AN ECOLOGICAL STUDY OF THE LOWLAND VEGETATION OF KEY AFER-SHALA LUQA AND SOUTHWEST OF LAKE CHAMO, SOUTHERN ETHIOPIA

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ABSTRACT

Studies in the vegetation of Key Afer-Shala Luqa and Southwest of Lake Chamo, Southern Ethiopia were conducted from Nov. 21, 1996 to February 27, 1997. The data on aboveground herbaceous phytomass was collected using $1m^2$ quadrat from 13 selected sites. To determine the different plant communities, data from 71 quadrats (400 m^2) was collected following a 1-9 modified Braun Blanquet scale (van der Maarel, 1979). The environmental data collected consists of soil, altitude, slope and aspect.

The average aboveground herbaceous phytomass ranged between 35.9 gm^{-2} in Shala plain to 1016.8 gm^{-2} in Southwest of Lake Chamo. Multivariate methods were employed to summarise the vegetation data. Seven community types and an outliers were identified. Statistical test (Post-hoc comparison of means) among the community types showed significant variation in altitude indicating that altitude is the most important factor.

Analysis of diversity among community types showed that the *Hyparrhenia filipendula-Combretum molle* dominated community is richer in species than others, while the *Commiphora cyclophylla-Actiniopteris radiata-Sansevieria ehrenbergii* dominated community is the least species rich community.

The low aboveground herbaceous phytomass in sites like Shala might be attributed to ecological incompatibility with prevailing stocking rate. To ameliorate the interrelated causes of resource degradation, destocking should be taken into consideration.

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1. INTRODCTION

1.1 Scope of the Problem

In Ethiopia as a whole, the area covered by natural vegetation is being reduced at a faster rate. Deforestation has occurred to such an extent that only 3.6% of the country, which is 9% of the area above 1,500 m is covered by closed forests (Zerihun and Mesfin, 1990). Ensermu *et al.* (1992) also suggested that, much of the woody vegetation especially in the north western part of the country covered by *Combretum-Terminalia* woodland has been removed due to the intensification of agriculture.

Despite the fact that woodlands have been sustainably managed for centuries by indigenous inhabitants, Ethiopia's woodland resources are under sever pressure as a consequences of population growth and an associated need for agricultural and pastoral lands. Zerihun and Mesfin (1990) pointed that degradation of woodland is most remarkable in the central rift valley where woodlands were reduced to 4 percent of the original extent within a time span of 50 years.

Although there are some woodland and bushland resources in the southern Ethiopia, there is little information available on the condition and decline of these resources. Inorder to suggests on the use of these resources on a sustainable basis, a clear understanding of these resources is seen to be important.

The interest of bringing an understanding on the woodland and bushland resources of Ethiopia was initiated on the occasion of Ethiopian Forestry Action program Donor conference in May 1994. Then Ethio-Germany Government consultations agreed to co-operate in implementing the project. The project (wooldland and bushland survey) was taken care by the Savannah Woodland Management Study Project (SWMSP). This study as part of the SWMSP therefore dealt with the woodland and bushland vegetation of Key Afer-Shala Luqa and Southwest of Lake Chamo in Southern Ethiopia. The objectives were:

(i) to characterize the vegetation of Key Afer-Shala Luqa and Southwest of Lake Chamo.

(ii) to relate the distribution of plants to some environmental parameters and compare the species richness of the different community types.

(iii) to determine aboveground herbaceous phytomass.

(iv) to obtain information that could provide some clue to implement sustainable management of these woodland resources.

1.2 Background to the Study Area

1.2.1 Location of the Study Area

The study areas are Key Afer-Shala Luqa and Southwest of Lake Chamo. Key Afer-Shala Luqa is located about 709 km south west of Addis Ababa and 200 km south of Arbaminch between longitudes 37°20' and 37°32'E and latitudes 5°41' and 5°56'N (see Fig. 1 on page 3). Key Afer-Shala Luqa lies between 600-1900 m a.s.l. in altitude. Topographically the general area is flat with undulating mountains.

Southwest of Lake Chamo is located between longitudes 36°34' and 36°56'E and latitudes 5°15' and 5°40'N, which is about 530 km from Addis Ababa. Altitudinally it ranges between 1100 m a.s.l. around the Lake Chamo and 1900 m a.s.l. around Zeyise (see Fig. 2 on page 4). Topographically the general area is mountainous with valley and plains.

1.2.2 Geology

The oldest known rocks in Ethiopia are of pre-Cambrian origin (Last, 1963; Mohr, 1971; FAO, 1980; FAO, 1984a) and these are over 600 million years old (Ethiopian Mapping Agency, 1988). Because these rocks (pre-Cambrian rock) underlie all other rocks, they are called the basement complex. The basement of the southern part of the country, where gneisses predominate, has been strongly metamorphosed (Chaffey, 1979; FAO, 1980).

In the Lake Chamo basin faulting accompanied by wide spread volcanic activity lead to the formation of basaltic lava. According to Ethiopian Mapping Agency (1988) most of the area around Lake Chamo is covered by gravel and stones, where as hard rock occur within 50 cm of the surface around Key Afer-Shala Luqa. Basalts also form the greater part of the Trap series in Gamo-Gofa (which is in the southern Ethiopia), and more silicic lavas, where they occurs, lying above the basalts (Mohr, 1971).

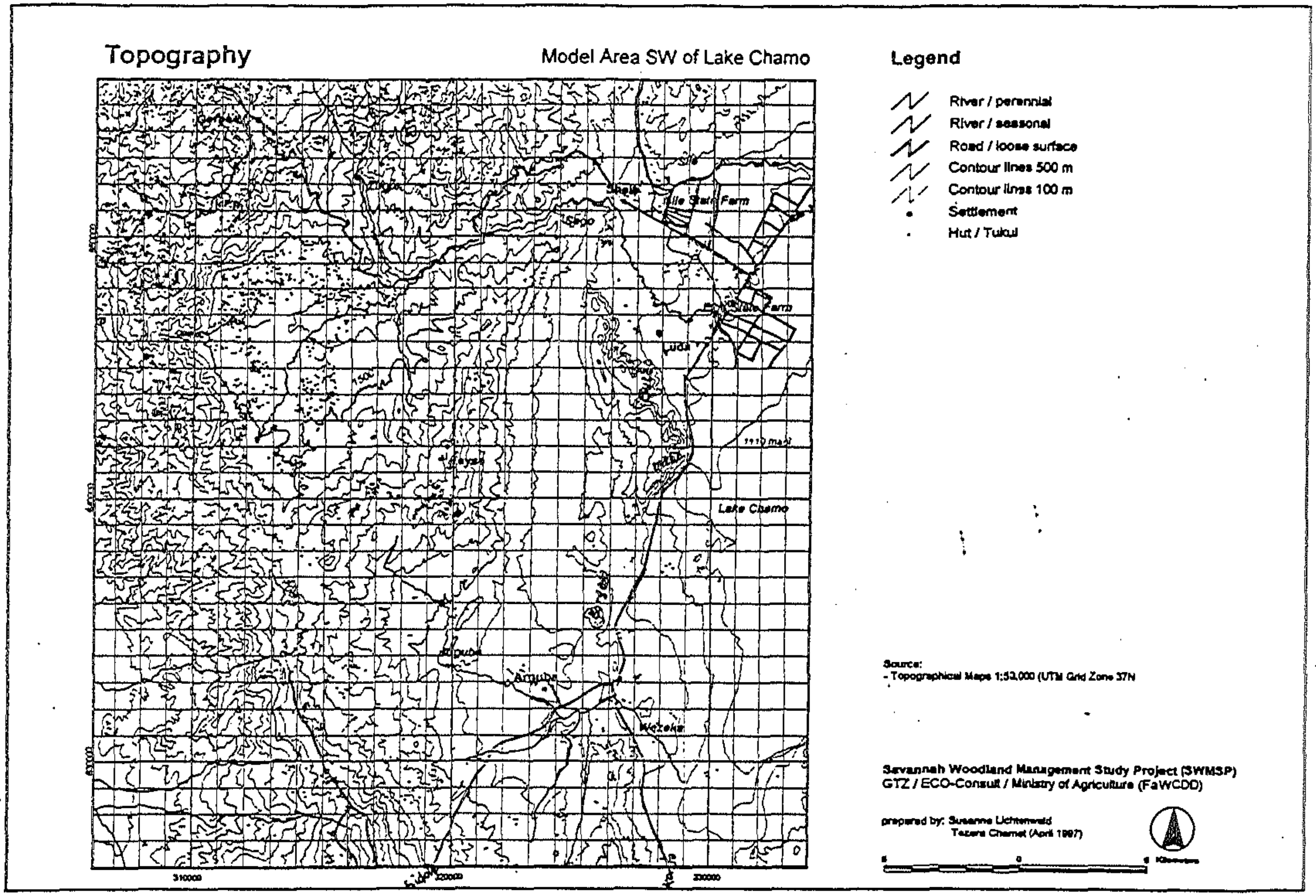

Fig.2 Topographic map of south west of Lake Chamo.

1.2.3 Climate

The climate of Ethiopia is influenced by two main factors, the proximity to the equator and the topography (Liljequist, 1986). Because Ethiopia is close to the equator, the monthly average temperature shows very little variation, which is 2°C in the south (Liljequist, 1986). Kebede (1964), Daniel (1977 & 1986) and Liljequist (1986) have given a generalized account on the climate of Ethiopia and the following summary on temperature is based on their observations.

1.2.3.1 Temperature

The annual variation of temperature is fairly small in the southern Ethiopia (Daniel, 1977). There is a traditional classification of temperature in the country (Wirch over 3000 m a.s.l., Dega between 2300-3000 m a.s.l., Weina Dega between 1500-2300 m a.s.l., Qolla between 800-1500 m a.s.l. and Bereha less than 800 m a.s.l.) which correspond to altitudinal variation (Daniel, 1977; Liljequist, 1986). Accordingly the present study areas are Weina Dega around Zeyise in Southwest of Lake Chamo and around Key Afer, while it is Qolla and Bereha around Elgo-Wezeka plain in Southwest of Lake Chamo and around Shala Luqa respectively.

1.2.3.2 Rainfall

According to Daniel (1977), the high lands of Gamo-Gofa (areas of one rain and one dry season) are characterized by nine rainy months which extend from March to October and in January. Furthermore, the southern parts of Gamo-Gofa (areas of two rainy seasons) are characterized by eight rainy months from February to July and in September and October. In the present study areas high concentration of rainfall occurs in the month of April.

The mean monthly rainfall, mean monthly maximum and mean monthly minimum temperatures for locations in and near the study areas (Southwest of Lake Chamo and Key Afer-Shala Luqa) are given in Tables 1, 2 and 3 respectively. Among the areas included

Sile station is located about 25 km south of Arbaminch. Gidole is about 40 km from Arbaminch and Dimeka is 38 km from Key Afer.

Table 1 Mean monthly rainfall in mm for locations in and near Key Afer-Shala Luqa and Southwest of Lake Chamo.

Location and Altitude (m a.s.l.)	Dimeka 1170	KeyAfer 1650	Sile 1190	Gidole 2250
January	48.90	34.80	17.32	22.53
February	57.41	37.74	35.03	53.45
March	72.00	98.20	86.02	106.20
April	122.10	140.60	116.33	202.39
May	100.10	120.50	163.17	150.69
June	72.30	86.80	73.42	84.46
July	50.68	63.70	36.48	68.75
August	14.12	58.50	55.71	89.38
September	60.77	85.30	60.37	81.00
October	65.44	76.95	93.93	77.11
November	58.32	73.75	74.3	59.84
December	73.50	42.38	34.12	20.30
Total	795.64	919.22	846.2	1016.10

Source of information-Ethiopian National Meteorological Service Agency (ENMSA) (1976-1996), m a.s.l.-meter above sea level.

Table 2 Mean monthly maximum temperatures (°C) for locations in and near Key Afer-Shala Luqa and Southwest of Lake Chamo.

Location and Altitude(m a.s.l.)	Dimeka 1170	KeyAfer 1650	Sile 1190	Gidole 2250
January	33.58	29.02	33.83	27.69
February	34.01	29.14	34.10	28.78
March	33.41	28.67	34.18	28.59
April	30.86	27.45	31.30	27.27
May	30.78	24.45	29.65	25.59
June	30.86	25.36	29.10	23.80
July	30.70	25.57	29.60	24.01
August	30.92	24.36	30.78	24.73
September	31.52	26.60	32.71	25.24
October	31.04	27.20	31.50	25.15
November	31.42	27.52	30.43	25.28
December	31.65	28.24	32.16	26.06
Mean annual	31.72	26.96	31.60	26.00

Source of information-Ethiopian National Meteorological Service Agency (ENMSA)-(1979-1996)

Table 3 Mean monthly minimum temperatures (°C) for locations in and near Key Afer-Shala Luqa and Southwest of Lake Chamo.

Location and Altitude(m a.s.l.)	**Dimeka 1170**	**KeyAfer 1650**	**Sile 1190**	**Gidole 2250**
January	12.83	17.5	12.43	14.43
February	14.11	17.62	13.21	15.29
March	16.03	17.54	15.07	15.09
April	15.42	16.25	15.11	14.84
May	15.77	15.65	13.9	14.31
June	14.37	15.14	14.43	13.86
July	13.33	15.12	15.45	12.6
August	12.6	15.16	15.15	13.37
September	12.98	15.6	14.02	12.96
October	13.9	16.09	13.48	12.73
November	12.41	15.98	10.83	12.42
December	12.35	16.88	10.62	13.03
Mean annual	13.84	16.21	13.64	13.73

Source of information-ENMSA (1979-1996)

1.2.4 Population and Land Use

1.2.4.1Southwest of Lake Chamo

The study area is located in North Omo administrative zone, Arba Minch Zuriya. According to the Office of Population and Housing Census Commission Central Statitcal Authority (1996) there are 153,550 people in Arba Minch Zuriya district, and of these 40,020 are in urban areas and 113,530 in rural areas. The census shows that the majority of the people live in the rural area. The major ethnic group of the area is Zeyise. The major occupation of Zeyise is cultivation of crops and cattle rearing. Some are also engaged in traditional bee keeping. In this connection up to 29 beehives could be observed on a single *Acacia tortilis* tree around Lake Chamo. There are also some villages around the Zeyise peak, who are engaged in pottery making and weaving.

Cultivation is usually carried out using oxen. But at present there is a trend to use hoe for cultivation, which is caused by the prevalence of trypanosomiasis that killed the cattle population.

During the early and late dry period of the year, the Zeyise people burn vegetation to clear bushes for agricultural purposes. In addition, it was noted during field observation that some portions of vegetation were also burn to get new green herbage.

In Southwest of Lake Chamo the main annual crops are maize, sorghum, cotton and to a certain extent teff. Other commonly cultivated perennial crops include banana, coffee, papaya and lemon.

1.2.4.2 Key Afer-Shala Luqa

Key Afer-Shala Luqa is located in South Omo administrative zone, Dimeka (Hammer Benna) district. The total population of Dimeka is 59,181, of these 2,303 are from urban centers and 56,878 from the rural area (Office of population and Housing Census Commission Central Statistical Authority, 1996). Key Afer is a small town in the Benna area, which is found relatively at a higher altitude (1650 m a.s.l.). The soil around the Key Afer town, is reddish brown to red in color. The Benna use this soil for decorating (mudding) their hair and facial parts. Thus, it seems that Key Afer probably got its name from the color of the soil which means red in Amharic. The Benna live in and around Key Afer, Alduba, Dimeka, Qaqo and chain of mountains that surround Shala Plain.

Luqa is a small village located in the suoth eastern part of Key Afer. It is a semi-arid area found at a lower altitude (about 650 m a.s.l.). The people in this village are the Tsamako, who also live in the fragile and semi-arid ecosystem of the Weyto valley west of the Weyto River and north east of Key Afer.

The Tsamako and the Benna share some common features in their way of life. Both are agropastoralists, i.e. societies that secure their livelihood mainly from the product of their domestic animals and cultivation of crops (Brown, 1972; Melese, 1995). At present the Benna and Tsamako are moving toward sedentary agriculture, which is carried out using oxen and hoe. Nevertheless, the young boys move with their cattle during the dry season in search of grass and water. The movement of the Benna with their cattle, **'Barqatii idii'** as they call it, is partly toward the Mago Park. On the other hand, some cattle stay in the village during this period, which the Benna call '**Haajudhuun Waanii Koti Shidhidii**'. The Tsamako move to the Male area and to the areas from where the Benna have left in search of grass and water.

There is severe shortage of water and grazing material in the Tsamsko land. The Weyto River, which is about 25 km east of Luqa, is shared between the inhabitants and the recently estabilished Birale private farm. Apiculture is a common practice among the agropastoral population of Benna and Tsamako.

The major annual crops grown by the Benna and Tsamako are maize and sorghum. The major perennial crop cultivated by the Benna is banana. In addition, the Benna and Tsamako cultivate a tree *Moringa stenopetala,* the leaves of which are boiled with maize and eaten. Burning of vegetation in the dry season is commonly practiced around the Benna area.

2. LITERATURE REVIEW

2.1 Plant Diversity

Biodiversity is defined as the total variability of all living organisms and the ecological complexes they inhabit (IPGRI, 1993; WRI-IUCN-UNEP, 1992). Plant diversity refers to the totality and variability of all plants and their ecosystems.

Plants are fundamental to the earth's life support system and central to human survival, yet species and ecosystems are being lost due to uncontrolled human activities (Tisdell, 1991). The recognition of this loss at a global level has led scientists and concerned groups to draw up World Conservation Strategy and the Convention on Biological Diversity held at the Earth Summit in Rio, Brazil in June 1992. At the national level, a Biodiversity Institute and National Conservation Strategy have been estabilished. In addition, various richness and equitability which is the evenness of the contribution of different species to the given community (Greig-Smith, 1983).

Ecologists have been devising different diversity indices (Pielou, 1969; Greig-Smith, 1983). Recently the use of parametric families of diversity indices was proposed instead of a diversity index with a numerical value (Bela, 1995). However the most applicable index is Shannon-Wiener index of diversity (Tramer, 1975; Greig-Smith, 1983). The index is calculated using the following formula:

$$H' = -\sum_{i=1}^{s} Pi \ln pi \qquad (1)$$

Where H′ = diversity

S = the number of species

pi = the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of total cover

ln = log $base_n$.

Equitability or evenness index is calculated using the following formula.

$$J = \frac{H'}{H' \max} = - \frac{\sum_{i=1}^{s} PiInPi}{In^{s}} \qquad (2)$$

Where J = equitability (evenness)

S, pi and ln are the same as in formula (1) above.

In the present study Shannon-Wiener diversity index was employed.

2.2 The Vegetation of Ethiopia

Ethiopia is an agricultural country with about 85 percent of the population mainly depending on it. Agriculture occurs throughout the highlands with the highest production being in the central and north western areas. However, the Ethiopian highlands were, in ancient times, covered by vast forest (Breitenbach, 1962). According to National Conservation Strategy (1990), high forest was reported to cover 16% of the country in the early 1950s, 3.6% in the early 1980s and 2.7% by 1989. Therefore, one can deduce that the forest cover of Ethiopia in the past was much larger than at present.

The vegetation of Ethiopia have been classified and described by several authors. These include Russ (1945), Breitenbach (1962), Tewolde *et al.* (1978), Sebsebe (1980 & 1988), Hailu (1982), FAO (1984b), Zerihun (1985), Friis (1986 & 1992), Ethiopian Mapping Agency (1988), Lisanework (1988), Tewolde (1986 & 1988), Friis and Mesfin (1990), Zerihun and Mesfin (1990), Zerihun and Backeus (1991), Haugen (1992), Mesfin (1992) and Tamrat (1994). In studies like Breitenbach (1962) and Ethiopian Mapping Agency (1988), general distribution of the vegetation types have been given. But the classification of vegetation types made by Ethiopian Mapping Agency (1988) was based on the climatic climax concept.

The most intensive physiognomic study is that of Pichi-Sermollis' (1957). Pichi-Sermolli (1957) have recognized 24 vegetation units in his publication on the geobotany of Ethiopia, Eritrea, Djibouti and Somalia. In a reconnaissance inventory of forests in south west Ethiopia, Chaffey (1979) described the forests in Sidamo, south west Arsi, the Welmel river area of Bale, and those in the highlands of Illubabor, Keffa, Western Shewa and Wellega.

Recently National Report on Environment and Development (1992) grouped the Ethiopian vegetation into nine categories. The categories are:

1. Desert and semi-desert scrub land
2. Small leaved deciduous woodland
3. Wet evergreen forest
4. Lowland (semi-) evergreen forest
5. Broadleaved deciduous woodland
6. Dry evergreen montane forest
7. Afroalpine and sub-afroalpine vegetation
8. Coastal vegetation and
9. Riparian and swamp vegetation

savanna categories were proposed. These include savanna woodland, savanna parkland, savanna grassland, low tree and shrub savanna and ticket and scrub.

In most of the savanna classifications, the savanna woodland have been included as one of the category. It is defined as widerleaved tall grasses with forest patches (IUCN, 1973); tree canopy interrupted (50-75%), crowns frequently touching, grass cover well developed (Young, 1976); and a formation of vegetation where single-stemmed woody plants over 3m tall occur with >0.2% cover and where there is a > 2% graminoid cover (Gillison, 1983). Menaut (1983) working in Africa, defined savanna woodland as the vegetation where the upper stratum is composed of deciduous, small or medium sized trees (8-20 m tall), no woody understorey, the herbaceous layer sometimes sparse and often made up of tall grasses. Sarmiento (1983) while working in American savanna gave the definition that, the tree cover above 15%, reaching cover values of 20% to 30% on the average. Cole (1986) in her book 'Biogeography and Geobotay of the savanna vegetation' defined savanna woodland as, deciduous and semi-deciduous woodland of tall trees (more than 8 m high) and tall mesophytic grasses (more than 8o cm high), the spacing of the trees more than the diameter of the canopy. Therefore, the definition appears to be formation of vegetation where the upper stratum is composed of deciduous trees more than 5 m tall and the field layer (herbaceous layer) mainly dominated by tall grasses above 80 cm.

The savanna vegetation changes as a result of a combination of factors. As changes seems to occur continuously in this vegetation, some of their components in the course of their evolution seem to have developed adaptations to extreme changes. Although different authors identified other environmental factors that determine the savanna vegetation, most authors have taken fire as an important factor. Among these are Daubenmire (1950), Ewusie (1980), Ola-Adams and Adegbola (1982), Sanford (1982a & 1982b), Gillon (1983), Cole (1986), Bowman *et al.* (1988), Goldammer (1994) and Hochberg *et al.* (1994). Fire occurs regularly in the savanna woodlands. It can be caused by a lightning strike or by man in order to drive out wild games during hunting (Goldammer, 1994), to destroy dry grass and stimulate the growth of new shoots for grazing animals and to clear bushwood in preparation for cultivation (Ewusie, 1980; Cole, 1986).

Most savanna plants have become adapted to burning. Survival of perennials after fire is possible due to the survival of buds, provided that the fire does not descend to the level of the soil surface where it affects the buds (Kruger, 1977; Trabaud, 1987).

2.3.2 Effect of Burning on Trees

The ability of some savanna trees to survive repeated burning is due to the development of a thick bark, and the ability to grow shoots from underground parts of the plant (Daubenmire, 1950; Sarmiento and Monasterio, 1983). However, Menaut (1983) reported that the number of woody species and individuals increased quickly during the first years after protection from fire, and continued to increase regularly. The increased shrub cover and the resulting shade inhibited the growth of a grass layer and the habitat then become favorable for settlement by tree species.

Fire damage to savanna trees varies with the time of burning, the intensity of fire and the species concerned (Gillon, 1983; Nakagoshi *et al.*, 1987). Characters that reduce the degree of injury to certain species by fire are: deep-rooting habits, canopies sufficiently elevated above the ground so that leaves and buds are not killed, and especially thick layers of non living bark (Daubenmire, 1950).

2.3.3 Regeneration of Plants After Fire

Three different sources of regeneration are recognized after fire: from subterranean organs, from the seed bank, and from newly invading seeds (Nakagoshi *et al.*, 1987; Cheplick and Quinn, 1988).

In woodland, if gaps are opened by events like elephant trampling, drought or windstorms, grasses will establish and this will facilitate fires that may damage the trees or at least reduce their regeneration. This contributes to further thinning of the woody cover and promotion of grasses and further fires (Skarpe, 1992). Louis (1991) also indicated that frequent fires tend to increase the phytomass of herbaceous plants and lower the phytomass quantity of shrubs.

2.4 Aboveground Herbaceous Phytomass

The production of primary producers is defined as the rate at which energy is bound or organic material created by photosynthesis per unit area of vegetation on the earth's surface per unit time (Ewusie, 1980). Productivity can be measured in terms of dry weight per square meter per year or other given period. Standing crop is the dry weight of plant material present in a system at a given period of time (Zerihun, 1985). Thus, production values can be estimated from standing crop values in some circumstances.

In many cases, only the aboveground herbaceous phytomass has been studied since the study of belowground phytomass is difficult and time consuming to measure (Isichei, 1982; Lamotte and Bourliere, 1983; Sarmiento, 1984). The most widely used method of estimating aboveground herbaceous phytomass is clipping (Mayhew, *et al.* 1984; cited in Zerihun, 1985). During the present study the herbaceous layer in $1m^2$ (1m x 1m) quadrat was clipped and the aboveground herbaceous phytomass was recorded.

Several factors have been reported to affect herbage yields. For example, in more humid regions, the maximum standing crop of the herbaceous layer usually reaches much higher values than in semi-arid areas. Rutherford (1978) while working in Etosha National Park in South West Africa found out that, in areas where the mean annual rainfall averages less than 500 mm, very low production figures (0.2 to 0.6 t ha^{-1} yr^{-1}) were obtained from various communities. In a northern Guinean savanna of Nigeria (rainfall 1200 mm), Egunjobi (1973) as cited in Lamotte and Bourliere (1983) found a peak phytomass value of 19.5 t ha^{-1}. Production studies have also been related to burning with the usual assertion that 'late' burning results in higher grass yield than 'early' burning (Isichei, 1982; Sandford, 1982b).

2.5 Vegetation Sampling

A detailed vegetation study is based on the description and investigation of plant communities that must first be recognized in the field. Sampling is necessary because studies of the whole vegetation segement of an area consumes too much time. Therefore, ecologists use different sampling techniques to obtain the necessary information (Mueller-Dombois and Ellenberg, 1974).

Reconnaissance survey and observation are very important in determining where and how to sample plant communities. Mueller-Dombois and Ellenberg (1974) support this notion and recommend a thorough survey and familiarization before sampling.

Greig-Smith (1983), Kershaw (1973), and Mueller-Dombois and Ellenberg (1974) provided a comprehensive and detailed account of the importance of sampling a plant community so as to obtain the maximum information from one set of samples. However, it is necessary to outline the more important aspects since the conclusion will be based on the samples obtained, and if sampling procedure is incorrect, then the conclusion derived may be invalid.

According to Greig-Smith (1983), the object of sampling procedures, with few exceptions, fall into one or another of the following three categories. (1) An estimate of the overall composition of the vegetation within certain boundaries, with a view to make comparisons with other areas or with the same area at another time, (2) the investigation of variation within the area, or (3) correlation of vegetation differences with differences in one or more habitat factors.

There must inevitably be an element of subjectivity in sampling procedure because the boundaries within which a set of samples is taken are fixed by the ecologist on the basis of his judgment (Grieg-Smith, 1964). Therefore, the choice of sampling procedure involves many considerations to minimize this subjectivity. Firstly, the sample should be homogenous in structure and composition, if the purpose is to represent community types by samples or to relate vegetation to environment (Shimwell, 1971; Mueller-Dombois and Ellenberg, 1974). Secondly, the sample stand should be large enough to contain all species belonging to the plant community (Muller-Dombois and Ellenberg, 1974). It is obvious that as the sample size is increased a better measure of the mean of the population is obtained, but if the sample is too large difficulties are encountered in meeting the homogeniety of the sample stand and efficiency of sampling. As a result, the characteristics of a plant community appear when a certain minimum area is examined which is defined as the smallest area on which the species composition of the community in question is adequately represented (Mueller-Dombois and Ellenberg, 1974).

The minimal area gives an indication of the relevé or quadrat size that should be used. This minimal area depends on the kinds of community and varies within wide limits (Mueller-Dombios and Ellenberg, 1974). These authors have given emprical values for Temperate Zone vegetation from 200-500 m^2 for forest to 0.1-1 m^2 for lichen communities. Using similar arguments some workers have employed a sample size of 20 m X 20 m (400 m^2) to study woody vegetation in Ethiopia. Among these are Tewolde (1975), Sebsebe (1980), Hailu (1982), Zerihun and Mesfin (1990) and Zerihun and Backeus (1991).

Where the emphasis is on sampling the quantitative variations of species within large communities defined only by dominant species, the idea of representing species composition is commonly reduced to certain quantitative measures of the more abundant species only (Mueller-Dombois and Ellenberg, 1974).

According to Greig-Smith (1983), sampling procedure must always be related to the importance of the information sought to the problem under investigation, and to the degree of precision necessary. Since considerable numbers of samples may be needed, the sampling procedure should be designed to obtain and record the kinds of information regarded as most important. Greig-Smith (1964) pointed out that, among the kinds of information that might be gathered about a plant community, some are more significant, appropriate to the character of the community and informative in relation to time spent and the purpose of the particular technique used to analyze the vegetation data than others.

Since the choice of sample sites is dependent on the observer's preconceived ideas of the character of the vegetation, selection of typical sites for samples is clearly inappropriate for a quantitative approach (Greig-Smith, 1983). As an alternative, Greig-Smith (1983) considered random or systematic sampling. Both Greig-Smith (1983), and Muller-Dombois and Ellenberg (1974) have argued that random sampling has the advantage that a statistical error term can be assigned to the mean value, thus the variation about the mean can be accurately assessed, at least for the more common species. On the other hand, systematic sampling has more advantages if interest centers on variability within the area (Greig-Smith, 1964; Shimwell, 1971). Therefore, it appears that the choice is not necessarily between entirely systematic and entirely random samples, rather a combination of both (preferential) (Greig-Smith, 1983; Mueller-Dombois and Ellenberg, 1974).

2.6 Techniques of Analysing Vegetation Data

Techniques of summarizing and arranging the available information are necessary since it is the basis for comparing this information with environmental and other factors affecting the composition of vegetation (Greig-Smith, 1983). A wide variety of multivariate techniques are now available to study the complex nature of plant communities. Multivariate analysis of plant communities primarily involves classification and ordination with the general purposes of summarizing large complex data sets obtained from community samples, aiding the interpretation of environmental factors, and hypothesis generation about community and structure (Greig-Smith, 1983).

These two approaches toward vegetation study are based on different concepts of the essential nature of vegetation. Classification methods emanated from the belief that vegetation is composed of certain distinct and fairly discrete plant communities (the concept of community unit theory) (Whittaker, 1962 & 1967; Shimwell, 1971). On the other hand, ordination is believed to have developed from the concept of vegetation as a continuum (Kershaw, 1973; Mueller-Dombois and Ellenberg, 1974).

In the past, although there has been considerable controversy between the application of these techniques by ecologists, it is now generally recognized that both classification and ordination techniques could be appropriately applied to the same vegetation data and that the choice between the two approaches depends on the ecological question to be answered (Greig-Smith, 1983). Similarly, Zerihun and Backeus (1991) in the study of shrubland vegetation of western Shewa and Tamrat (1994) in his studies on remnant afromontane forests of the central plateau of Shewa have employed both techniques.

2.6.1 Classification

Classification involves arranging stands into classes, the members of each class having in common one or more features setting them apart from the members of other classes (Greig-Smith, 1983). Detailed notes on the development of classification have been given in Whittaker (1962) and Shimwell (1971).

Classification can be hierarchical or non-hierarchical. An ecologist must make a choice between the two systems if his/her aim is to classify certain sets of stands (Greig-Smith, 1983).

Non-hierarchical (reticulate) classifications divide samples into a number of clusters, the links between them being in the form of a network but specifying no structure interrelating the clusters at varying levels. Hierarchical classification techniques define relationships among the clusters in that the classes at any level are subclasses of classes at a higher level, the highest level being that of all the stands (Mueller-Dombios and Ellenberg, 1974; Greig-Smith, 1983). According to Greig-Smith (1983), hierarchical procedures are better because the procedures are less cumbersome and ecologically more readily interpreted.

After accepting a hierarchical system as being preferable, two further choices of strategy are required. This choice is between divisive or agglomerative strategy. In a divisive strategy the population is progressively subdivided into groups of diminishing size, while in an agglomerative strategy, a hierarchy may be built up by fusing individuals progressively into groups of increasing size until the whole population is merged into a single group (Greig-Smith, 1983). Similarly, there is a choice between monothetic strategy, which is based on a single attribute and polythetic strategy, which is based on a number of attributes. Thus, in polythetic strategy, groups are defined interms of the overall similarity of their members.

Polythetic techniques use the data as fully as possible while monothetic techniques are wasteful of information and may lead to mis-classification and over-simplification as they are highly dependent upon the sampling design using presence and absence information (Greig-Smith, 1983).

The variety of hierarchical classification techniques may be summed up into three groups: monothetic divisive, Polythetic divisive, and Polythetic agglomerative (Mueller-Dombois and Ellenberg, 1974; Greig-Smith, 1983). The following is a summary of these three groups.

As already outlined above, monothetic divisive techniques begin with the entire sample in a single group. Williams and Lambert (1959) presented their procedure called Association Analysis, and then used it for numerical classification methods in plant community studies. Monothetic divisive procedures have the disadvantage that they are liable to misclassify a stand if, by chance, it lacks the particular species serving as the division criterion, but they provide an immediate means of doing so by dichotomous keying. On the other hand, polythetic divisive classification techniques utilize information on all species. Beginning with all samples together, it ends up with smaller and smaller clusters, each cluster containing only one sample or some specified small number of samples. Polythetic divisive techniques have the disadvantages that the groups, no matter how homogeneous they are, result in classification hierarchies, which may contain little information about the natural structure within the population.

Polythetic agglomerative classification techniques use information on all species, beginning with each sample alloted to cluster with a single member and end up with agglomerating these into a hierarchy of larger and larger clusters until finally a single cluster is formed. Since Polythetic agglomerative procedures cluster on the basis of overall similarity, they are in general less likely to lead to misclassification (Greig-Smith, 1983). Several measures of similarity function are currently in use and include average linkage clustering, furthest neighbour, group averaging, centroid sorting and minimum variance clustering. All these sorting strategies are considered by Sokal and Sneath (1963). Taking all these classification techniques into account, a cluster analysis which is hierarchical, polythetic and agglomerative was employed to analyze the data of the present study.

2.6.2 Ordination

Ordination emanates from the concept that vegetation is continuous (the continuum concept). In ordination an attempt is made to place each stand in relation to one or more axes in such a way that a statement of its position relative to the axes conveys the maximum information about its composition (Greig-Smith, 1983). According to Orloci (1966), ordination is a summarization of the information content of a matrix whose elements, distances or angles, defines the spatial relationships between ecological entities; the entities may represent either species, stands, environmental factors or habitats.

Although there are differences between ordination and classification, both methods are employed in the description of vegetation. And, both methods are also complementary in their treatment of sample data (Mueller-Dombois and Ellenberg, 1974). In the present study principal component analysis as an ordination method was employed.

3 MATERIALS AND METHODS

3.1 Aboveground Herbaceous Phytomass

Based on the reconnaissance survey made, 13 sites in the study area were selected following homogeneity of their vegetation. The study on aboveground herbaceous phytomass was carried out between November 21, 1996 and December 25, 1996. Using a 1 m^2 metal frame quadrat, a total of 260 samples were taken from 13 different sites, sites 1-5 being from Southwest of Lake Chamo and 6-13 from Key Afer-Shala Luqa. In the different sites investigated, signs of disturbances (such as grazing, fire, etc.) were considered uniform. Within each 1 m^2 (1 m X 1 m) metal frame quadrat the cover of herbaceous species was estimated and recorded based on the dominance concept, as the first, second and the third dominant phytomass class. The other herbs and grasses within the quadrat were also estimated and the herbs and grasses in the quadrat were clipped at ground level using shears and scissors and then air-dried in a sack. These sacks were first perforated so as to enhance the air-drying process. 40 holes were punched in each sack (around the center of the sack) which is about 50 cm x 40 cm. The air-dried matter was then weighed with the sack using a Beam balance. The weight of each sack in which samples were taken was also measured independently and then the net aboveground herbaceous phytomass was recorded.

3.2 Vegetation Data

Vegetation sampling was made during two field trips (January 20, 1997 to February 9, 1997 and February 17, 1997-February 27, 1997). Sampling was done following homogeneity through preferential means. In both study areas, Southwest of Lake Chamo and Key Afer-Shala Luqa, a total of 71 quadrats (relevés) were considered using 400 m^2 (20 m x 20 m) quadrat. The co-ordinates of each sample stand were determined using Garmin GPS 45XL (Geographical Position System). Plants in each quadrat were recorded as present. Trees and shrubs were counted and then percentage covers of both herbs and

(2) Soil texture was determined using the Bouyoucos Hydrometer method. Sodium hexamethaphosphate was used as the dispersing agent.

(3) For the determination of potassium and sodium, standard solutions of potassium and sodium were prepared. The bases were extracted with 1N ammonium acetate at pH 7. Using Gallenkamp flame photometer analyzer, both sodium and potassium were determined.

(4) Color was determined using Munsell's color chart.

(5) Phosphorous was determined using Bray No.1 method.

Post-hoc comparison of means was performed using Statistica program (Statsoft, 1993) at the probability level $p < 0.05$ based on the environmental data among groups of community types identified.

4 RESULTS

4.1 Aboveground Herbaceous Phytomass

In both study sites (Southwest of Lake Chamo and Key Afer-Shala Luqa), the average aboveground herbaceous phytomass ranged from 35.9 gm^{-2} in Shala Plain (site 10) to 1016.8 gm^{-2} in Southwest of Lake Chamo (site 2). The average aboveground herbaceous phytomass in gm^{-2} with the respective site is presented in Fig. 3. From the value presented in Fig. 3, there is a variation in the mean aboveground herbaceous phytomass. The highest value was recorded from site 2 in Southwest of Lake Chamo, where *Thypha angustifolia* is dominant. The variation in species encountered and the community type could result in differences in the aboveground herbaceous phytomass recorded. Number of herbaceous species, altitudinal range and species commonly encountered in each site are given in Table 5. Sample stands (quadrat) and their respective net aboveground phytomass in gm^{-2} in each site are also given in Appendix 5. The lowest values 35.9 gm^{-2} and 40.2 gm^{-2} were recorded from the Shala Luqa plain, where the herbaceous cover was very small. *Perotis patens* and *Pupalia lappacea* are the species commonly occuring in sites where the lowest average aboveground herbaceous phytomass were recorded.

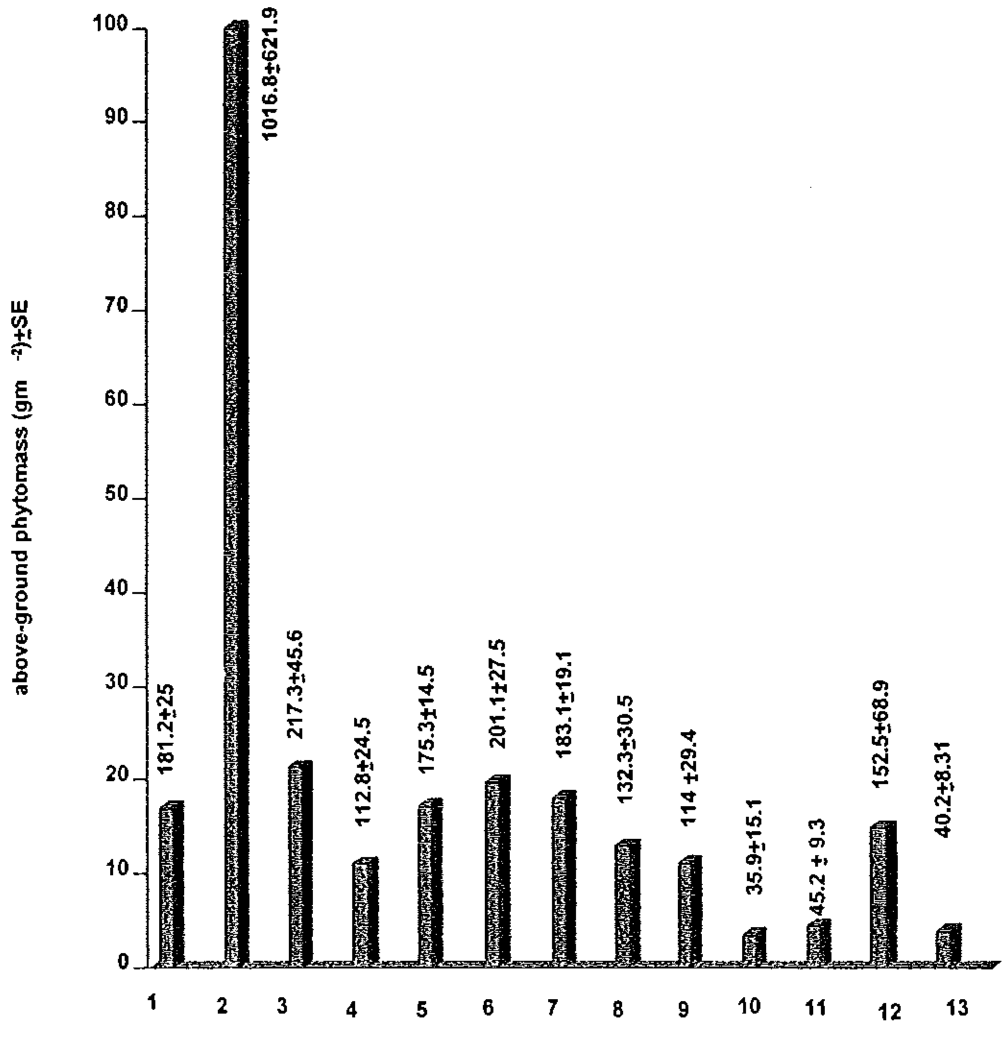

Fig. 3 The average aboveground herbaceous phytomass in gm^{-2} with the respective site (sites 1-5 from Southwest of Lake Chamo & 6-13 from Key Afer-Shala Luqa)

Table 5 Number of herbaceous species, altitudinal range and species commonly encountered in each site (species commonly encountered is given here in Teshome S. Col. No., see Appendix 1a for species list).

Site	No. of herb species	Altitudinal Range	Species Commonly Encountered in the Site
1	17	1140-1180	*Cynodon dactylon, Cenchrus ciliaris, Cynodon nlemfuensis*
2	11	1110-1160	*Thypha angustifolia, Echinochloa pyramidalis, Urochloa panicoides*
3	15	1160-1210	*Aristida kenyensis, Cynodon dactylon, Indigofera schimperi*
4	08	1200-1340	*Cenchrus ciliaris, Aristida kenyensis, Pupalia lappacea*
5	16	1250-1750	*Hyparrhenia filipendula, Setaria incrassata, Heteropogon contortus*
6	30	1470-1850	*Hyparrhenia filipendula, Hypoestes forskolei, Heteropogon contortus*
7	31	1200-1570	*Heteropogon contortus, Hypoestes forskolei, Hyparrhenia filipendula*
8	29	860-1140	*Enteropogon macrostachyus, Digitaria abyssinica, Indigofera ambelacensis*
9	18	690-830	*Indigofera spinosa, Barleria quadrispina, Solanum somalense*
10	15	720-860	*Perotis patens, Tribulus terrestris, Barleria quadrispina*
11	07	740-890	*Indigofera spinosa, Asystasia gangetica, Blepharis ciliaris*
12	21	580-1070	*Indigofera spinosa, Barleria quadrispina, Aristida kenyensis*
13	02	660-670	*Pupalia lappacea, Truimfetta flavescens*

4.2 Vegetation Data

Multivariate numerical methods were employed to summarize the vegetation data sets. Classification was carried out by similarity ratio from the various options provided under hierarchical clustering by distance optimization, Syntax Program (Podani, 1988). Seven ecologically meaningful community types (clusters) designated as 1, 2, 3, 4, 5, 6 and 7 were identified (Fig. 4). The plant communities were named by the dominant species, which occur in each group, using the relative magnitude of mean cover abundance (see Table 6). Table 6 shows the mean cover abundance of major species in the community type. The species names used for the naming of the community type was based on the values in Table 6. The bald values of Table 6 are the values with which naming was done. The vegetation data collected from Key Afer-Shala Luqa and Southwest of Lake Chamo is given in Appendix 2.

Analysis of the vegetation data using similarity ratio made possible the grouping based on the habitat of the dominant species. As a result, the seven community types were named after two or three of the dominant species and the communities are decribed below.

Type 1. ***Heteropogon contortus-Acacia hockii*** **type**

This type was described from Southwest of Lake Chamo and Key Afer-Shala Luqa. The dominant tree species of this community are *Acacia hockii* and *Combretum molle*. Other dominant tree species includes *Acacia seyal* and *Terminalia brownii*. *Heteropogon contortus*, *Hypoestes forskolei* and *Sporobolus ioclados* dominate the field layer of the community.

Type 2. *Hyparrhenia filipendula-Combretum molle* type

This type was described from Southwest of Lake Chamo and Key Afer-Shala Luqa. The dominant tree species in this community type, in addition to the two included in the type name are *Terminalia brownii* and *Ozoroa insiginis*. The field layer of the community is dominated by *Hyparrhenia filipendula*.

Type 3. *Achyranthus aspera-Acacia tortilis* type

This community type was described from Southwest of Lake Chamo only. The tree layer of this community is dominated by *Acacia tortilis*. Other dominant tree species includes *Acacia seyal* and *Acacia nilotica*. *Achyranthus aspera*, *Cynodon dactylon* and *Cenchrus ciliaris* dominate the herbaceous layer.

Type 4. *Acacia mellifera-Acalypha fruticosa-Acacia brevispica* type

This type was described from the bushland formation of Southwest of Lake Chamo and from Shala plain including its mountain chains. The dominant shrubs *Acacia mellifera*, *Acalypha fruticosa* and *Acacia brevispica* characterize this type. Other abundant shrub of the community is *Combretum aculeatum*. The most important field layer species are *Sansevieria ehrenbergii*, *Barleria quadrispina* and *Sansevieria abyssinica*. Climbers associated with this community, although not dominant, are *Cissus quadrangularis* and *Cissus rotundifolia*.

Type 5. ***Commiphora cyclophylla-Actiniopteris radiata-Sansevieria ehrenbergii*** **type**

This community was described from Shala Luqa plains including the ridges and peaks. The dominant species in this community type is the tree *Commiphora cyclophylla*, the flekky stem of which is seen at a distant. Other tree and shrub species include *Boswellia neglecta, Euphorbia tirucali, Acacia mellifera, Tarenna graveolensis* and *Premna recinosa*. The most dominant field layer species are *Actiniopteris radiata* and *Sansevieria ehrenbergii*. Other field layer species are *Selaginella phillipsiana*, *Sansevieria abyssinica* and *Barleria quadrispina*. The climbers *Cissus rotundifolia* and *Cissus quadrangularis* are also associated with this community.

Type 6. *Acacia tortilis-Indigofera spicata* type

This type was decribed from the Luqa plain. *Acacia tortilis* is the dominant tree in this community. *Balanites rotundifolia* is a tree associated with this community. The most dominant field layer species is *Indigofera spicata*.

Type 7. *Acacia reficiens-Megalochlamys violacea* type

This community type was described from the Luqa plain and around Birale farm. The dominant shrub of this community is *Acacia reficiens*. Other tree and shrub species of this community include *Commiphora cyclophylla, Balanites rotundifolia, Acacia oerfata, Acacia mellifera, Salvadora persica* and *Grewia tenax*. The field layer of the community is dominated by *Megalochlamys violacea*. Species recorded for the vegetation data and the quadrat in which it occurs is presented in Appendix 2.

The result of classification also produced an outlier groups, which is from Southwest of Lake Chamo and Key Afer-Shala Luqa. These outliers are represented by sample stand (quadrat) number 5, 18 and 38 (Fig. 4). However, these sample stands did not show sufficient similarity with any of the seven clusters (community types). The outliers were then considered to be a group by it self and was not considered in further analysis since it was not amenable for statistical analysis.

Ordination of the vegetation data was performed using Principal Component Analysis. The result of ordination (Fig. 5) shows a configuration that agrees in general with the result of classification. From Fig. 5 axis 1 and 3 provided information on the distribution of the sample stand along the axes. There is however a clumping of community types 3, 5, 6, and 7 around the origin along the x-axis.

Diversity analysis between the community types identified by similarity ratio was made using the Shannon-Wiener diversity index. The groups showed variation in species richness and evenness. The result of diversity analysis is given in Table 7.

Table 7 Diversity analysis using the Shannon-Wiener Diversity Index.

OBJ	**No.OF ATR.**	**H′**	**H′MAX**	**H′/HMAX**
1	83	3.930	4.419	.889
2	123	4.367	4.812	.908
3	38	2.988	3.638	.821
4	67	3.861	4.205	.918
5	58	3.102	4.060	.764
6	22	2.711	3.091	.877
7	31	2.980	3.434	.868

OBJ = Objects (community types)

NO. OF ATR. = Number of Attributes (No. species)

H′ = Diversity

H′MAX = Diversity assuming all the constituent species are evenly distributed

H′/HMAX = Evenness

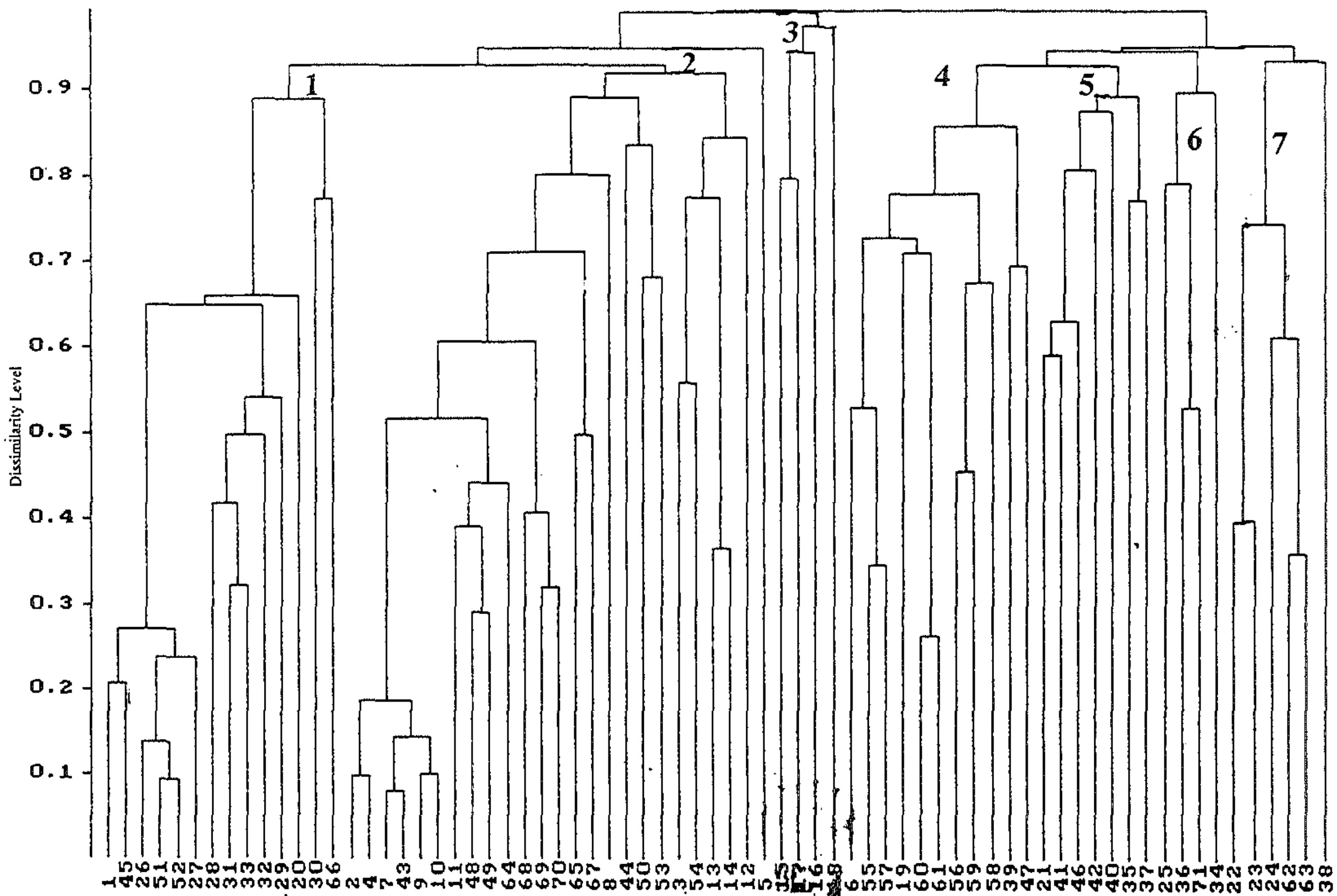

Fig.4 Dendrogram of the vegetation data using similarity ratio.

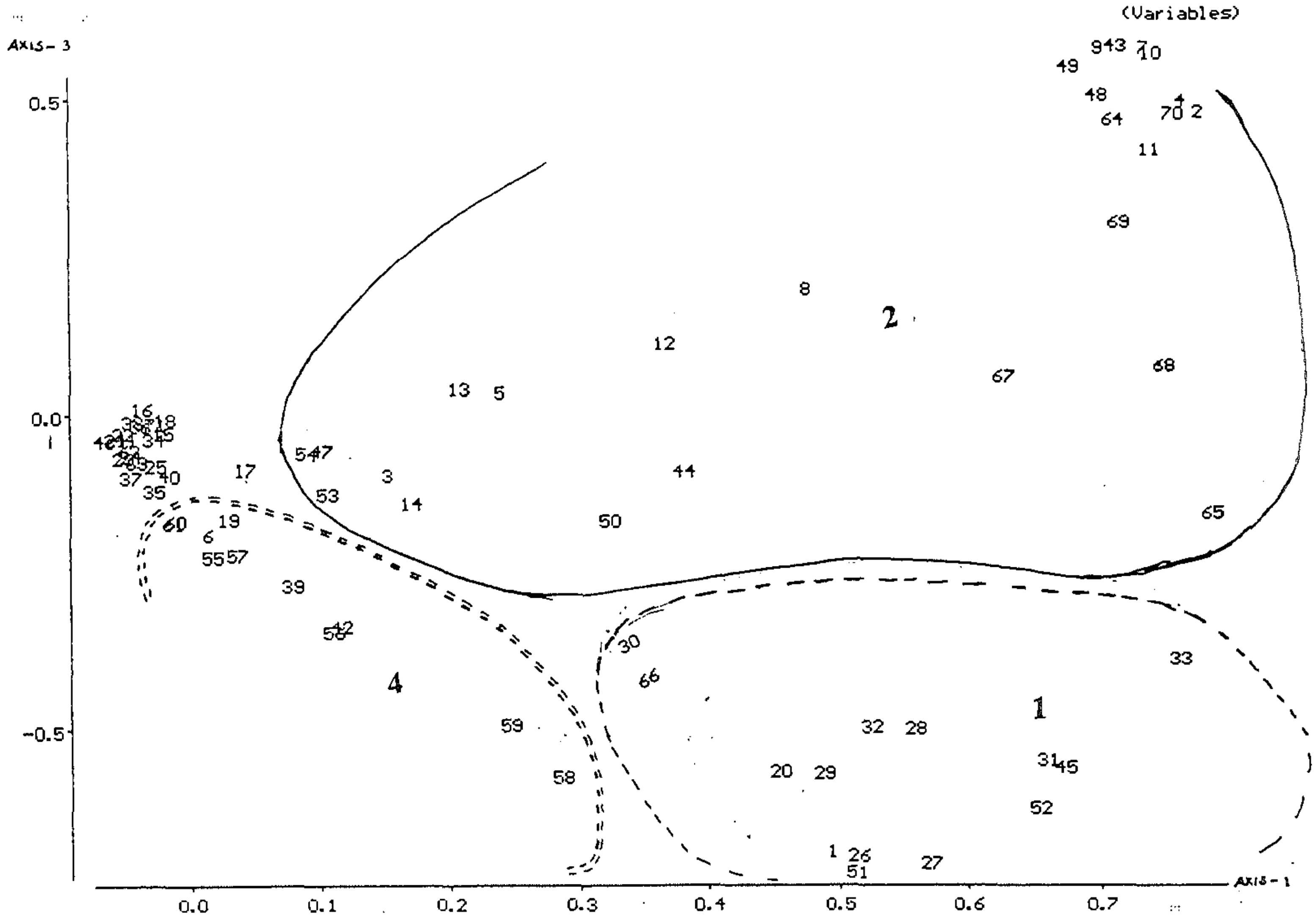

Fig.5 Scatter diagram of the vegetation data using PCA. Position of the 71 releve's along axes 1 & 3 of the PCA ordination (larger numbers indicate community types).

4.3 Physiographical and Pedological Variables

The physiographical and pedological variables were averaged for each of the major community types identified by both ordination and classificatory approaches.

In order to examine the significant differences and/or similarities between the community types identified, post-hoc comparison test was employed for the measured environmental parameters. This was achieved by the LSD (Least Significant Difference) test (Statsoft, 1993). The result is given in Table 8. Moreover, Pearson's product moment correlation coefficient for correlations between environmental variables is given in Appendix 6. Percent sand is negatively correlated with other variables except with pH and slope. Percent clay and silt are negatively correlated only with pH and slope. pH shows positive correlation with potassium, % sand and phosphorus. Potassium is negatively correlated with % sand, altitude and slope. Altitude showed positive correlation with % clay, % sand and sodium.

Table 8 Post-hoc comparison of means between environmental variables and plant community types (1-7). The letters in each row indicate significant difference and insignificant differences at $P < 0.05$ (The same letter stands for insignificance).

Community Type	1	2	3	4	5	6	7
% Sand	68.2	56.2	52.9	74.2	81.6	50.7	76.3
	ab	b	b	ab	a	b	ab
% Clay	16.2	21.6	14.4	11.0	3.7	26.8	8.1
	ab	b	ab	ab	a	b	ab
% Silt	17.7	26.3	32.6	14.8	10.3	22.5	15.6
	ab	b	b	ab	a	ab	ab
pH (in water)	7.1	7.1	7.5	7.2	7.4	7.3	7.5
	b	b	a	ab	a	ab	a
K (in ppm)	29.1	27.3	49.1	14.8	13.4	42.4	33.2
	ab	ab	a	bc	c	a	ab
Na (in ppm)	0.8	1.6	1.5	0.3	0.2	0.4	0.4
	ab	a	ab	ab	b	ab	ab
P (in ppm)	1.6	2.1	2.1	1.2	2.9	3.6	2.2
	ns	ns	ns	ns	ns	ns	ns
Altitude (m a.s.l.)	1430	1528	1095	1232	884	725	662
	a	a	b	b	c	c	c
Slope (%)	4.2	10.6	0	18.8	14.3	0	0
	a	b	a	c	bc	a	a

5. GENERAL DISCUSSION

5.1 Aboveground Herbaceous Phytomass

One hundred and one plant species were recorded for the study of aboveground herbaceous phytomass. These plant species were from *Selaginellaceae*, *Actiniopteridaceae* and 28 Angiosperm families. In connection with this most of the herbaceous species considered for aboveground herbaceous phytomass in both study areas belong to the families *Poaceae*, *Acanthaceae, Fabaceae, Asteraceae, Lamiaceae* and *Euphorbiaceae*. The family *Poaceae* is represented by 28 species, among which species of *Hyparrhenia* and *Heteropogon* are the most important. The family *Acanthaceae* is represented by 10 species. *Fabaceae, Asteraceae* and *Lamiaceae* are represented each by 8 species. *Euphorbiaceae* is represented by 4 species. The genera *Hypoestes* and *Barleria* which belong to the family *Acanthaceae* and *Indigofera* which belongs to the *Fabaceae* are the most encountered species.

The total average aboveground herbaceous phytomass was found to be low in the Shala Luqa plain and higher near the Lake shore vegetation (in Southwest of Lake Chamo). Since the herbaceous cover was sparser with the increasing tree density (Kauffman, *et al.*, 1994; Mordelet & Menaut, 1995), the tree density being higher in site 1 than in site 2, the Lake shore vegetation (which is wet), was considered independently. The result obtained from sites 1 and 2 show that there is a difference in the herbaceous aboveground phytomass. This indicates that increase in tree density and moisture content might have an impact on the herbage yield.

Milligan and Sule (1982), working on the Nigerian Savanna observed that, depending on local site conditions, the yields of herbaceous material of natural savanna rangelands are reported to vary between 150 gm^{-2} and 1800 gm^{-2}. Zerihun (1985) working on the grassland vegetation of the Shewan plateau found that the aboveground herbaceous phytomass in the grazed site ranged between 73.35-372.22 gm^{-2}. Lamotte & Bourliere (1983), Bourliere and Hadely (1983) and Zerihun (1985) have given a summary of the various works on the aboveground herbaceous phytomass. Except for the aboveground herbaceous phytomass recorded from site 10, 11 and 13, the result obtained from this study falls in the results obtained by the aforementioned authors. Generally, sites 8-13 are from the Tsamako areas and 6 and 7 are from the Benna areas.

In general, the overall decrease in aboveground herbaceous phytomass of the Shala Luqa plain could be due to the erratic rainfall of the area. Overstocking and community types are also factors responsible for the fall of the aboveground herbaceous phytomass. For example *Commiphora* spp. and *Boswellia neglecta* are found on rocky sites, from where the aboveground herbaceous phytomass were low.

The Tsamako used to live in the Shala areas about half a century ago (Aliyo Ayike, personal communication) and many inhabitants moved to Luqa plain in search of grass and water, as a result of the depletion of resource in the Shala area. There are still some inhabitants in the Shala area. Although in the past, the Tsamako came to the Luqa plain to utilize the better resources, at present there is no enough herbaceous layer to support their cattle. Since there is no accurate figure on the livestock populations belonging to a family in both Benna and Tsamako, it has not been possible to determine the livestock population in the area under investigation, which would have been useful to correlate the aboveground herbaceous phytomass and the livestock population of the sites.

5.2 Classification, Ordination and Community Diversity

Classification of the vegetation data using similarity ratio gives seven plant community types and outliers represented by three quadrats (5, 18 and 38). In terms of floristics, the species composition of quadrat 5 includes *Aristida kenyensis, Themeda triandra, Hyparrhenia filipendula, Dodonoea angustifolia, Plectranthus barbatus, Ozoroa insignis, Acacia seyal, Commiphora confusa, Terminalia brownii, Combretum molle, Rhus glutinosa, Acacia hockii, Grewia trichocarpa* and *Balanites aegyptiaca*. These species occur in community type 1, 2 and 4. Although these species occur in three communities, quadrat 5 was sampled from a transitional area between community type 2 and community type 4. Perhaps this could account for its being as ouitlier. On the other hand quadrat 18 is composed of a unique species near the Lake shore (Lake Chamo). The species of quadrat 18 are *Thypha angustifolia, Aeschynomene elaphroxylon, Sesbania goetzei* and *Echinochloa pyramidalis*. Quadrat 38 was sampled from a former settlement of the people where *Balanites rotundifolia* was selected as a shade plant and made so abundant.

In the present study 216 plant species were recorded. These plant species were grouped under 58 families (see Appendix 1b). The family *Fabaceae* is represented here by 33 species, which make up 15% of the total species recorded. The family *Poaceae* is represented by 22 species and this makes 10% of the total. *Capparidaceae* is represented by 12 species; *Asteraceae* and *Lamiaceae* each by 10 species; *Acanthaceae* and *Anacardiaceae* each by 9 species; *Euphorbiaceae* and *Combretaceae* by 6 species each; *Tiliaceae, Vitaceae* and *Rubiaceae* are represented each by 5 species. Family *Burseraceae, Asclepiadaceae, Sapindaceae* and *Solanaceae* are represented by 4 species. Other families are represented by one, two or three plant species. From the data on the study of aboveground herbaceous phytomass and plant community types, all the families belong to an angiosperm except the family *Selaginellaceae* and *Actiniopteridaceae*.

Community type 1 is from both Southwest of Lake Chamo and Key Afer-Shala Luqa. In Southwest of Lake Chamo it is represented by quadrat 1 and others are from Key Afer-Shala Luqa. In both areas *Heteropogon contortus* and *Acacia hockii* appear to be the dominant species. The second community type (community type 2) includes trees such as *Combretum molle, Acacia hockii, Terminalia brownii, Acacia seyal, Lannea schimperi, Cussonia ostinii, Stereospermum kunthianum* and others. The shrub *Euclea divinorum* is also a species occurring in this community. The field layer of community 2 is largely dominated by *Hyparrhenia filipendula*.

Community type 3 is a unit characterized by different species of *Acacia*, among which *Acacia tortilis* is the dominant in the tree layer. *Achyranthus aspera* is the dominant in field layer of the community. This woodland (*Acacia* woodland) occurs on the south west direction of Lake Chamo adjacent to the Lake and on the eastern side of the Elgo-Wezeka road. On the other hand, on the western side of Elgo-Wezeka road along the mountain chain, is a bushland formation where quadrats in community 4 are found. This type (type 4) also includes some quadrats from the Shala plain. The most important species of community type 4 are *Acacia mellifera, Acalypha fruticosa* and *Acacia brevispica.*

Community 5, 6 and 7 occur relatively on the lower altitudinal areas of Shala Luqa and Weyito, where the precipitation is low. To some extent, *Actiniopteris radiata, Sansevieria ehrenbergii, Indigofera spicata, Solanum somalense* and *Megalochlamys violacea* cover the field layer of these communities. The upper layer is mainly composed of *Commiphora cyclophylla, Acacia tortilis, Balanites rotundifolia* and *Acacia reficiens.*

In the Shala Luqa plain including the Birale area, there are some isolated hills, which are stony and rocky. *Commiphora* species and *Boswellia neglecta* which form an open stand, were mostly recorded from these isolated hills. Similarly *Boswellia* woodland found on rocky site was described from Sudan (Menaut, 1983). On the other hand, *Acacia tortilis* and *Balanites rotundifolia* are commonly seen around the villages in Luqa. Particularly, *Balanites rotundifolia* is common around the villages for the following reasons according to the local informant.

1. It provides shade for cattle in the dry season. When other species shade their leaves in the dry season, *Balanites rotundifolia* together with other species such as *Salvadora perisca* and *Maerua* spp. provide shade for the cattle due to their evergreen leaves.
2. The fruit of *B. rotundifolia* is eaten by the children when ripe and are also sold in market. The seeds of *B. rotundifolia* are roasted with the seeds of *Sterculia africana* and *Cucurbita pepo* to be eaten as non-cultivated food.

The result of ordination from the vegetation data set agrees in general with the result obtained by classificatory approach, except for the clumped community types, which are relatively found in the low altitude.

Community diversity was calculated from the mean cover abundances of all species in all sample stands grouped in the same cluster. Diversity is the measure of species richness (the number of species present) and evenness (the relative abundance of the species) (Duffey, 1974). Vegetation is said to have high diversity if it has many species and their abundance is fairly even, conversely, diversity is low when the species are few and their abundance is unevenly distributed.

In the present study, the highest species richness was found in community type 2, which is from Southwest of Lake Chamo and Key Afer areas. The least species richness was found from community type 6, which is from the Luqa plain. An arrangement of the community types in decreasing species richness gives the order community type 2, 1, 4, 5, 3, 7 and 6. The high species richness is probably attributed to the optimum environment that supports the Savanna Woodland species or attributed to the minimum level of disturbances.

The community, which is relatively lower in species richness (community type 4), appears to have high evenness. An arrangement of the groups in decreasing evenness gives the order 4, 2, 1, 6, 7, 3 and 5. This arrangement does not agree with the arrangement of the community types in decreasing species richness. In some community type like type 4, where the constituent species appear to be distributed evenly, there is less species richness as compared to others.

Generally, diversity follow the trends observed in species richness (Whittaker, 1975). It is highest in species rich and lowest in species poor community. Nevertheless, maximum diversity is achieved when each species is represented by equal numbers of individuals (Pielou, 1969). Therefore, from the present information at hand, maximum diversity could not be achieved, because communities with species rich in general did not appear to have an evenly distributed species.

It has been proposed that, the more numerous the species in an ecosystem and/or community, the greater the stability. In other words, high environmental stability leads to higher community stability, which inturn permits high diversity of species (Bormann & Kellert, 1991). Accordingly, community type 5, 6 and 7 are in less stable environment and therefore have less species richness. Community type 3 also shows fewer species richness, because it represents species from four sample stands (quadrats). Since it is known that the increase in the number of samples will increase the species encountered (McNaughton and Wolf, 1973), the less species richness encountered in community 3 could be the few sample stands (quadrats) representing the community. Moreover, the area covered by community type 3 is also small, thus represented by few sample stands (quadrats).

5.3 Relations Between Sites of Herbal Phytomass and Plant Communities

From the vegetation data set, community 1 (*Heteropogon controtus-Acacia hockii* type) and community 2 (*Hyparrhenia filipendula-Combretum molle* type) belong to the savanna woodland, with a varying degree of tree density. In general the genera recorded from the present savanna woodland agrees with the genera described by other workers in Africa (Chachu, 1982; Menaut, 1983). According to these authors, genera like *Combretum, Terminalia, Acacia, Hyparrhenia, Indigofera, Piliostigma, Strychnos, Stereospermum, Isoberlinia,* etc. were described from savanna woodland. In the vegetation data set, the phytomass site (Site1 and 2 from Southwest of Lake Chamo) is described as *Achyranthus aspera-Acacia tortilis* community type. Sites 5, 6 and 7 belong to communities 1 and 2 (see Table 9) of the vegetation data set of Southwest of Lake Chamo and Key Afer. Site 6 was from community type 1 around the pick of Key Afer and 7 was from community 2, on the lower plateaux of Key Afer-Alduba

Table 9 Selected sites for aboveground herbaceous phytomass and the plant community to which it belongs.

Sites	Community types
1 & 2	*Achyranthus aspera-Acacia tortilis* community
3	Disturbed *Acacia* woodland *
4 & 11	*Acacia mellifera-Acalypha fruticosa-Acacia brevispica* community
5 & 6	*Hyparrhenia filipendula-Combretum molle* community
7	*Hetropogon contortus-Acacia hockii* community
8	*Commiphora cyclophylla-Actiniopteris radiata-Sansevieria ehrenbergii* type
9 & 13	*Acacia tortilis-Indigofera spicata* community
10	Cultivated and fallow land *
12	*Acacia reficiens-Megalochlamys violacea* community

*-Samples were not considered for the study of plant communities.

The reduction in aboveground herbaceous phytomass of site 4 from Southwest of Lake Chamo could be due to the woody vegetation cover. This site belongs to *Acacia mellifera-Acacia brevispica-Acalypha fruticosa* community type of the vegetation data set. This site is a bushland found on the Western side of Elgo-Wezeka road, along the mountain chain (Gulgo and Mele). Due to the dense cover of the woody vegetation, the aboveground herbaceous phytomass was found to be smaller.

Site 8 belongs to *Commiphora cyclophylla-Actiniopteris radiata-Sansevieria ehrenbergii* community type. However, samples for the aboveground herbaceous phytomass (site 8) did not cover all places from where samples for vegetation analysis were considered. A small portion of the community, where *Acacia and Commiphora* appear to be dominant (hence *Acacia-Commiphora* for site 8), was considered. Site 8 is, therefore, on the way from Luqa to Key Afer along the Gedo and Tuga ridges and on the east facing side toward Shala plain of the Gedo ridge. Site 9 belongs to *Acacia tortilis-Indigofera spicata* type described from Luqa areas. Site 10 and 11 belong to Shala Plain, 11 being in community type 4. Site 12 was from *Acacia reficiens-Megalochlamys violacea* community type described from east of Luqa toward the Birale farm.

According to an informant (Yimar Ali), site 13 had flood accumulated on it some 40-50 years ago. Although this belongs to community 6 of the vegetation data set, it was considered independently for the aboveground herbaceous phytomass based on the previous history (flood accumulation).

5.4 Community-Environment Relations

Soil is an important ecological factor that determines plant growth. In the present study the soil data collected from Key Afer-Shala Luqa and Southwest of Lake Chamo is shown in Appendix 4. The values of the analysis were averaged in accordance with the community types identified and tested statistically for the significant differences between communities.

Particle size distribution has a considerable effect on the flora of the region (Etherington, 1974). It affects soil aeration, water movement, root penetration and water holding capacity. The result of the textural analysis of the soils from the present study areas using the triangular diagram relating particle size distribution to textural classes (Hunt, 1972; Fitzpatrick, 1974) revealed that, all the soils fall in the textural class of sandy loam. The highest percent of sand was found in the Luqa plain where *Commiphora* spp. and *Acacia reficiens* were recorded (Table 7). Statistical test on soil particle size, especially in sand and clay shows a similar significant variation between communities as presented in Table 7. Arrangement of the communities based on the mean values of sand and clay in decreasing percent give the order 5, 7, 4, 1, 2, 3 and 6 and 6, 2, 1, 3, 4, 7 and 5 respectively. An arrangement of the communities based on the percent silt in decreasing order gives 3, 2, 6, 1, 7, 4 and 5.

Soil pH is a factor which affects the organic matter content of the soil through the effect it has on the activity of decomposing micro organisms (Etherington, 1974). According to this author, low pH slows the rate of organic matter decomposition. Organic matter decomposition is fast in soils having pH values around neutrality. However, there is no standard scale of qualitative terms for pH ranges. According to Young (1976), the following ranges were considered useful for description. Values of pH less than 4 is very strongly acidic, pH ranges between 4-5 is strongly acidic, 5-6 moderately acidic, 6-7 weakly acid, (c 6.5-7.5 neutral), 7-8 weakly alkaline, 8-9 moderately alkaline and pH values greater than 9 can be considered as strongly alkaline. Following this, the result of the pH analysis of the present study could be grouped in neutral pH, since the mean values of the communities based on pH ranges from 7.1 to 7.5. Arrangement of the community types based on pH values in decreasing order gives 3 and 7, 5, 6, 4 and 1 and 2. On the other hand, Tewolde (1975) indicated that, average pH is not necessarily indicative of the pH to which the plant is subjected, as in some habitats, species can grow and develop by keeping their roots at different levels of the soil profile.

Sodium and potassium content of the soil are low in community 5. An arrangement of the community types based on the mean values of potassium in decreasing (ppm) order, for example gives 3, 6, 7, 1, 2, 4 and 5. Similarly the arrangement of the community types based on the mean values of sodium in decreasing order (ppm) gives 2, 3, 1, 6 and 7, 4 and 5. Since community 5 is a community that is found on rocky area and relatively on sloppy area, it appears that this community is on poor nutrient content. This community (community 5) also showed highest % sand, low %clay and % silt.

The analysis of phosphorous indicated that, the phosphorous content of the soil is uniformly low. According to Murphy (1958), a large proportion of phosphorous at any one time is stored in forms unavailable to plants. For example, $H_2PO_4^-$ which becomes available at low pH values, suffers from fixation by hydrous oxides and silicate minerals. Therefore, the low availability could be attributed to the aforementioned facts. Analysis of variance between community groups based on phosphorous content also shows insignificant differences.

Generally soil color is strongly influenced by the humus content and iron compounds in the soil (Fitzpatrick, 1974; Young, 1976). Humus coats the soil particles and imparts a black coloration, while red, yellowish red and yellow colors are mainly caused by iron product. In the present study, most soil samples have the hue (the dominant spectral color or quality) more or less 10YR and 7.5YR. The value (the lightness of color as compared to absolute white) ranges from 2.5 to 6 and the chroma (strength of the color or departure from neutral gray or white) ranges from 1-6. Although there is variation, the general color appears to be dark yellowish brown and strong brown.

Physiographical variables such as altitude and slope significantly affect the distribution of plants. Variation in altitude, for example, could mostly result in variation in the composition of natural vegetation. Since altitude affects temperature, radiation and moisture it can influence the growth and development and the distribution of plants. In the present study, the communities produced using classification and ordination follow the altitudinal variations recorded. Therefore, it appears that altitude is the most important environmental element that determined the occurrence and distribution of the community types in the study areas.

Slope is also an important element. The effect of slope is manifested in its influence on the run-off and drainage and consequently upon the nutrient, depth and water content of the soil. In the present study, the effect of slope is prominent in community type 5, although the mean value is highest in type 4 and in type 2. This is due to the fact that community 5 occurs on rocky areas and appears to have less herbaceous cover that reduce run-off. Moreover, from the soil data analyzed in the present study, it can be deduced that community 5 has low potassium, sodium, phosphorous, % clay and % silt as compared to others. This shows that slope has an impact on this community. Although slope is high in community 4 and community 2 its effect is probably masked due to higher herbaceous cover than in community 5.

From the foregoing discussion it can be said that, the environmental parameter (altitude, slope, soil potassium and sodium and the texture of the soil) have a significant roles on the differentiation of the different communities identified.

The causes of natural fires in the past were attributed to lightning strikes and volcanic activities, in addition to burning vegetation by hominids for various purposes (Goldammer, 1994). In the present study areas the cause of fire appears to be anthropogenic aiming at certain goals. The Zeyise, who are living around Southwest of Lake Chamo burn vegetation mainly for the expansion of agricultural land and to some extent to get new grass shoots as observed from Borgela area on the north east direction of Arguba village (on 18-02-97 during field work). On the other hand, the Bennas, who live in Hammer Benna district, burn vegetation primarily to get new grass shoots for their cattle and occasionally for the expansion of agricultural lands.

For an agropastoralist, the measure of wealth is his/her cattle. This necessitated the burning of the vegetation for the new shoots by the Benna. The Ministry of Agriculture had tried to enforce regulations prohibiting the use of forest fire in the Benna areas (Abebe Mekonnen Developmental Agent of Key Afer, personal communication). Despite the regulation they were burning vegetation during the present field study. Although fire has different impacts on different species, burning appears to be important for the agropastoral Benna, to obtain new grazing or browsing material and expanding agricultural lands. With the primary goal of getting new grass shoot by the Benna, periodic burning may be one of the important management tools for controlling bush encroachment, improving grass vigour, controlling pest and vector populations.

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6. CONCLUSIONS AND RECOMMENDATIONS

In the present study the aboveground herbaceous phytomass, plant community types with some pedological and physiographical variables from Key Afer-Shala Luqa and Southwest of Lake Chamo, Southern Ethiopia were determined.

In the study of aboveground herbaceous phytomass 260 samples in $1m^2$ sample stand (quadrat) were considered. The average aboveground herbaceous phytomass ranged from 35.9 gm^{-2} in Shala plain to 1016.8 gm^{-2} in Southwest of Lake Chamo. Reduction in aboveground herbaceous phytomass in the Tsamako area (Shala Luqa) indicates that there is ecological incompatibility between aboveground herbal phytomass, livestock population and climatic factors.

The analysis of data from 71 sample stands revealed that the vegetation of Key Afer-Shala Luqa and Southwest of Lake Chamo can be categorized into seven distinct plant communities and an outliers, mainly depending upon altitude. Accordingly, the plant community type 1 is *Heteropogon contortus-Acacia hockii* (the average altitude being 1430 m a.s.l.). Type 2 is *Hyparrhenia filipendula-Combretum molle* at an average altitude of 1528 m a.s.l.; type 3 *Achyranthus aspera-Acacia tortilis* at an average altitude of 1095 m a.s.l.); type 4 is *Acacia mellifera-Acalypha fruticosa-Acacia brevispica* (1232 m a.s.l.); type 5 *Commiphora cyclophylla-Actiniopteris radiata-Sansevieria ehrenbergii* (884 m a.s.l.); type 6 *Acacia tortilis-Indigofera spicata* (725 m a.s.l.) and type 7 *Acacia reficiens-Megalochlamys violacea* type at an average altitude of 662 m above sea level.

The analysis of diversity from the vegetation data set of 71 stands showed that plant community type 2 is a species rich community and community type 6 is a species poor community. Evenness appears to be highest in community type 4 and lowest in 5. Thus, maximum diversity was not achieved.

The soils of Key Afer-Shala Luqa and Southwest of Lake Chamo fall in the textural class of sandy loam. Neutral pH and somewhat excessive drainage also characterize the soils.

In general, from the ecological assessment made in Key Afer-Shala Luqa and Southwest of Lake Chamo the following recommendations could be made.

In order to get more information on the aboveground herbaceous phytomass, measurement should also be made late in the dry season. The overall decrease in the average aboveground herbaceous phytomass and reduction in species richness in Shala Luqa might be due to the high stocking rate and uneven rate of precipitation. Therefore, instead of having numerous cattles, it would be better to have fewer cattle with high milk (milk and milk product) and meat yield. Raising the awareness of the Tsamako and destocking (which is somewhat time consuming in agropastoralists) are then the necessary tasks, since destocking itself is source of finance and enable the Tsamako to solve some of the socio-economic problems as well. Moreover, destocking can have an advantage on the ecological balance of the area.

In Zeyise, Benna and Tsamako areas there is a scarcity of water, which is scarcer in Tsamako village in the dry season. The fact that there are a few water wells and building dams to obtain water in Shala Luqa and Key Afer, does not satisfy the need for the water in the areas. Therefore more water sources are required for Shala Luqa and Key Afer area. Since it is vital to manage these areas with the consideration of present and future generations, the availability of water (as in Tewolde, 1990) with afforestation practice (of indigenous plant species) may at least prolong the ecosystem for certain time.

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Appendix 1a List of species encountered during the study of aboveground herbaceous phytomass, its collection number and the sample stand (quadrat) in which it occurs.

Col. No	*Species*	*Family*	Stands in which the species were encountered
1	*Heteropogon contortus* (L.) Roem. & Schult.	*Poaceae*	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 22, 23, 25, 26, 27, 28, 29, 30, 31, 42, 45, 46, 188, 193, 194, 195, 196, 198, 199, 238, 239, 240, 241, 254 & 259.
2	*Eragrotis superba* Peyr	*Poaceae*	1, 2, 3, 5, 6, 7, 8, 10, 11, 188 & 194.
3, 51	*Lepidagathis scariosa* Nees	*Acanthaceae*	1 & 109.
4, 18	*Hypoestes forskolei* Roem. & Schult.	*Acanthaceae*	2, 6, 16, 22, 23, 26, 33, 34, 35, 37, 38, 44, 46, 47, 48, 52, 54, 56, 58, 64, 68, 70, 72, 73, 85, 190, 191, 194, 195, 199, 202 & 236.
5	*Aristida kenyensis* Henr.	*Poaceae*	57, 58, 76, 77, 83, 84, 91, 93, 94, 96, 97, 105, 108, 161, 165, 197, 202, 221, 223, 229, 238, 243, 257 & 258.
36, 6	*Eragrostis paposa* (Roem. & Schult.) Steud.	*Poaceae*	8, 36 & 61.
7	*Hyparrhenia filipendula* (Hochst.) Stapf.	*Poaceae*	9, 11, 12, 13, 14, 15, 16, 17, 18, 24, 25, 30, 32, 33, 34, 36, 38, 39, 40, 41, 44, 47, 48, 49, 50, 51, 52, 53, 54, 55, 58, 60, 62, 63, 64, 65, 66, 68, 69, 70, 71, 72, 73, 157, 246, 247, 248, 249, 250, 251, 252, 253, 255 & 256.
8	*Plectranthus barbatus* Benth.	*Lamiaceae*	10 & 28.
9	*Melinis repens* (Willd.) Zizka	*Poaceae*	12.
10	*Leucas abyssinica* Briq.	*Lamiaceae*	12 & 71.
11	*Rhynchosia resinosa*(A. Rich.) Bak.	*Fabaceae*	13.
12	*Vernonia popeana* C. Jeffery	*Asteraceae*	13.
13	*Indigofera ambelacensis* Schweinf.	*Fabaceae*	14, 17, 27, 29, 30, 39, 40, 43, 44, 65, 73, 161, 171, 174, 198, 199 & 238.
14	*Phyllanthus maderaspatensis* L.	*Euphorbiaceae*	14 & 43.
15	*Bidens pachyloma*(Oliv. & Hiern)Cuf.	*Asteraceae*	15.
16	*Laggera alata* (D. Don) Sch.Bip ex Oliv.	*Asteraceae*	16, 33, 69, 102 & 159.
17	*Tragia abortiva* M. Gilbert	*Euphorbiaceae*	16 & 32.
19	*Triumfetta rhomboidea* Jacq.	*Tiliaceae*	19.
20, 59	*Acalypha fruticosa* Forssk.	*Euphorbiaceae*	20, 117, 122 & 124.
21	*Tagetus minuta* L.	*Asteraceae*	19 & 20.
22	*Eragrostis aspera* (Jacq.) Nees	*Poaceae*	20.

Col. No	Species	Family	Stands in which the species were encountered
23	*Sporobolus ioclados* (Trin.) Nees	*Poaceae*	21, 22, 24, 26, 35, 37, 51, 57, 64, 72, 188, 190, 191, 192, 195 & 200.
24	*Barleria quadrispina* Lindau	*Acanthaceae*	28, 59, 62, 63, 66, 67, 84, 85, 87, 89, 108, 116, 126, 141, 145, 146, 147, 149, 150, 151, 152, 153, 154, 155, 156, 166, 167, 185, 187, 197, 201, 202, 203, 222, 224, 236, 243 & 258.
25	*Wahlenbergia abyssinica* Thulin	*Campanulaceae*	32.
26	*Satureja abyssinica* (Benth.) Briq.	*Lamiaceae*	34, 35, 36, 49 & 52.
27	*Gnaphalium spp.*	*Asteraceae*	54.
28	*Ocimum urticifolium* Roth.	*Lamiaceae*	37, 38 & 55.
29	*Spermacoce spp.*	*Rubiaceae*	36, 39 & 40.
30	*Loudetia simplex* (Nees) Hubbard	*Poaceae*	41 & 59.
31	*Hyparrhenia hirta* (L.) Stapf.	*Poaceae*	42 & 43.
32	*Tephrosia elata* Defl.	*Fabaceae*	45, 48 & 49.
33	*Leucas martiniensis* (Jacq.) R. Br.	*Lamiaceae*	51, 53 & 213.
34	*Solanum incanum* L.	*Solanaceae*	55, 89 & 121.
35	*Kalanchoe crenata* Haw.	*Crassulaceae*	59, 85, 158 & 210.
37	*Aerva lanata* (L.) Juss.	*Amaranthaceae*	60 & 63.
38	*Asystasia riparia* Lindau	*Acanthaceae*	67 & 162.
39	*Drimia altissima* Ker-Gawl.	*Hyacinthaceae*	68.
40	*Setaria megaphylla* Th. Dur & Schinz	*Poaceae*	40, 115 & 116.
41	*Melhania ovata* (Cav.) Spreng.	*Sterculaceae*	74, 76, 77, 162, 164 & 165.
42, 43	*Digitaria abyssinica* (A. Rich) Stapf.	*Poaceae*	78, 80, 81, 82, 83, 92, 93, 94, 103, 107, 117, 118, 119, 156 & 175.
44	*Indigofera spinosa* Forssk.	*Fabaceae*	77, 80, 95, 96, 97, 102, 105, 106, 110, 111, 112, 126, 127, 128, 129, 131, 135, 177, 179, 181, 182, 183 & 184.
45	*Asystasia gangetica* (L.) T. Anders	*Acanthaceae*	87, 90, 91, 92, 95, 101, 145, 156, 164,169, 184 & 203.
46	*Indigofera spp.*	*Fabaceae*	88.
47	*Blepharis ciliaris* L.	*Acanthaceae*	95, 97, 98, 104, 105, 106, 112, 127, 133 179 & 182.
48	*Commelina africana* L.	*Commelinaceae*	104 & 168.
49	*Plectranthus defoliatus* Hochst.ex Benth.	*Lamiaceae*	107, 157, 165, 200, 201, 222 & 224.
50	*Aloe macrocarpa* Tod.	*Aloaceae*	107, 129, 142 & 233.
52	*Tetrapogon tenellus* (Roxb.) Chiov.	*Poaceae*	109.
53	*Truimfetta flavescens* Hochst. ex A. Rich.	*Tiliaceae*	109, 111, 136, 172, 226 & 228.
54	*Portulaca quadrifida* L.	*Portulacaceae*	111, 114 & 152.
55	*Solanum somalense* Franch.	*Solanaceae*	106, 131, 132, 144 & 149.

Col. No	Species	Family	Stands in which the species were encountered
56	*Perotis patens* Gand.	*Poaceae*	112, 113, 114, 124, 133, 160 & 186.
57	*Tribulus terrestris* L.	*Zygophyllaceae*	114, 121, 123, 124, 125, 133, 134, 153, 154, 185, 186 & 187.
58	*Cyperus comosipes* Mattf. & Kuk.	*Cyperaceae*	116.
60	*Hibiscus micrantus* L. f.	*Malvaceae*	118.
61	*Euphorbia borenensis* M. Gilbert	*Euphorbiaceae*	122, 126 & 141.
62	*Ammocharis tinneana* Milne-Redh. & Schweick	*Amaryllidaceae*	125.
63	*Asystasia calyculata* Deflers	*Acanthaceae*	134.
65	*Senna septemtrionalis* Irwin & Barneby	*Fabaceae*	135.
66, 98	*Pupalia lappacea* (L.) Juss.	*Amaranthaceae*	136, 137, 138, 139, 140, 216, 223, 236& 245.
67	*Asparagus africanus* Lam.	*Asparagaceae*	142.
68	*Chascanum laetum* Fenzl ex Walp.	*Verbenaceae*	157.
69	*Pennisetum pedicellatum* Trin.	*Poaceae*	159 & 197.
70	*Enteropogon macrostachyus* Benth.	*Poaceae*	160, 166, 167 & 174.
71	*Chloris roxburghiana* Schult.	*Poaceae*	160 & 229.
72	*Chascanum heldebrandtii* (Vatke) Gillett	*Verbenaceae*	161.
73	*Cenchrus ciliaris* L.	*Poaceae*	163, 169, 215, 230, 234, 242 & 243.
75	*Enneapogon schimperianus* (Hochst. ex A. Rich.) Renv.	*Poaceae*	164.
76	*Megalochlamys violacea* (Vahl) Vollesen	*Acanthaceae*	179 & 181.
77	*Cycnium montane* N. E. Br.	*Scrophulariaceae*	190.
78	*Urochloa panicoides* P. Beauv	*Poaceae*	204.
79	*Echinochloa pyramidalis* Chase	*Poaceae*	205.
80	*Hibiscus diversifolius* A. Rich.	*Malvaceae*	206.
81	*Launaea cornuta* C. Jeffery	*Asteraceae*	207.
82	*Abutilon figarianum* Webb.	*Malvaceae*	207, 214, 234, 259 & 233.
83	*Cynodon dactylon* (L.) Pers.	*Poaceae*	208, 209, 213, 227, 231, 232 & 235.
84	*Cynodon nlemfuensis* Vanderyst	*Poaceae*	209.
85	*Indigofera spicata* Forssk.	*Fabaceae*	209.
86, 87	*Achyranthus aspera* L.	*Amaranthaceae*	210.
88, 89	*Shoenoplectus microgulmia* Lye	*Cyperaceae*	211 & 212.
90	*Thypha angustifolia* L.	*Thyphaceae*	211 & 262.
91	*Phyla nodiflora* (L.) Green	*Verbenaceae*	212.
92	*Ipomoea Cairca* (L.) Sweet	*Convolvulaceae*	212.
93	*Ocimum canum* Sims	*Lamiaceae*	213, 221 & 245.
94	*Justicia flava* Vahl	*Acanthaceae*	214.
96	*Chloris virgata* Swartz	*Poaceae*	215, 216, 217 & 223.
97	*Tetrapogon cenchriformi* (A. Rich.) Clayton	*Poaceae*	216 & 229.
99	*Leucas glabrata* (Vahl) Smith	*Lamiaceae*	217.
100	*Eragrostis schweinfurthii* Chiov.	*Poaceae*	218.
101	*Boerhavia erecta* L.	*Nyctaginaceae*	218.
102	*Kalanchoe lanceolata* Forssk.	*Crassulaceae*	224, 226 & 228.
103	*Aspilia gilletti* Wild	*Asteraceae*	226, 228 & 231.

Sl. No	Species	Family	Stands in which the species were encountered
	…digofera schimperi Jaub. & Spach	*Fabaceae*	227, 230, 231, 241 & 257.
06	*…taria incrassata* (Hochst.) Hack	*Poaceae*	237, 251, 252, 253, 255 & 256.
07	*…nidia schweinfurthii* Gilg	*Thymeleaceae*	246.
08	*…uchnera capitata* Benth.	*Scrophulariaceae*	246.
09	*…sparagus flagellaris*(Kunth.) Baker	*Asparagaceae*	247.
…0	*…oudetia arundinacea* (A. Rich.) …teud.	*Poaceae*	248.
…1	*…ernonia karaguensis* Oliv.	*Asteraceae*	250 & 252.
…9	*…ctiniopteris radiata* (Swartz) Link	*Actiniopteridaceae*	166 & 167
…	*Selaginella phillipsiana* Alston	*Selaginellaceae*	166 & 167.

Appendix 1b Scientific names and vernacular names of plant species collected from Key Afer-Shala Luqa and Southwest of Lake Chamo

Scientific Name	*Family*	Benna Name (B.)	Tsemako Name	Zeyise Name (Zy.)	Col. No.
Abutilon figarianum Webb.	*Malvaceae*			Fuddo	82
Acacia abyssinica Hochst. ex Benth.	*Fabaceae*	Okuma		Gobba	207
Acacia asak (Forssk.) Willd.	*Fabaceae*			Sebbunee	199
Acacia brevispica Harms.	*Fabaceae*	Zergo		Zalimoo	155
Acacia drepanolobium Harms. ex Sjösted	*Fabaceae*				*5361
Acacia etbaica Schweinf.	*Fabaceae*	Dhera			295
Acacia goetzei Harms.	*Fabaceae*				156
Acacia hockii De Wild	*Fabaceae*	Cheqenti		Gicho	323
Acacia mellifera (Vahl) Benth.	*Fabaceae*	Dille	Boytekko	Bi'ule	326
Acacia nilotica (L.) Willd. ex Del.	*Fabaceae*				206
Acacia oerfota (Forssk.) Schweinf.	*Fabaceae*		Deqela	Zequssa	321
Acacia reficiens Wawra.	*Fabaceae*		Zamba		327
Acacia senegal (L.) Willd.	*Fabaceae*	Gorle	Gololko		*5439
Acacia seyal Del.	*Fabaceae*	Fulanti		Pule	*5328
Acacia tortilis (Forssk.) Hayne	*Fabaceae*	Sewut	Dhetteko	Chuwenna	255
Acalypha fruticosa Forssk.	*Euphorbiaceae*	Siringo (chantela)	Chebbo	Pisamo	20, 152
Acanthus pubescens (Thoms.) Engl.	*Acanthaceae*			Heshesho	179
Achyranthus aspera L.	*Amaranthaceae*			Dhaza	86, 87
Actiniopteris radiata (Swartz) Link	*Actiniopteridaceae*				339

Scientific Name	*Family*	Benna Name (B.)	Tsemako Name	Zeyise Name (Zy.)	Col. No.
Adenia venenata Forssk.	*Passifloraceae*		Urshe'atte		235
Adenium obesum Roem. ex Schult.	*Apocynaceae*	Aredengo	Aredengo		324
Aerva lanata (L.) Juss.	*Amaranthaceae*				37
Aeschynomene elaphroxylon Taub.	*Fabaceae*			Sorfondo	202
Albizia amara (Roxb.) Boiv.	*Fabaceae*	Rumbe			245
Aloe gilbertii Sebsebe & Brandham	*Aloaceae*	Welqo		Tolkos	158
Aloe macrocarpa Tod.	*Aloaceae*	Welqo	Argekko		50
Aristida kenyensis Henr. [1]	*Poaceae*			Silleqefe	5
Asparagus africanus Lam.	*Asparagaceae*	Serki		Germagaguma	67
Asparagus falcatus L.	*Asparagaceae*	Ergenso			230
Asparagus flagellaris (Kunth) Bak.	*Asparagaceae*	Serki			241, 106
Aspilia gillettii Willd.	*Asteraceae*			Shonetta	103
Asystasia gangetica (L.) T. Anders	*Acanthaceae*			Odode	45
Balanites aegyptiaca Del.	*Blanitaceae*	Domoko		Morgo	196, 197
Balanites rotundifolia Blatter	*Balanitaceae*	Kuz	kuyyetto		309
Barleria eranthemoides C. BCl.	*Acanthaceae*				307
Barleria quadrispina Lindau	*Acanthaceae*		Irboo	Akula	24
Blepharis ciliaris L.	*Acanthaceae*				47
Blighia unijugata Bak.	*Sapindaceae*			Gobbogulta	137
Boerhvia erecta L.	*Nyctaginaceae*			Osholo	101
Boscia angustifolia A. Rich.	*Capparidaceae*		Sarakko /Qelqalko/		316
Boscia salicifolia Oliv.	*Capparidaceae*		Kedhi	Gachuma	140, 292

Scientific Name	*Family*	Benna Name (B.)	Tsemako Name	Zeyise Name (Zy.)	Col. No.
Boscia senegalensis Lam. ex Poiret	*Capparidaceae*		Tubaqe		259
Boswellia neglecta S. Moore	*Burseraceae*		Dengeree	Suga	331
Cadaba farinosa Forssk.	*Capparidaceae*	Firtso(Zegente)	Lago/Regumu/	Qallo	121
Cadaba rotundifolia Forssk.	*Capparidaceae*				251, 317
Calotropis procera (Ait.) Ait. f.	*Asclepiadaceae*			Qoppe	201
Calyptrotheca somalensis Gilg.	*Portulacaceae*	Lagisho	Bela		232, 270
Canthium setiflorum Hiern	*Rubiaceae*	Birri	Birri	Mirtsamirtso	260
Capparis tomentosa Lam.	*Capparidaceae*	Mello(Kumbi)		Gurdadde	144
Cardiospermum halicacabum L.	*Sapindaceae*		Chummo		262
Carisa edulis (Forssk.) Vahl	*Apocynaceae*	Akem'a			282
Cenchrus ciliaris L.	*Poaceae*			Kirzya	95
Cissus quadrangularis L.	*Vitaceae*	Kiriru	Wercheleqqe		120
Cissus rotundifolia (Forssk.) Vahl	*Vitaceae*		Kelalo	Menenakko	203
Clematis hirsuta Perr. & Guill.	*Ranunculaceae*			Tura	*5219
Cleome monophylla L.	*Capparidaceae*	Kedhi			250
Coccinia adoensis (A. Rich.) Cogn	*Cucurbitaceae*			Echerodhans	209
Coccinia grandis (L.) Voight	*Cucurbitaceae*			Echerobullo	211
Combretum aculeatum Vent.	*Combretaceae*	Mega	Doyrekko	Zumburo	*5272
Combretum collinum Fres.	*Combretaceae*	Sebe		Wurkule	160
Combretum hereroens Schinz.	*Combretaceae*		Doyrakko		258, 273
Combretum molle G. Don	*Combretaceae*	Sebe		Wurkule	114, 332
Commelina africana L.	*Commelinaceae*			Gelges	48
Commelina imberbis Ehrenb. ex. Hassk.	*Commelinaceae*				136

Scientific Name	*Family*	Benna Name (B.)	Tsemako Name	Zeyise Name (Zy.)	Col. No.
Commicarpus plumbagineus (Cav.) Standl.	*Nyctaginaceae*				220
Commiphora bruceae Chiov.	*Burseraceae*		Kurdheko		272
Commiphora confusa Vollesen	*Burseraceae*	Dhenga	Qeyi	Mokko	195
Commiphora cyclophylla Chiov.	*Burseraceae*	Weqaqo	Silbne		234
Cordia gharfa (Forssk.) Aschers	*Boraginaceae*		Dongo		329
Croton zambesicus Muell. Arg	*Euphorbiaceae*	Werqeqa			247
Cussonia ostinii Chiov.	*Araliaceae*	Getem			*5422
Cynodon dactylon (L.) Pers.	*Poaceae*			Zersa (Gerdhiste)	83
Cyphostemma adenanthum Descoings	*Vitaceae*	Sarcostemma			287
Cyphostemma adenocaule Willd. & Drumm.	*Vitaceae*	Nasundekkelle			132
Delonix elata (L.) Gamble	*Fabaceae*		Wuharekko		236, 312
Dichrostachys cinerea (L.) Wight & Arn.	*Fabaceae*				*5428
Digitaria abyssinica (A. Rich.) Stapf.	*Poaceae*				42
Diospyros scabra (Chiov.) Cufod.	*Ebenaceae*		Goyitee		254
Dissotis decumbens (P. Beauv.) Triana	*Melastomataceae*				210
Dodonoae angustifolia L.	*Sapindaceae*	Serqo		Saringa	333
Dombeya torrida P. Bamps	*Sterculiaceae*			Okedhe	123
Drimia altissima Ker-Gawl.	*Hyacinthaceae*	Tumbukho			39
Echinochloa pyramidalis Chase	*Poaceae*				79
Echinops amplexicaulis Oliver	*Asteraceae*	Bura			*5206
Enteropogon macrostachyus Benth.	*Poaceae*				70
Eragrostis aspera (Jacq.) Nees	*Poaceae*			Kefomata	22

Scientific Name	*Family*	Benna Name (B.)	Tsemako Name	Zeyise Name (Zy.)	Col. No.
Eragrostis papposa (Roem. & Schult.) Steud.	*Poaceae*				6
Eragrostis superba.	*Poaceae*	Qercha			2
Erianthemum dregei (Eckl. & Zeyh.) V. Teigh.	*Loranthaceae*				224
Eriosema spp.	*Fabaceae*			Bostura	146
Erythrina abyssinica Lam.ex DC.	*Fabaceae*	Bori			330
Euclea divinorum Hiern	*Ebenaceae*	Unsi		Geyzo	129
Euphorbia borenensis M. Gilbert	*Euphorbiaceae*		Kera		61
Euphorbia tirucalli L.	*Euphorbiaceae*	Tsude			*5437
Faurea rochetiana (A. Rich.) Pichi-Serm.	*Proteaceae*	Qelshi		Gordhumma	184, 289
Ficus vallis-choudae Del.	*Moraceae*			Bobba	164
Ficus vasta Forssk.	*Moraceae*	Shafa			284
Gardenia ternifolia Schum. & Thonn.	*Rubiaceae*	Gembela		Shuluro	125, 239
Glycine wightii Verdc.	*Fabaceae*			Tura	213
Gnidia glauca (Fresen.) Gilg.	*Thymeleaceae*	Koysha			286
Gnidia schweinfurthii Gilg.	*Thymeleaceae*	Gebere			107
Grewia tenax (Forssk.) Fiori	*Tiliaceae*	Dhemek			*5440
Grewia trichocarpa Hochst. ex. A. Rich.	*Tiliaceae*	Bereza		Dhodhogo	225
Grewia velutina (Forssk.) Vahl	*Tiliaceae*	Bereza	Dhewekko	Badhe	124
Harrisonia abyssinica Oliv.	*Simaroubaceae*	Zergo		Tsutsa (Qecha chello)	116, 242

Scientific Name	*Family*	Benna Name (B.)	Tsemako Name	Zeyise Name (Zy.)	Col. No.
Herpachne schimperi Hochst.ex. A. Rich.	*Poaceae*			Dhonqofa	335
Hetropogon contortus (L.) Roem. & Schult.	*Poaceae*	Suni		Seha	1, 151
Hibiscus crassinervius A. Rich.	*Malvaceae*	Lengekko			274
Hibiscus diversifolius A. Rich.	*Malvaceae*			Ogeche	80
Hyparrhenia filipendula (Hochst.) Stapf.	*Poaceae*	Ompala		Horille	7,174
Hyparrhenia hirta (L.) Stapf.	*Poaceae*			Burchele	31
Hyperthelia dissoluta (Steud.) Clayton	*Poacea*				132
Hypoestes forskolei Roem. & Schult.	*Acanthaceae*	Gusunta			4, 18
Indigofera schimperi Jaub. & Spach.	*Fabaceae*	Agergero		Gazzemekille	104
Indigofera spicata Forssk.	*Fabaceae*		Hatsime	Gazemekille	85
Indigofera spinosa Forssk.	*Fabaceae*			Gazzemekille	44
Ipomoea cairica (L.) Sweet	*Convolvulaceae*			Melmelo	208
Ipomoea kitiuensis Vatke	*Convolvulaceae*	Gali			243
Jasminum floribundum L.	*Oleaceae*			Kondoro	166
Justicia caerulea Forssk.	*Acanthaceae*				135
Kalanchoe crenata Haw.	*Crassulaceae*	Deri			35
Kalanchoe lanceolata Forssk.	*Crassulaceae*	Deri			102
Kleina longiflora DC.	*Asteraceae*				320
Kleina squarrosa Cufod.	*Asteraceae*				304
Laggera alata (D.Don) Sch. Bip. ex. Oliv.	*Asteraceae*				16
Lannea humilis (Oliv.) Engl.	*Anacardiacaeae*	Gumade			246

Scientific Name	*Family*	Benna Name (B.)	Tsemako Name	Zeyise Name (Zy.)	Col. No.
Lannea schimperi (Hochst. ex A. Rich.) Engl.	*Anacardiaceae*	Dafi (Heyyette)		Dobbe	189, 277
Lepidagathis scariosa Nees	*Acanthaceae*				51
Leptadenia hastata (Pres.) Decne	*Asclepiadaceae*			Dhomoqqe	219
Leucas abyssinica Briq.	*Lamiaceae*	Kiro		Kertsinte	157
Leucas martiniensis (Jacq) R. Br	*Lamiaceae*			Chogora	33
Lippia abyssinica (Otto & Dietr.) Cuf.	*Verbenaceae*	Gemuri (chudo)		Kishurette	178, 266
Loudetia arundinacea (A. Rich.) Steudl	*Poaceae*				110
Maerua angolensis DC.	*Capparidaceae*				310
Maerua crassifolia Forssk.	*Capparidaceae*		Qelqelku	Shishiqallo	311, 318
Maerua oblongifolia (Forssk.) A. Rich	*Capparidaceae*				296
Maerua subcordata (Gilg.) De Wolf	*Capparidaceae*		Sedhakko		253
Maerua triphylla A. Rich.	*Capparidaceae*				301
Maytenus gracilipes (Welw. ex Oliv.) Exell.	*Celastraceae*			Gurjum	175
Maytenus senegalensis Excell	*Celastraceae*	Bedha		Margite	163, 288
Megalochlamys violacea (Vahl) Vollesen	*Acanthaceae*		Tse'akko		76
Myrsine africana L.	*Myrsinaceae*	Shinkii		Biltsando	165
Ocimum canum Sims	*Lamiaceae*			Banedde	93
Ocimum forskolei Benth.	*Lamiaceae*	Suto			283
Ocimum urticifolium Roth	*Lamiaceae*			Dolhiron	28, 217
Olea europea L. subsp *cuspidata*	*Oleaceae*	Irmit		Gulta	280
Oncocalyx fischeri (Engl.) Ined	*Loranthaceae*	Pogo			238

Scientific Name	*Family*	Benna Name (B.)	Tsemako Name	Zeyise Name (Zy.)	Col. No.
Ormocarpum tricocarpum (Taub.) Engl.	*Fabaceae*	Shibde	Shibde		328
Osyris quadripartita Decn.	*Santalaceae*			Metsetsello	145
Ozoroa insignis Del.	*Anacardiaceae*	Selbenna		Salbennama	115
Panicum maximum Jacq.	*Poaceae*			Hoshe	133
Pappea capensis Eckl. & Zeyn.	*Sapindaceae*			Uriche	122
Pavetta crassipes Schum.	*Rubiaceae*				171
Perotis patens Gand.	*Poaceae*				56
Phyla nodiflora (L.) Greene	*Lamiaceae*				91, 214
Phyllanthus sepialis Muell Arg.	*Euphorbiaceae*			Do'apisemo	128
Plectranthus barbatus Benth.	*Lamiaceae*	Dare		Dhibodhi	8
Plectranthus defoliatus Hochst. ex Benth.	*Lamiaceae*	Dare			49
Pluchea ovalis DC.	*Asteraceae*			Iremacho	205
Premna recinosa Schauer.	*Verbenaceae*	Hetsero	Hetsero		271
Pseudarthria hookeri Wight & Arn.	*Fabaceae*	Shumhube		Qurillibo	181
Psydrax schimperiana Bridson	*Rubiaceae*	Selle			248
Pupalia lappacea (L.) Juss.	*Amaranthaceae*				66
Rhoicissus tridentata (L.) Willd & Drumm	*Vitaceae*			Dhodhe	173
Rhus glutinosa A. Rich.	*Anacardiaceae*			Tsitseno	142
Rhus natalensis Krauss.	*Anacardiaceae*	Tsakke		Qkedhe	130
Rhus quartiniana A. Rich.	*Anacardiaceae*	Kupure			237
Rhus ruspolii Engl.	*Anacardiaceae*			Zergee	177
Rhus vulgaris Meikle	*Anacardiaceae*	Mangille			279

Scientific Name	*Family*	Benna Name (B.)	Tsemako Name	Zeyise Name (Zy.)	Col. No.
Rhynchosia resinosa (A. Rich.) Bak.	*Fabaceae*				11
Salvadora perisca L.	*Salvadoraceae*		Ee'akko		252
Sansevieria abyssinica N. E. Br.	*Agavaceae*	Qoserko		Suga	337
Sansevieria ehrenbergii Schw. ex Back.	*Agavaceae*	Alge	Alge	Suga	338
Sarcostemma viminale (L.) R. Br.	*Asclepidiaceae*		Gojjo	Matse	139, 233
Satureja abysinica (Benth.) Briq.	*Lamiaceae*				26
Satureja Punctata (Benth.) Briq.	*Lamiaceae*		Gemuri		285
Scherebera alata (Hochst.) Welw.	*Oleaceae*	Zabo			180
Sclerocarya birrea (A. Rich.) Hochst.	*Anacardiaceae*			Bollo	190
Secamone parviflora (Oliv.) Bullock	*Asclepiadaceae*				300
Selaginella phillipsiana Alston	*Selaginellaceae*				340
Senecio hadiensis Forssk.	*Asteraceae*	Shesha			275
Senna septemtrionalis Irwin & Barneby	*Fabaceae*				65
Senna singueana (Del.) Lock	*Fabaceae*	Zinzeqeli			*5221
Sesbania goetzei Harms.	*Fabaceae*			Shoshottoo	216
Setaria incrassata (Hochst.) Hack.	*Poaceae*			Ayish	106
Solanum incanum L.	*Solanaceae*	Gerenti		Bulo	34
Solanum panduriform	*Solanaceae*			Gazze bulo	131
Solanum somalense Franch.	*Solanaceae*		Cummo		55
Sporobolus pyramidalis P. Beauv.	*Poaceae*				298
Sporobolus consimilis Fresen.	*Poaceae*			Tsophe	134
Sporobolus ioclados (Trin) Nees	*Poaceae*	Gichela		Hoshe	23

Scientific Name	*Family*	Benna Name (B.)	Tsemako Name	Zeyise Name (Zy.)	Col. No.
Steganotaenia aralicea Hochst.	*Umbelliferae/Apiaceae* /				291
Sterculia africana (Lour.) Fiori	*Sterculiaceae*	Qeytso	Qura'e	Tseqqa	200
Stereospermum Kunthianum Cham.	*Bignoniaceae*				170, 314
Strychnos spinosa Lam.	*Loganiaceae*				264
Tagetus minuta L.	*Asteraceae*			Sorase	21
Tamarindus indica L.	*Fabaceae*	Roqa	Ruqe'e	Yepho	117, 245
Tapinanthus globiferus (A. Rich.) V. Tiegh	*Loranthaceae*				294
Tarenna graveoless Bremek.	*Rubiaceae*	Shedo (Serkule)	Shedo		231, 297
Terminalia brownii Fres.	*Combretaceae*	Ara		Galunda	194
Terminalia laxiflora Engl. ex Diels	*Combretaceae*				162
Themeda triandra Forssk.	*Poaceae*			Gashokirja (Horille)	138
Thephrosia elata Defl.	*Fabaceae*				185
Tragia abortiva M.Gilbert	*Euphorbiaceae*	Ususu			17
Triumfetta flavescens Hochst.	*Tiliaceae*		Lengekko		53
Triumfetta rhomboidea Jacq.	*Tiliaceae*			Kemshulla	218
Typha angustifolia L.	*Thyphaceae*				90
Vernonia karaguensis Oliv.	*Asteraceae*	Chebbo (Tuti)		Filfanto	111, 269
Vernonia myriantha Hook f.	*Asteraceae*			Gora	212
Vigna membranacea (L.) A. Rich.	*Fabaceae*			Shabba	222
Viscum tuberculatum A. Rich.	*Viscaceae*				223
Withania somnifera (L.) Dunal.	*Solanaceae*			Dhemitte	215

Scientific Name	*Family*	Benna Name (B.)	Tsemako Name	Zeyise Name (Zy.)	Col. No.
Ximenia americana L.	*Olacaceae*			Limmo	119
Ximenia caffra Sond.	*Olacaceae*	Moqola		Dhekkina	293
Zanthoxylum chalybeum Engl.	*Rutaceae*	Gedda'e		Gedda	118,267,302
Zizyphus mucronata Willd.	*Rhamnaceae*	Anshela		Shafa	149

*-Sebsebe D. and Ensermu K. collections'.

Appendix 2 Vegetation data collected from Key Afer-Shala Luqa and Southwest of Lake Chamo. The species list is given here in the collection number with the sample stands (quadrats) in which it occurs. For the scientific name & vernacular names see appendix 1b. T-tree, S-seedling, Sh-shrub.

Col.No.	Sample stand (Quadrat) & % cover abundance values (numbers in bracket)
1, 151	1(50), 2(5), 3(1), 11(1), 14(5), 19(1), 20(15), 26(40), 27(40), 28(15), 29(15), 31(15), 32(15), 33(15), 39(5), 42(5), 45(50), 50(1), 51(40), 52(40), 56(5), 58(15), 59(10), 65(10), 66(1) & 68(5).
101	16(1).
102	14(1).
103	3(1), 11(1), 13(1) & 14(1).
104	7(1).
106	3(15), 10(1), 11(5), 12(10), 13(45) & 14(30).
107	7(1), 8(1), 10(1), 49(1) & 64(1).
11	26(1), 48(5), 49(1) & 64(1).
110	43(1).
111, 269	7(1), 8(1), 9(5), 10(5), 11(1), 46(5), 48(1), 49(1), 68(1), 69(1) & 70(1).
114(S)	1(5), 2(3), 7(4), 9(3), 11(5), 12(3), 33(5), 45(7), 64(3), 69(2) & 70(3).
114(T)	1(7), 2(7), 3(2), 4(8), 5(3), 3(9), 8(3), 9(6), 10(10), 11(12), 12(10), 13(1), 20(1), 27(7), 28(9), 29(3), 30(1), 31(13), 32(5), 33(11), 43(4), 44(13), 45(16), 48(8), 49(5), 50(7), 51(4), 52(10), 64(7), 65(5), 66(2), 67(6), 68(16), 69(15) & 70(12).
115(S)	11(1), 44(3), 45(1), 52(1) & 70(2)
115(T)	5(1), 7(3), 28(2), 32(1), 43(3), 45(2), 48(6), 51(1), 52(2), 64(1), 67(1), 68(7), 69(4) & 70(3).
116, 242	1(3), 2(12), 3(3), 4(5), 5(7), 11(3), 14(8), 15(2), 20(9), 27(1), 56(6), 58(3) & 60(1).
117, 245	14(1) & 29(2).
118, 267	1(1), 2(3), 44(3), 51(2), 52(1) & 59(3).
119	1(6), 4(1), 5(6), 7(2), 12(2), 14(1), 55(1), 56(3), 58(4), 59(3), 65(1) & 67(2).
120	3(1), 6(5), 17(1), 37(1), 38(1), 25(1), 35(5), 37(5), 40(1), 46(1), 47(1), 55(5), 56(5), 57(10), 58(5), 59(1), 60(5) & 61(1).

Col.No.	Sample stand (Quadrat) & % cover abundance values (numbers in bracket)
121	3(5), 6(5), 15(1), 17(1), 22(5), 23(1), 31(1), 34(1), 35(5), 38(1), 40(1). 44(1), 47(1), 51(1), 53(5), 55(1), 57(1), 61(1) & 63(1).
122(S)	1(5).
122(T)	1(3) & 11(3).
123	2(2).
124	8(2), 14(3), 25(2), 39(6), 42(2), 50(1), 55(3), 56(3), 57(1), 58(3), 59(4) & 69(1).
125, 239	9(5), 10(5), 26(1), 28(1), 33(3), 48(1), 68(1), 69(2) & 70(1).
128	3(3).
129(S)	33(1), 68(2), 69(7) & 70(4).
129(sh)	4(7), 9(7), 10(5), 12(12), 20(3), 33(9), 48(1), 67(1), 68(6), 69(2) & 70(8).
130	3(1), 14(5), 19(6), 26(1), 44(1), 45(1), 55(8), 56(3), 58(3), 65(3), 60(2), 67(1), 69(1) & 70(2).
131	3(1).
133	3(1).
134	6(1).
135	3(1).
135	26(1), 61(5) & 66(1).
137	6(5).
138	5(1), 7(5), 9(1) & 12(20).
139	4(1). 21(1), 42(1), & 46(1).
140, 292	4(2), 50(1) & 63(1).
142	1(9), 3(3), 5(5), 9(1), 11(2), 12(1), 13(4), 19(6), & 64(5).
144	6(1). 11(1), 14(5), 15(5), 17(1), 20(1), 26(1), 29(5), 44(1), 53(1), 56(1) & 61(1).
145	1(4), 2(2), 4(4), 5(6), 9(1), 11(3) & 12(1).
146	1(1).
149	4(2), 20(1) & 60(1).
155	1(6), 6(9), 12(1), 20(1), 41(1), 44(3), 51(1), 53(3), 55(18), 56(3), 57(3), 58(18), 60(19), 61(32) & 65(1).
156(S)	9(3).
156(T)	9(1).
157	10(1), 11(1), 48(1), 49(5) & 64(1).
158	12(1) & 26(1).
16	64(19.

Col.No.	Sample stand (Quadrat) & % cover abundance values (numbers in bracket)
160	10(1) & 64(1).
162	10(1).
163, 288	10(1) & 49(8).
164	10(1).
165	10(5), 48(1), 49(1) & 64(1).
166	10(1) & 11(1).
17	27(1), 30(1), 42(1), 68(1) & 69(1).
170, 314	11(1).
171	10(1).
173	9(1), 43(1), 48(1) & 49(1).
175	9(1).
177	9(8), 10(9), 11(8) & 12(2).
178, 266	7(1), 9(1), 12(1), 49(1) & 64(1).
179	9(5).
180	43(1).
181	9(1), 10(1), 48(1) & 64(1).
184, 289	7(4), 49(7) & 64(10).
185	11(5), 12(10), 48(15) & 49(15).
189, 277	8(7), 10(2), 12(4), 26(1), 27(1), 44(1), 45(1), 46(1), 48(2), 50(1), 51(1), 52(1), 57(1), 65(1), 67(1) & 69(2).
190	8(1), 59(5), 65(2), 66(1) & 67(1).
194(S)	1(1), 12(1) & 45(1).
194(T)	1(4), 2(5), 4(7), 5(6), 9(1), 10(1), 11(3), 12(2), 13(2), 14(1), 19(3), 28(2), 30(1), 31(1), 32(1), 43(1), 44(1), 45(4), 48(1), 50(3), 51(3), 52(1), 58(1), 59(4), 67(1), 68(2) & 70(1).
195(S)	1(2), 27(1), 40(2), 44(2), 59(2) & 769(3).
195(T)	1(8), 2(2), 4(4), 5(7), 12(3), 19(6), 26(1), 27(2), 33(1), 50(1), 55(1), 56(5), 58(4), 59(5), 60(3), 62(4), 63(2), 65(2), 67(1), 68(2) & 70(1).
196, 197(S)	5(3) & 30(1).
196, 197(T)	3(1), 30(1), 31(1), 33(1), 56(1), 57(1), 59(3) & 61(1).
199	7(2).
2	26(1), 27(1) & 31(1).

Col.No.	Sample stand (Quadrat) & % cover abundance values (numbers in bracket)
20,152	6(15), 17(30), 19(10), 40(5), 41(5), 42(1), 47(1), 50(1), 51(1), 53(5), 55(10), 56(1), 57(5), 58(1), 59(1), 60(5), 61((5), 65(5), 66(1), 67(5), 68(1) & 70(1).
200	19(1), 38(1), 40(2), 46(3), 47(1) & 60(1).
201	71(1).
202	18(12).
203	19(1), 21(1), 24(1), 25(5), 27(1), 30(10), 31(1), 33(1), 35(10), 36(1), 37(1), 38(5), 40(5), 41(1), 42(1), 46(5), 47(1), 53(1), 60(1), 61(5), 66(1), 67(1), 68(1) & 70(1).
205	15(1) & 16(1).
206(S)	15(1).
206(T)	15(2) & 66(1).
207 (T)	20(7), 27(3) & 45(1).
207(S)	20(4).
208	16(5).
209	16(1).
21	1(5) & 3(1).
210	16(5)
211	16(1)
212	16(1).
213	16(1).
215	16(1).
216	16(18) & 18(14)
218	6(5), 16(1) & 68(1).
219	16(1).
22	1(5), 2(5), 4(5), 9(1), 17(1) & 42(5).
220	16(1).
222	36(1).
223	20(1).
224	20(1).
225	1(10), 2(3), 4(7), 5(4), 6(3), 10(3), 19(7), 20(3) & 26(3).
23	14(5), 26(5), 27(20), 28(15), 30(5), 31(10), 32(15), 33(5), 44(5), 45(1), 48(1), 49(1), 65(1), 67(5) & 69(15).
230	20(1), 21(1), 22(1), 35(5), 55(1), 60(1), 61(5) & 62(1).
231, 297	21(3), 22(4), 25(1), 37(2), 38(1), 41(1), 42(4), 46(3), 60(1) & 61(5).
232, 270	21(1) & 46(1).

Col.No.	Sample stand (Quadrat) & % cover abundance values (numbers in bracket)
234(S)	21(1), 40(1) & 42(1).
234(T)	21(3), 22(3), 23(1), 25(3), 37(5), 40(1), 41(8) & 42(2).
235	21(1), 37(1), 40(1) & 46(2).
236, 312	46(1) & 62(1).
237	26(1), 28(2) & 31(1).
238	26(1).
24	4(1), 19(5), 20(1), 21(1), 25(1), 29(10), 31(1), 32(10), 33(5), 35(10), 37(5), 55(1), 56(1), 57(5), 58(1), 59(1), 60(1), 65(1), 66(30) & 67(10).
241, 106	27(1) & 28(1).
243	28(1), 30(1), 33(5), 51(1), 66(1) & 67(1).
245	26(1), 45(2) & 64(1).
246	42(5), 44(3) & 50(2).
247	20(1), 26(1), & 29(4).
248	30(2) & 37(2).
250	67(5) & 68(1).
251, 317	22(1), 24(4), 34(5), 35(6), 36(1), 40(1) & 62(1).
252	36(1), 56(1), 62(1) & 63(1).
253	36(1) & 37(2).
254	37(3) & 42(1).
255(S)	15(6), 25(2), 36(2), 59(2) & 60(1).
255(T)	6(3), 15(23), 17(11), 24(2), 25(4), 30(3), 36(9), 39(1), 42(3), 46(1), 53(2), 56(1), 66(3), 70(1) & 71(19).
258, 273	39(1) & 46(1).
259	40(1).
26	65(1) & 68(1).
260	6(8), 19(9), 61(4) & 66(1).
262	42(1).
264	43(2).
271	5(12), 6(3), 7(5), 21(1), 22(2), 25(10), 26(3) & 30(6).
272	21(1), 24(1), 30(1), 35(2), 46(2) &47(1).
274	48(1).
275	48(1) & 49(1).
279	48(1) & 49(3).
28, 217	15(1), 16(1), 17(10), 29(5), 32(10), 38(1), 60(1) & 66(1).
280(S)	48(4).
280(T)	7(1).

Col.No.	Sample stand (Quadrat) & % cover abundance values (numbers in bracket)
282	26(1) & 48(2).
283	48(1), 49(1) & 64(1).
284	48(1).
285	49(1).
286	49(2) & 64(1).
287	49(1), 53(5) & 64(1).
291	49(1).
293	4(3), 17(1) & 50(1).
294	44(1), 51(1), 55(1), 60(1), 65(1) & 66(1).
295	53(8).
296	61(3), 62(7), 63(3) & 65(2).
298	19(1), 55(5), 56(1), 59(10), 60(10) & 61(5).
300	58(1).
301	55(1), 56(1), 58(1), 59(2), 60(3) & 61(4).
304	55(5), 56(1) & 58(1).
307	39(5), 40(5), 41(5), 42(5), 46(1) & 61(5).
309 (S)	38(7).
309 (T)	21(1), 23(1), 24(7), 38(17), 63(1) & 71(3).
310	23(1) & 62(1).
311, 318	17(1), 23(1), 35(3), 36(2), 40(1), 47(4), 62(1), 63(1), 65(1) & 66(1).
312	22(21), 23(7) & 56(2).
316	22(1) & 24(1).
320	56(1).
323(S)	1(2), 10(3), 13(7), 26(8), 51(4), 64(3), 65(3), 66(5), 67(2), 68(3), 69(2) & 70(1).
323(T)	2(12), 3(4), 4(13), 5(2), 7(2), 8(6), 10(4), 11(3), 12(6), 13(15), 20(7), 26(6), 27(5), 28(6), 29(4), 30(42), 31(8), 32(17), 33(8), 43(2), 48(2), 49(1), 51(2), 52(6), 64(3), 65(9), 66(21), 67(6), 68(10), 69(4) & 70(3).
324	19(1), 21(1), 37(2), 41(2), 42(1), 46(1), 55(1), 60(1) & 61(1).
326	6(14), 13(1), 19(6), 22(3), 23(2), 24(2), 34(5), 35(6), 37(3), 39(2), 40(2), 42(3), 46(3), 47(9), 55(28), 56(13), 57(29), 58(9), 59(6), 60(9), 61(9), 62(3) & 63(3).
327	22(12), 23(14), 24(9), 35(2), 62(8) & 63(8).
328	1(1), 27(1), 38(1), 39(11), 43(2), 47(39), 59(3), 65(9), 67(4), 68(3), 69(4) & 70(3).

Col.No.	Sample stand (Quadrat) & % cover abundance values (numbers in bracket)
329	34(3).
33	1(1), 6(1), 50(1), 59(1) & 65(1).
330	53(1).
331	21(5), 39(12), 41(2) & 46(5).
333(S)	68(9), 69(12) & 70(7).
333(Sh)	5(3), 29(3), 33(1), 48(8), 68(4), 69(12) & 70(7)
335	1(1).
337	6(5), 19(5), 25(1), 37(5), 38(10), 46(15) & 60(1).
338	6(10), 19(5), 21(5), 35(10), 37(5), 38(5), 46(5), 59(5) & 60(5).
339	21(5), 41(15), 42(5) & 46(5).
34	3(5), 16(5), 17(1), 20(5), 27(1), 31(1), 44(), 50() & 64(1).
340	21(5), 41(10), 42(1) & 46(5).
35	27(1), 30(1), 40(1), 53(5) & 66(1).
37	25(1).
39	8(1), 20(1), 49(1) & 66(1).
4, 18	1(5), 3(1), 4(1), 6(5), 11(1), 12(1), 14(1), 15(1), 17(10), 20(1), 25(1), 26(1), 27(5), 28(15), 29(10), 30(5), 31(5), 32(5), 33(5), 39(1), 44(1), 48(5), 49(1), 50(1), (52)1, 53(20), 55(1), 57(5), 64(5), 65(1), 66(5), 67(5), 68(1), 69(1) & 70(1):
42	46(1).
44	24(5), 49(1) & 62(1).
45	17(1).
47	38(1).
48	1(1) & 3(1).
49	37(5) & 42(1).
5	4(1), 5(50), 19(1) 20(5), 21(1), 28(10), 31(1), 33(1), 39(1), 40(1), 42(1), 50(10), 51(5), 57(5), 68(1) & 69(5).
50	20(1), 28(1), 46(1) & 61(1).
51	27(1).
5206	49(1).
5219	9(1), 10(1), 11(1) & 32(1).
5221	3(1), 7(1), 9(1), 10(1), 26(2), 27(2), 28(8), 29(1), 31(1), 32(4), 43(3), 44(4), 45(1), 52(1), 64(2), 67(2), 69(3) & 70(4).
5272	19(14), 25(3), 39(10), 41(2), 42(2), 60(28) & 61(18),
53	39(10) & 42(5).
5328(S)	1(2), 2(2), 14(1), 15(2), 18(2), 26(1), 29(2), 51(4), 52(2), 54(9) & 58(2).

Col.No.	Sample stand (Quadrat) & % cover abundance values (numbers in bracket)
5328(T)	1(2), 2(2), 3(13), 4(10), 5(9), 8(4), 14(8), 15(4), 18(9), 20(1), 26(1), 27(6), 28(1), 29(6), 30(7), 32(12), 44(3), 45(1), 50(2), 51(3), 53(1), 54(17), 57(1) & 58(5).
5361	15(1).
5422	49(3), 52(1), 64(4) & 65(1).
5428	56(1), 57(3), 59(3), 61(3) & 69(4).
5437	25(1), 29(2) & 41(5).
5439	6(2), 25(1), 30(2), 47(2), 50(1) & 59(1).
5440	46(1), 60(1), 62(7) & 63(3).
55	36(5), 47(5) & 71(5).
56	47(1).
6	1(5).
61	19(1), 29(1), 30(1), 37(5), 60(5) & 61(5).
65	38(2).
66	34(5).
67	11(1), 12(1), 30(1), 40(1), 44(1), 49(1) & 50(1).
7, 174	2(60), 4(50), 5(10), 7(50), 8(5), 9(40,), 10(50), 11(20), 12(5), 13(5), 33(5), 43(55), 45(10), 48(30), 49(30), 52(5), 64(20), 65(10), 67(5), 68(10), 69(20) & 70(25).
70	6(1), 37(5), 57(1), 59(5), 60(5) & 66(1).
76	21(1), 22(20), 23(10), 35(10), 46(5), 53(1), 62(5) & 63(1).
79	18(5).
8	1(1), 3(1), 4(1), 5(1), 6(1), 11(1), 12(1), 14(1), 26(1), 27(1), 30(40), 31(5), 43(1), 44(1), 49(1), 64(1), 69(1) & 70(1).
80	16(30).
82	17(1).
83	3(10), 6(1), 15(10), 54(20) & 57(5).
85	1(1), 2(1), 6(1), 7(1), 9(1), 12(1), 17(1), 19(1), 25(1), 34(25), 35(5), 36(10), 38(5), 39(1), 58(1), 59(1), 61(1), 65(5) & 65(1).
86, 87	3(1), 15(30), 16(10), 17(15), 25(1), 40(1) & 53(1).
90	18(30).
91, 214	16(5).
93	19(15).
95	14(1), 17(10) & 57(5).

Apendix 3 Altitude, GPS/UTM, Slope and Aspect of Sample Stands sampled from Key Afer-Shala Luqa and Southwest of Lake Chamo.

Stand No.	Altitude (m)	GPS/UTM (E;N)	Slope (%)	Aspect
1	1350	325433,645772	20	W
2	1310	324550,644621	15	W
3	1270	324121,643200	3	W
4	1350	325000,646521	20	W
5	1380	325336,647100	17	W
6	1250	326891,646811	8	E
7	1600	320333,648830	0	
8	1750	321628,647694	0	
9	1720	321304,649820	20	NW
10	1740	320561,638544	15	E
11	1560	321261,635771	8	S
12	1520	322611,634001	6	S
13	1180	325095,642050	4	SW
14	1220	324017,640511	4	NE
15	1080	330425,641506	0	
16	1080	330722,641603	0	
17	1112	330171,642330	0	
18	1100	321748,639668	0	
19	1270	325990,635196	15	E
20	1360	236347,600712	5	SW
21	680	264331,603257	25	N
22	670	260545,602175	0	
23	670	Poor GPS	0	
24	670	263947,603822	0	
25	910	254485,605259	0	
26	1360	237000,601998	0	
27	1390	239034,601112	0	
28	1420	240100,603011	5	NW
29	1380	243541,602833	0	
30	1460	244567,604788	4	W
31	1490	245001,606638	7	NW
32	1540	246321,608347	3	SE
33	1560	246382,609541	2	NW
34	640	264899,606975	0	
35	660	262566,606656	0	
36	670	263445,606421	0	
37	780	263256,602215	20	NE
38	760	259860,611727	0	
39	1280	243707,585797	28	NE
40	1070	244272,586756	0	
41	1020	253209,604793	27	NW
42	1150	250947,605682	5	E
43	1730	230211,596427	55	E
44	1400	234103,597858	0	

Stand No.	Altitude (m)	GPS/UTM (E;N)	Slope (%)	Aspect
45	1380	232026,593087	0	
46	830	256893,596899	23	N
47	960	252507,590120	0	
48	1720	248481,612983	15	E
49	1820	247408,613249	22	E
50	1530	245046,617834	15	SW
51	1400	243424,621461	3	SW
52	1380	242352,622666	4	W
53	1330	242053,623701	0	
54	1210	328783,640893	0	
55	1220	328613,643707	25	NE
56	1220	328529,643802	18	N
57	1270	327977,644302	27	E
58	1270	327936,644266	28	SW
59	1210	328256,644445	13	E
60	1300	326572,633900	16	E
61	1290	326670,633800	29	E
62	650	271564,600386	0	
63	650	273261,600166	0	
64	1900	247471,613146	18	E
65	1530	249223,609173	8	E
66	1550	249272,609167	6	E
67	1520	249210,609160	6	E
68	1590	248437,609756	8	E
69	1580	248476,609665	8	E
70	1600	248396,609760	5	S
71	680	262554,602457	0	

Sample stands (quadrats) 1-19 & 54-61 are from Southwest of Lake Chamo others are from Key Afer-Shala Luqa.
W-west, E-east; NE-north east, SW-south west, SE-south east, NW-north west, N-north, S-south

Appendix 4 Soil data collected from Key Afer-Shala Luqa and Southwest of Lake Chamo.

	Particle size Distribution			pH	Exchangeable basis		P	Soil Color	
Stand No.	%Sand	%Clay	%Silt	In water	K(in ppm)	Na(in ppm)	in ppm	Munsell Notation	Color Names
1	51.1	16.2	32.7	7.1	40.4	1.1	4.3	10YR 2.5/1	very dark gray-black
3	26.6	47.4	26	7.4	17.5	6.9	0.4	2.5YR 4/4	reddish brown
7	52.6	13.4	34	7.2	23.2	1.9	3.1	2.5YR 5/4	reddish brown
9	57.8	13.4	28.7	7.2	42.01	1.1	3.4	10YR 2.5/1	very dark gray -black
11	53.5	24.2	70.7	7.2	31.4	1.9	3.3	10YR 3/2	very dark greyish brown
12	26.6	51.4	22	6.7	36.3	1.9	0.6	2.5YR 4/4	reddish brown
13	38.6	35.4	26	7.3	37.9	2.6	0.9	10YR 3/2	very dark greyish brown
14	51.5	22.2	23.4	7.6	37.1	1.1	1.8	10YR 3/1	very dark gray
15	38.6	16.2	45.3	7.8	55.1	15.8	2.1	7.5YR 5/4	Brown
16	92.6	2.2	5.3	7.2	53.5	1.9	2.2	7.5YR 5/4	Brown
17	27.8	24.9	47.3	7.4	37.9	1.1	1.9	7.5YR 3/4	dark brown
19	64.6	16.2	19.3	7.5	22.4	0.4	0.4	10YR 2.5/1	very dark gray-black
20	54.4	30.2	15.4	7.3	31.4	0.4	0.7	2.5YR 4/4	reddish brown
21	81.8	8.2	10	7.8	25.7	0.4	3.5	5YR 5/6	Yellowish red
22	52.5	14.2	33.3	7.8	61.3	0.4	1.4	7.5YR 5/4	Brown
23	84.6	7.8	7.6	7.2	25.7	0.4	2.9	5YR 5/6	Yellowish red
24	91.8	2.2	6	7.5	12.6	0.4	2.4	10YR 6/3	pale brown
25	81.8	7.8	10.4	6.9	22.4	0.4	4.9	2.5YR 4/4	reddish brown
26	80.2	5.8	14	6.6	19.1	0.4	0.6	2.5YR 3.5/4	red-darkred
27	75.8	11.4	12.7	7	26.5	0.4	0.3	10YR 3/2	very dark greyish brown
29	76.2	9.8	14	6.3	22.4	0.3	0.7	2.5YR 4/7	Red

	Particle size Distribution			pH	Exchangeable basis		P	Soil Color	
Stand No.	%Sand	%Clay	%Silt	In water	K(in ppm)	Na(in ppm)	in ppm	Munsell Notation	Color Names
30	69.8	20.2	10	7.2	46.9	0.4	0.4	2.5YR 3/6	dark red
31	76.2	11.8	12	7.3	19.1	0.3	0.6	5YR 5/6	Yellowish red
32	75.8	11.8	35.9	7.1	24.9	0.3	0.5	2.5YR 3/6	dark red
33	23.1	50.2	26.7	7.8	38.7	4.8	1.6	10YR 4/3	Brown
34	19.5	45.8	34.7	7.6	62.4	0.4	2.4	7.5YR 4/4	Brown
35	87.5	1.8	10.7	6.9	12.6	0.2	3.9	7.5YR 5/4	Brown
37	81.5	5.8	12.7	7.8	10.2	0.2	2.8	10YR 6/3	pale brown
38	79.5	3.8	16.7	7.1	10.9	0.3	0.6	5YR 4/6	Yellowish red
39	73.8	13.4	12.7	7.6	14.2	0.2	1.5	7.5YR 5.5/4	reddish yellow-strong brown
40	87.8	3.4	8.7	7.7	14.2	0.2	2.1	7.5YR 5.5/4	reddish yellow-strong brown
41	85.8	1.4	12.7	7.3	7.7	0.2	1.1	7.5YR 5.5/4	reddish yellow-strong brown
43	79.8	9.4	10.7	6.8	10.9	0.1	0.8	7.5YR 4/6	strong brown
44	63.8	9.4	26.7	8	43.6	0.2	2.4	10YR 4/6	dark yellowish brown
45	93.8	1.4	4.7	7.5	20.8	0.2	4.2	10YR 5/6	yellowish brown
46	91.8	1.4	6.7	6.7	10.2	0.1	4.2	10YR 4.5/2	greyish brown-dark greyish brown
47	84.2	3.4	12.4	6.6	7.7	0.2	1.7	10YR 4.5/2	greyish brown-dark greyish brown
49	79.8	9.4	10.7	6.5	12.6	0.2	3.4	7.5YR 4/4	brown
50	87.8	1.4	10.7	6.7	7.7	0.2	2.7	7.5YR 4/6	strong brown
51	73.8	9.4	16.7	6.6	29.7	0.2	4.02	10YR 2.5/1	dark yellowish brown

Appendix 5 Sample stand (quadrat) and their respective net aboveground herbaceous phytomass in gm^{-2} (the values in bracket) in each site.

Site	Sample stand (quadrat) & aboveground phytomass in gm^{-2}
1	208(203.3), 209(181.2), 210(359.7), 213(170.7), 214(162), 215(132), 216(88.6),217(145.4) & 218(187.8)
2	204(521.3), 205(298.3), 206(337.3), 207(272.1), 211(592.1), 212(357.2) & 262(4739)
3	221(83.7), 222(396.6), 223(220.6), 224(418.3), 225(0), 226(475.3), 227(80), 228(375.3), 229(60.3), 230(363.2), 231(98.5), 232(121.1) & 233(132.5).
4	234(217.9), 242(277.2), 243(129.2), 244(0), 245(150.6), 258(34.2), 259(87.3), 238(72.4), 239(175.7), 240(68.6) & 241(138.8).
5	235(195), 236(187.9), 237(123.2), 246(307.9), 247(118.5), 248(167), 249(212.1), 250(199.4), 251(169.7), 252(247.7), 253(177), 254(100.8), 255(191.4), 256(122) & 257(109.4).

Site	Sample stand (quadrat) & aboveground phytomass in gm^{-2}
6	11(37), 12(137.8), 13(295), 14(133.9), 15(111.7), 16(186.7), 17(121.9), 18(184.9), 19(138.7), 20(783.7), 21(308.4), 27(170.4), 28(824.3), 29(60.2), 30(182), 31(84.2), 32(149.6), 33(250.8), 34(135.8), 35(322.6), 36(92), 37(492.1), 38(408.7), 39(47.9), 40(42.8), 41(355.9), 42(54.5), 43(58.6), 44(58.6), 45(98.3), 46(125.5), 47(284.6), 48(110.8), 49(196.2), 50(260.8), 51(78.9), 52(171.2), 53(115.5), 72(145.9) & 73(145.6).
7	1(137.9), 2(254.9), 3(52.9), 4(108.8), 5(107), 6(34.2), 7(156.6), 8(319.1), 9(387.6), 10(211.4), 22(176.1), 23(140.9), 24(504.2), 25(90), 26(178.7), 54(166.8), 55(97.2), 56(245.6), 57(93), 58(357.2), 59(57.6), 60(149), 61(145.8), 62(302.5), 63(250.4), 64(247.3), 64(247.3), 65(82.2), 66(314), 67(125.7), 68(146.5), 69(224.7), 70(60.5), 71(126.7), 157(733.1), 158(275), 188(87.3), 189(0), 190(33.1), 191(219.2), 192(330.9), 193(244.5), 194(389.5), 195(267.8), 196(189.7), 197(144.5), 198(102), 199(138.7), 200(3.2), 201(74.4), 202(3.2) & 203(48.5).
8	115(188.8), 116(58.9), 117(139.8), 118(51.8), 119(51.4), 120(0), 121(73), 159(11.5), 160(78.7), 161(247.2), 162(100.9), 163(332.1), 164(65.1), 165(718.2), 166(288), 167(125.4), 168(130.2), 169(42), 170(113.9), 171(37.6), 172(66.8), 173(64.7), 174(112.3) & 175(76.8).

Site	Sample stand (quadrat) & aboveground phytomass in gm^{-2}
9	106(52.2), 107(636.2), 111(23.1), 112(31.4), 131(55.6), 132(220.2), 133(24.5), 134(41.3), 135(178.8), 145(110.1), 146(269.5), 147(25.2), 148(0), 149(178.3), 150(66.5), 151(194.1), 152(71.3), 153(40.2), 154(127.1), 155(78.2), 156(28.5) & 181(70).
10	104(21.2), 105(24.9), 122(136.6), 123(5.2), 124(3.8), 125(7.2), 126(174.6), 127(32.9), 185(13.2), 186(18.3), 187(21.1), 113(2.9) & 114(4.6).
11	91(129.8), 92(50.5), 93(27.9), 94(20), 95(65.3), 96(33.5), 97(44.7), 98(35.9) & 184(25.2).
12	74(56.3), 75(0), 76(225.3), 77(88.8), 78(72.9), 79(0), 80(79.6), 81(12.4), 82(12.4), 83(43.8), 84(44.6), 85(83.7), 86(0), 87(62.4), 88(294.6), 89(13.3), 90(38.9), 108(106.2), 109(104.8), 111(125.1), 128(14.2), 129(76.2), 130(0), 141(1826), 142(1376), 143(0), 144(32.2), 176(0), 177(24), 178(0), 179(62.7) & 180(0).
13	136(66.6), 137(24.1), 138(47.8), 139(21.1) & 140(41.4).

Appendix 6 Pearson's product moment correlation coefficient for correlations between environmental variables

	Sand	Clay	Silt	pH	K	Na	P	Altitude	Slope
Sand	-								
Clay	-0.887	-							
Silt	-0.89	0.61	-						
pH	0.15	-0.46	-0.05	-					
K	-0.79	0.55	0.79	0.37	-				
Na	-0.66	0.42	0.86	-0.18	0.48	-			
P	-0.23	0.30	0.03	0.35	0.32	-0.22	-		
Altitude	-0.19	0.23	0.28	-0.78	-0.23	0.61	-0.64	-	
Slope	0.53	-0.38	-0.5	-0.42	-0.89	-0.25	-0.39	0.4	-