of eastern Gambella at an average altitude of 1303 m.

Phytogeographical affinity

The plant communities identified in the present study have affinity to two phytogeographical regions which have been described by White (1983), in his classification of African vegetation and phytogeography. The regions are the Sudanian and the Guineo-Congolian centers of endemism. Thus, the plant communities 1-5 have affinity to the Sudanian vegetation type. They occur on the slope down to the Gambella plain and extend toward Sudan border and termed by White (1983), as Ethiopian undifferentiated woodland. The affinity is by the presence of woodland trees such as *Anogeissus leiocarpa, Balanites aegyptiaca, Combretum collinum* and *Lonchocarpus laxiflorus*.

The remaining two of the seven plant communities identified in the present study, *i.e., Baphia abyssinica-Tapura fischeri* and *Manilkara butugi-Cordia africana* communities consist of species such as *Alistonia boonei, Pouteria altissima, Celtis zenkeri, C. philippensis* and *Milicia excelsa.* These species are characteristic in the Guineo-Congolian vegetation type (White, 1983; Friis, 1992).

Plant community - environment relationships

The averaged values of soil properties and topographic variables and tests of significance for the seven major plant communities are given in Table 2. The importance of each parameter in explaining variation in the plant communities is discussed below.

Soil pH: The averaged topsoil pH values of the plant communities gave a sequence (from lowest to highest) 1, 2, 3, 6, 4, 7 and 5. Communities 1 and 2 occur in slightly acidic soil. Communities 3, 4, 6 and 7 occur on neutral soil while community 5 occurs on slightly basic soil. Based on increasing order of the averaged pH values of the subsoil, a sequence 4, 3, 6, 5 and 7 was obtained. In community 4 the subsoil was found to be medium acidic, in 3 slightly acidic and 6,5 and 7 were neutral.

Soil texture: The average particle size percentage values of topsoil gave textural class designations of clay loam soil (Community 1), clay (Community 2), loam (community 3) and sandy loam (communities 4-7). Textural analysis of the subsoils revealed the following textural classes: sandy loam soil (communities 3-5), clay (community 6) and loam (community 7).

Table 2. Comparison of the soil physical and chemical properties and topographic features among seven plant communities.

Plant Community	pH		Sand (%)		Silt(%)		Clay (%)		CEC (meq/100g soil)	
	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
1: *Commelina zambesica-Hygrophila auriculata*	6.02cd	—	40.10bc	—	31.60ab	—	28.30b	—	26.09bc	—
(N=2)	(0.01)	—	(5.00)	—	(4.00)	—	(1.00)	—	(9.57)	—
2: *Sorghum purpureo-sericeum-Pennisetum thunbergii*	6.10c	—	36.83c	—	11.60b	—	51.57a	—	79.13ab	—
(N=3)	(0.07)	—	(3.14)	—	(1.89)	—	(2.91)	—	(12.43)	—
3: *Loudetia arundinacea-Hyparrhenia pilgeriana*	6.79bd	6.19bc	53.94bc	55.26b	27.32a	19.90bc	17.28bc	24.50bc	25.85c	27.63b
(TS, N=24; SS,N=18)	(0.11)	(0.15)	(4.49)	(5.59)	(3.07)	(2.88)	(2.82)	(4.78)	(5.81)	(12.13)
4: *Combretum adenogonium-Anogeissus leiocarpa*	6.94ab	5.69c	75.55a	64.76b	16.30b	19.98bc	8.78d	6.23bc	5.90c	13.02b
(N=8)	(0.11)	(0.15)	(4.44)	(6.33)	(2.83)	(4.84)	(1.87)	(4.55)	(3.63)	(7.60)
5: *Tamarindus indica-Anogeissus leiocarpa*	7.26ab	6.78ab	73.16a	67.06b	16.26ab	12.44c	10.58cd	24.10ac	74.78b	27.36b
(N=5)	(0.10)	(0.46)	(2.65)	(7.22)	(1.28)	(1.94)	(1.97)	(8.47)	(23.09)	(10.88)
6: *Baphia abyssinica-Tapura fischeri*	6.79bc	6.73ab	62.16ab	34.33a	26.43ab	5.17bc	11.41cd	40.50a	51.55b	18.02b
(N=7)	(0.30)	(0.35)	(2.38)	(5.24)	(3.60)	(4.31)	(1.51)	(5.23)	(6.65)	(7.56)
7: *Manilkara butugi-Cordia africana*	6.95ab	6.95a	70.00a	48.46b	21.57ab	28.18ab	8.44d	23.39ac	117.49a	83.38a
(N=9)	(0.19)	(0.16)	(4.77)	(5.14)	(3.18)	(3.40)	(1.89)	(4.29)	(12.64)	(8.49)

Table 2. (Contd.)

Plant Community	OC (%)		Nitrogen (%)		Phosphorus (ppm)		Potassium (ppm)		Sodium (ppm)		Average elevation	Slope (°)
	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS		
1: *Commelina zambesica-Hygrophila auriculata*	0.90b		0.19b	—	1.07cd	—	14.75ab	—	7.00a	—	535.00b	0c
(N=2)	(0.09)	—	(0.04)	—	(0.47)	—	(1.75)	—	(1.50)	—	(5.00)	(0)
2: *Sorghum purpureo-sericeum-Pennisetum thunbergii*	0.41b	—	0.15b	—	0.01cd	—	11.83b	—	12.83a	—	580.00b	0c
(N=3)	(0.17)	—	(0.05)	—	(0)	—	(1.69)	—	(1.17)	—	(0)	(0)
3: *Loudetia arundinacea-Hyparrhenia pilgeriana*	2.09b	1.10b	0.31b	0.15b	2.10d	0.74b	4.88b	6.89b	2.50bc	2.85b	635.00b	11.00ab
(TS, N=24; SS,N=18)	(0.85)	(0.15)	(0.03)	(0.02)	(0.52)	(0.30)	(1.91)	(1.14)	(0.49)	(0.42)	(9.63)	(2.46)
4: *Combretum adenogonium-Anogeissus leiocarpa*	1.28b	0.56b	0.25b	0.13b	2.38bc	0.92b	2.00b	6.88b	2.69bc	3.13b	686.25b	2.88b
(N=8)	(0.30)	(0.17)	(0.04)	(0.02)	(1.01)	(0.43)	(2.60)	(0.68)	(0.19)	(0.52)	(20.44)	(0.93)
5: *Tamarindus indica-Anogeissus leiocarpa*	2.68b	1.06ab	0.60b	0.16b	3.92bcd	4.00ab	13.30b	13.20ab	2.90bc	2.71ab	617.12b	3.8b
(N=5)	(0.44)	(0.42)	(0.18)	(0.05)	(2.07)	(3.28)	(2.75)	(2.50)	(0.64)	(0.73)	(24.17)	(1.71)
6: *Baphia abyssinica-Tapura fischeri*	2.39b	0.53b	0.51b	0.14b	4.17bc	3.51ab	16.93b	8.57b	1.07bc	1.07a	714.29b	5.14b
(N=7)	(0.36)	(0.15)	(0.06)	(0.03)	(0.77)	(1.44)	(4.59)	(1.00)	(0.37)	(0.37)	(11.92)	(1.30)
7: *Manilkara butugi-Cordia africana*	9.41a	1.79a	2.01a	0.58a	5.97ab	5.56a	28.00a	35.83a	1.06c	1.78ab	1303.33a	14.67a
(N=9)	(1.39)	(0.29)	(0.37)	(0.11)	(0.74)	(1.12)	(4.40)	(15.83)	(0.29)	(0.32)	(102.75)	(1.91)

CEC, Cation Exchange Capacity; OC, Organic Carbon; TS, Topsoil; SS, Subsoil; N, Number of soil samples. Values are means with standard error (in parentheses). Values within the same column followed by different letters are significantly different (ANOVA, $P < 0.05$).

The results of soil textural analysis show that communities 1 and 2 occur on poorly drained soils while communities 3–7 occur on well-drained soils. Dewan *et al.* (1985a and 1985b), also indicated the occurrence of poorly drained soils in Itang area (area represented by community 1 and 2) and well-drained soils in Abobo and Phugnudo area (area represented by community 3 and 4). Friis (1992) had also indicated the occurrence of the forests of Gambella (represented by community 6 and 7) on well-drained soil.

Organic carbon, cation exchange capacity, total nitrogen, available phosphorus and exchangeable potassium: These soil variables showed similar variation both in the top and subsoils. The values were found to be significantly higher in community 7. This community occurs in transitional rain forests (Tepi area) where climatic conditions are different from those for other communities. Higher precipitation and lower temperature, which is characteristic of the area, may reduce mineralization of humus (Foth and Turk, 1972). Also, the resulting accumulation of soil organic matter could increase cation exchange capacity and reduce leaching of nutrients, particularly nitrogen, phosphorus and potassium (Menassie Gashaw and Masresha Fetene, 1996). In communities 1–6, organic matter, nitrogen, phosphorus and potassium were very low. Similar results had been recorded in Gambella plain by Dewan *et al.* (1985a and 1985b).

Exchangeable sodium: The average values of exchangeable sodium in the topsoil resulted in the following sequence (from lowest to highest) 7, 6, 3, 4, 5, 1 and 2. Values for communities 2 and 1 were significantly high, while communities 3–7 had significantly low values. The average value of sodium in the subsoil, was found to be significantly low in community 6 compared to all other communities. The higher sodium concentration in communities 1, 2, 3 and 4 could be attributed to fire incidence in the grasslands and woodlands, which removes the humus and causes the accumulation of soluble salts such as sodium (Vickery, 1982).

Topographic factors: Community 7 was found at higher altitudes compared to the other communities. Community 7 had also the highest slope followed by communities 3, 6, 5 and 4 (in decreasing order). Communities 1 and 2 were found on flat plains.

CONCLUSION

Based on the present study, the analysis of floristic data on cover/abundance values revealed seven plant communities in the vegetation of Gambella Region. The communities identified are *Commelina zambesica-Hygrophila auriculata, Sorghum purpureo-sericeum-Pennisetum thunbergii, Loudetia* *arundinacea-Hyparrhenia pilgeriana, Combretum adenogonium-Anogeissus leiocarpa, Tamarindus indica-Anogeissus leiocarpa, Baphia abyssinica-Tapura fischeri* and *Manilkara butugi-Cordia africana.* This classification was further supported by the variation in environmental factors between the plant communities. Geological factors, soil, topographic features and hot climate in the region are believed to have contributed to the presence of these plant communities in Gambella.

All the plant communities identified in the region have phytogeographical affinity to central and western Africa rather than to central and eastern Ethiopia. The plant communities in the forests of Gambella show affinity to the Guineo-Congolian vegetation type while those from the woodlands belong to the Sudanian vegetation type.

ACKNOWLEDGEMENTS

We thank the institutions and individuals in Gambella Region for their help during the study period. We are grateful to the Institute of Biodiversity Conservation and Research for the financial support. Our thanks are extended to the Keepers of the National Herbarium (ETH) and the Royal Botanic Gardens, Kew (K) for availing herbarium specimens.

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