ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

Ecological Investigation on the Afroalpine Vegetation of Guna Mountain, South Gondar

MELKU MOLLA

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Ecological Investigation on the Afroalpine Vgetation of Guna Mountain, South Gondar

By
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Abstract

Ecological investigation was conducted on the afroalpine vegetation of the Guna Massif, South Gondar, Ethiopia, to characterize vegetation communities and type and extent of utilization of the area by the farming societies at lower slopes

The vegetation of the afroalpine area of Guna Mountain was studied for describing the major plant communities and relationships between vegetation and topographic, climatic and edaphic factors. Vegetation composition was studied from quadrats (10 x 10 m) while quadrat size 1 m x 1 m was used for herbaceous vegetation along an altitudinal gradient extending from 3481 m up to 4041 m. From each quadrat, species presence and absence, percent cover abundance and frequency of 56 plant species from a total of 45 quadrats were recorded. Soil samples were collected from each quadrat and were analyzed for texture, pH, conductivity and soil moisture. Association analysis was performed on the vegetation data using the program SYNTAX to identify the community types. Pearson Correlation Coefficient was applied to identify four species groups. Six major plant communities, namely: *Hypericum-Carex-Satureja* community, *Erica-Hypericum-Dipsacus* scrub community, *Festuca-Erica* complex community, *Festuca-Oestospermum* meadow community type, *Festuca-Lobelia-Thymus* community type and *Lobelia-Festuca-Helichrysum* heather community type was described. Vegetation cover and species diversity decreased with an increase in altitude. Soil moisture content also decreased with altitude. The sites occupied by the major plant communities differed significantly in their soil texture and soil moisture content

Socio-economic data were obtained through questionnaire, on site observation as well as using 1984 and 1994 population census results. Twenty informants were selected in each "Kebele" for the study using systematic random sampling. Chi-Square test and correlation analysis were used to relate mode of utilization of the natural resources (grazing, thatching and firewood) by the peasant associations adjoining Guna Massif. Grazing was the most important mode of utilization followed by thatching and firewood. Most respondents (60-70%) considered the Guna area as a very important source for thatching grass, while seven out of eight peasant associations depended on the Guna area as a source of fuel-wood.

The biomass production showed significant seasonal variations following rainfall. Peak biomass was obtained during the wet periods, June-October. It ranged from 85.1 g m^{-2} to 224.9 g m^{-2} for mixed stands (*Andropogon amethystinus* + *Festuca richardii*) and 96.1 g m^{-2} for *F. richardii* pure stand. There was relatively little growth in the dry period (October-January). The annual biomass production ranged from 112 g m^{-2} to 82 g m^{-2} for *F. richardii* and mixed stands, respectively. The biomass production of *F. richardii* stand was significantly lower than the mixed stand species.

1. BACKGROUND AND JUSTIFICATION

1.1 Scope of the Problem

The capacity of high mountain to produce food is limited by climate, soil conditions, and human impacts. Overuse caused by increasing populations usually leads to soil degradation and decreasing productivity (Grosjean and Messerli, 1988). With regard to cultivation, shorter fallow periods, the luck of alternative farming activities, and poor input supply and technology have been identified as some of the contributing factors to land degradation. Population pressure in many parts of the high mountains has forced people to intensify cultivation by drastically reducing fallow time (Mashalla, 1988). Moreover, he stated that erosion has been attributed to the mountainous topography combined with slash – and – burn practices. Furthermore, grazing has also contributed to the problem of land degradation. Cattle and sheep eat and trample down the young shoots of trees while herdsmen slash-and-burn vegetation to open up new pastures. The movement of stock also leads to the destruction of vegetation cover along their routs. With increasing grazing pressure, soil erosion has become wide spread. The rapid growth in animal numbers has resulted in a shortage of grazing land, and animals are grazed on step slops where cultivation is difficult. This has lead to soil compaction and increased run-off.

The areas, which on the average higher than 3200 meters above sea level are generally referred to as the afroalpine and sub-afroalpine (Hedberg, 1957). The lower limit of the afroalpine belt falls at about 3500 meters and sub- afroalpine areas ranges between 3200-3500 meters while the upper limit of vascular plants lies around 5000 meters (Hedberg 1964; Smith, 1987).

The character of the afroalpine climate is fundamentally governed by two geographical circumstances: the vicinity to the equator, and the high altitude above sea level. This entails, firstly, that the climate is of a diurnal type, where seasonal variations in temperature are less important than the diurnal ones. Secondly, the high level provokes low air pressure and temperature, intense radiation, high impact of ultra-violet (Hedberg, 1964). No less important to a land plant than the climate in the surrounding air is the soil in which it grows. Since all the relevant mountains except Ruwenzori are off volcanic origin, their most important bedrocks are lavas of various kinds. In most localities in the alpine belt of the high East African Mountains frost occurs at the soil surface on many or most nights of the year. Each frosty night when sufficient amount of water are available the surface layer will then become frozen to a depth of a few centimeters. The alteration between freezing and thawing causes for the formation of solifluction (Hedberg, 1964; Smith, 1987). Owing to the frequent and violent movements in their surface layer most afroalpine frost pattern soils seem to be difficult or impossible to colonize for ordinary plant seedlings.

The afroalpine areas are found on mountain slopes and tops of highest mountains on the country. The highest peak in Ethiopia is Ras Dashen where an alpine climate near 0°c, persists all year round, sometimes even with a snow cover lasting a couple of days (Hurni and Ludi, 1998). Ethiopia has the largest afroalpine habitats in Africa (Yalden, 1983) and dry lowland savannas and deserts surround these highland areas. According to Rundel (1994), further north, the Ethiopian Highlands present a broad plateau above 2000 meters elevation with several chains extending above 3000 meters. A number of

isolated peaks exceed 4000 m, with the high point at Ras Dashan in northern Ethiopia. Further, Bale, Chilalo, Choke, Mt. Abune Yoseph, Guna massif, Mt Gughe and Guassa area at Menz are the afroalpine and sub-afroalpine areas of the country (Simon Shibru, 1999). The landscapes together with ecological features in Ethiopia are responsible for its richness in both fauna and flora. This is due to great variety in topography and environmental conditions (Demel Teketay, 1994; Zerihun Woldu, 1999) making the country an important center of diversity and endemism. However, Ethiopia's natural vegetation has also been severely affected by agricultural activates for at least five thousand years and wide spread deforestation has probably taken place around 2500 years from now (WCMC, 1992; Lind and Marrison, 1994). Most of Ethiopia's highlands are believed to have been covered with dense forests in the past. The extent to which the highlands of Ethiopia were once forested is evidently indicated by the numerous isolated and mature forest trees or patches of forest as woodlands of approximately the same species composition as in the remaining areas with closed forest (Friis, 1986; Friis and Mesfin Tadese, 1990) as well as old trees found in many churchyards.

The forest cover of the country has been on decline in the last decades. According to Hedberg (1979) the reduction was estimated to be 16 percent in 1950s to 4 percent in 1970s. Report by the EFAP (1994) indicates that the forest cover was reduced to 2.7 percent in 1989 and less than 2.3 percent in 1990. One reason for the decline of the forest is attributed to energy requirement. About 94 percent of the energy requirement of the country relies on biomass alone (Haile Leul Tebicke, 2002) of which, trees and shrubs contribute the largest proportion. It is also stated that most of the existing forest

patches in Ethiopia are in a secondary state of development (Friis and Mesfin Tadesse, 1990; Tamrat Bekele, 1993). According to Landon (1996) the area of closed forest cleared annually in Ethiopia was about 10,000 hectares. But, recent estimate indicates that between 160,000 and 200,000 hectares are destroyed and natural vegetation is cleared annually (Konemund *et al.*, 2002). If this trend continuous for the next few years the only remaining high forest would be found scattered in inaccessible areas, like high mountains and along the ridges and rivers will disappear (EFAP, 1994). Michelsen *et al.* (1993), Tamrat Bekele (1993), and Yonas Yemshaw (2002) also indicated that these small patches of forests in the country are the most endangered of the forests, which could be wiped out in the near future if deforestation trend remains unchanged. These situations become more sever in the fragile environments, high mountains. Due to the increasing population pressure there are frequent encroachments by man that result in widespread destruction of wildlife and their habitats. Friis and Sebsebe Demissew (2001) further noted that intensive human pressures on the mountains is probably one of the major reasons for the discrepancies among the results or interpretations of the vegetation types by different authors. Hence, afroalpine and sub-afroalpine areas consists a fragile environment in nature. They are relatively sloppy, frosty, snow, low temperature and pressure as well as solifluction have been a major components of the ecosystem. Thus, enhanced degradation, low productivity as well as low bio-diversity (Tewelde Brhan G/Egziabher, 1986).

Comparatively, there are more floristic and faunal studies from the afroalpine and sub-afroalpine ecosystems of Semen and Bale Mountains than from the same ecosystems

of other afroalpine and sub-afroalpine areas such as Abune Yoseph, Chocke and Guna massif, etc,. In a series of publications Hedberg (1962, 1964, 1975, 1986 and 1992) made important analyses on the vegetation and ecology of afroalpine regions in Ethiopia. Besides, attempts have been made to describe vegetation types in the country. Some authors such as Van Breitenbach (1963), Beals (1969), Wilson (1977), Friis *et al.* (1992), Bonnefille *et al.* (1993), Putt and Price (1999), Zerihun Woldu (1999), Friis and Sebsebe Demissew (2001) have attempted to describe vegetation type and propose conservation measures. Moreover, Hailu Sharew (1982), Lisanework Nigatu (1987), Tamrat Bekele (1993), Teshome Sormesa (1997), Kumilachew Yeshitla (1997), Sebsebe Demissew (1998), Simon Shibru (1999), Yosef Assefa (2001), Tesfaye Awas *et al.* (2001), Desalegn Wana (2002), and Mekonnen Biru (2003) have tried to study some of the forest patches found in different parts of the country. Nevertheless, the Guna Massif is among the least studied parts of the country in terms of its vegetation wild life as well as its water potentials. However, it is clear that any plausible conservation or management strategy needs prior ecological investigation of the area. A study on ecology related to vegetation composition, environmental factors, socio-economic system and extent of grazing is expected to contribute on this line. The present study stems from this understanding. The study aims to characterize the community types, the physical and chemical properties of the soil, socio-economic situation of the area, and biomass production of the major grasses species in the afroalpine region of the Guna Mountain.

1.2. Objectives of the Study

This study addresses the following general and specific objectives:

1.2.1. General Objective

The general objective of the paper is to describe

- The afroalpine of Guna Massif in relation to vegetation,
- Socio-economic status of the area, and
- Grasses biomass production.

1.2.2. Specific Objectives

- To describe vegetation types and other essential characteristics of plant communities
- To correlate environmental factors including soil condition with present physiognomy and structure of afroalpine species.
- To relate extent and mode of utilization of the natural resources of the area by the local population of the adjoining areas.
- To assess primary production based on grasses biomass value.

2. LITERATURE REVIEW

A number of authors have attempted to define vegetation ecology and vegetation. Among these Polunin (1960), Greig-Smith (1964), Mueller-Dombois and Ellenberg (1974), Barber (1984), Taylor (1984), Forman and Godran (1986), Noy-Meir and Van der Maarel (1987) and Crawley (1997) are the major ones. These authors viewed vegetation ecology as the study of plant communities or vegetation and the subject matter, which is vegetation, is viewed as the entire plant communities consisting of many species. Functionally, vegetation is an organized and an integrated whole than the individual species, and therefore, possesses properties, which are not necessarily found in the species themselves. A plant community denotes associations of plants occurring in a particular locality and dominated by one or more prominent species in a given time and space (Begon *et al.*, 1996; Ricklefts, 1997). Regarding the structure of communities two different views have been presented in the past. These are the Clementesian view, which consider plant communities as discrete units and Galeasonian view that regarded plant communities as continuous entities (Lewis and Tayler, 1979; Chapin and Whiteman, 1988). But recently Collins *et al.* (1993) and Pearcy *et al.* (1994) proposed a hierarchical continuum concept of plant community, which reconcile the two views. These community concepts are briefly summarized below

2.1. Cluster Analysis (classification)

Cluster analysis or classification which originated from considerations of the community unit theory, seeks to divide the stands in to groups of high internal similarity with respect to their species. The history of the schools of ecology and techniques aimed at identifying the community units implied in the community unit theory have been reviewed by Whittaker (1962) and Fitzpatrick (1986). In the discrete community concept (community unit theory), the distinctive vegetation of each area represents a distinct community, which is separated by sharp vegetational transition from other communities (Ricklefts, 1997). Discontinuities over the continuous environment pattern are an important feature of discrete communities (Roberts, 1987; Stiling, 1996).

Classification methods could be non-hierarchical or hierarchical. Non-hierarchical clustering techniques partition samples into a number of clusters. The clusters are defined separately and the links between them have the form of a network rather than a tree (Pielou, 1984; Lovett, 1996). In hierarchical methods, on the other hand, the emphasis is on the extraction of groups at successive levels, i.e. classes at any level are sub-classes of a class at higher level and permit the construction of a tree diagram or dendrogram to show the sequence through which the division or unions of the groups were made.

Hierarchical classification methods are of various types, agglomerative or divisive; and monothetic or polythetic types. Detailed accounts of these methods are given by Whittaker (1962), Shimwell (1971), Mueller-Dombois and Ellenberg (1974), Hill *et al.* (1975), Westhoff and Maarel (1978), Greig-Smith (1980,1983), Gauch and Whittaker

(1981), Wildi and Orloci (1989), Lagonegro and Feoli (1984), Barry (1992), Dingby and Kempton (1994), and Gabelnick *et al.* (1997).

Agglomerative classificatory strategies start from individual stands. Those stands having maximum similarity are fused first and keep on combining such units until all individuals are eventually united in a single population .The divisive methods, however, start from the whole set of stands and keep on dividing successively into smaller groups, each group being examined independently for further possible division. The former increases heterogeneity as the union proceeds up ward, while the latter increases homogeneity as the division proceeds downwards (Wiliams and Lambert, 1961; Palmer and Dixon, 1990; Balmford *et al.,*1998).

Monothetic classification methods identify groups based on a single attribute, i.e. the sole criterion for assigning quadrats to be a subclass of a quadrat's population is the presence or absence of a single species. On the other hand, polythetic classificatory techniques partition samples based on more than one attribute. These methods are not wasteful of information like monothetic. The theoretical advantage of polythetic systems is that the classification obtained is usually more stable and by its nature more informative (Lambert and Dale, 1964; Lundgreen, 1971; Thompson and Troech 1977; Lewis and Taylor, 1979). Polythetic methods can be divisive or agglomerative types while monothetic methods only are divisive. Detailed treatments of such systems are given by Hill *et al.* (1975), Gauch (1982), Pielou (1984) and Landon (1996).

Polythetic agglomerative systems involve two steps to construct a complete hierarchy (Gauch, 1982; Dingby and Kempton, 1994). In the first step, from the sample by species data matrix one computes a sample-by-sample dissimilarity matrix. The second step is

an agglomeration procedure which is applied successively to build up a hierarchy of increasingly large clusters. At any step of agglomeration the system fuses individuals or groups of individuals, which are most similar.

There are various methods of clustering in agglomerative classification. Detailed accounts of these methods are given by Pritchard and Anderson (1971), Gauch (1982) and Greig-Smith (1983). The difference between the methods is in the way of defining distance (dissimilarity) of a sample to a given cluster to perform agglomeration. The methods which are used in this study were average linkage-clustering technique, which was hierarchical, polythetic and agglomerative.

2.2. Gradient Analysis (Ordination)

Ordination does not have distinct groups, which can be classified; instead it shows the interrelationship among species that are believed to be controlled by environmental gradient (Kershaw, 1973). In ordination, communities with most similar attributes, for instance, species composition and relative abundance will appear close together. Whereas, communities that differ greatly in the relative importance of similarity sets of species, or that possess quite different species appear for apart (Begon *et al.*, 1996). Regarding its final out put ordination allow community to be arranged on graph (Lambert and Dale, 1964).

Ordination is an arrangement of communities; species or environments in sequence which is hoped to reveal maximum information about the relationships among them and which will also reveal such classes as may exist (McIntosh, 1967). Ordination aims at representing the individuality of each stand. As opposed to the use of classification in describing discrete plant communities, ordination techniques have evolved for relating continuously variable communities. Ordination enables to obtain information on both continuity and discontinuity of the data studied as well as to recognize the number of possible clusters and their shapes. According to Digby (1987), nowadays, the term is used more generally and refers to an ordering number of dimensions that approximates some pattern of response of the set of objects.

The success of ordination method depends on the use of appropriate variety of environmental variables (Begon *et al.*, 1996). It provided some hypothesis to be tested about the relationships between community composition and environmental factors (Chapman and Reiss, 1994). Results obtained by ordination emphasize the occurrence of predictable association of species under particular set of environmental variables and their common trend, which are most important in sorting out a group (Begon *et al.*, 1996).

2.3 Species Diversity

Species diversity implies the number of species present in a given area (Mclean and Ivimex-Cook, 1973; Kumar, 1981; Paul, 1993). Diversity depends on such processes

like ecological evolutionary, geological, and biogeochemical and the interaction between them (Huston, 1994). In view of this, geologically older areas like the tropics would have high species diversity (Ewuisie, 1980). Species diversity tends to increase also with time following an environmental disturbance. The older and more stable the community is, the more will be species diversity (Misra, 1974; Ewuisie, 1980). According to the same sources, species diversity is a very useful parameter for comparison of two communities especially to study the influence of biotic disturbances or to know the state of succession and stability in the community. Species diversity is quantified by calculating species diversity index, which is the ratio between the number of species and importance value and number of biomass or productivity of the individuals (Misra, 1974). In mountainous ecosystems if there are abrupt changes in altitudes, slopes, moisture gradients, temperature, rainfall and drainage, diversity also may change abruptly with a shorter distance (Lovett, 1990; Begon *et al.*, 1996).

2.4. Socio-Economic System

Environmental degradation is understood here as the depletion of natural resources such as vegetation, soil, bio-diversity and water to the level that it may cause significant stress upon society through the physical and social constraints it exerts on productive options available (Feoli *et al.*, 2001). Environmental degradation may induce changes in settlement patterns, disrupt established norms of social relations, accelerate the depletion of productivity (Carl, 1992). A long history of land clearing and sedentary agriculture has changed the vegetation cover and degraded the environment on the

Ethiopian highlands (Feoli *et al.*, 2001). Further, the scale of human induced land degradation is very high in northern Ethiopia. However, there are only a few studies of land degradation and socio-economic survey in Ethiopian highlands which provide an integrated assessment of the driving forces and consequences. Some of the studies were made by Barber *et al.* (1987), Young and Giese (1990), Tewolde Berhan Gebre Egziabher (1991), Feoli *et al.* (2001), and Zelalem Tefera (2001). Due to the increasing population pressure there are frequent encroachments by man that result in widespread destruction of wildlife and their habitats. Friis and Sebsebe Demissew (2001) further noted that intensive human pressures on the mountains is probably one of the major reasons for the discrepancies between the maps, and different interpretations of the vegetation types by the different authors.

Similar to the other environmental factors mentioned above, soils of many of the Ethiopian alpine areas are little studied. Hurni (1986) and Menasie Gashaw and Masresha Fetene (1996) made soil analysis from the alpine and sub-afroalpine belt of the Semen and Bale Mountains. As of the various studies soils of alpine eco-systems are of volcanic origin and the composition of the bedrocks are lavas of various kinds, basalts, agglomerates and tufts, etc. The soils of upper alpine belts are comparatively porous with low water holding capacity, but offering good drainage. The immediate cause of the crisis was the deterioration of soil and as a consequence, reduction in agricultural productivity. Associated causes were lack of biomass resources and disruption of the hydrological cycle (Tewolde Berhan Gebre Egziabher, 1986). Soil erosion in Ethiopia is accelerated by steep slopes. Since the climate is tropical the

erosivity of rainfall is high. This high rate of soil erosion occurs because of deforestation and overgrazing have exposed the soils. Most of the highlands were originally covered by coniferous and broad-leaved forests (Ethiopian Mapping Authority 1988, Map 10). Forests with a biomass of 250 m^3/ha or more are now believed to cover only about 4.6 percent of the area of the country (Kothari, 1997). As a result, Hurni (1988) estimates soil loss on slopes at 42 t/ha/yr on cropland and as high as 70 t/ha/yr on recently unproductive land.

Higher up the mountains, in the afroalpine and sub-afroalpine proper, the soil temperature is very low, being continually near freezing. The most important factors influencing afroalpine micro-climates are insolation and outward radiation (Hedberg, 1964). In day time the intense insolation under a clear sky causes a strong heating of the surface of the ground and the vegetation, creating a marked temperature gradient above the surface. Under an over cast night sky so much of the outgoing radiation is compensated by re-radiation from clouds that the temperature of the soil surface does not fall much below that of the air. Moreover, mineralization as well as organic matter decomposition are slow in afroalpine areas while solifluction as a formation of stone polygons and stone stripes (Hedberg, 1964; Donahue *et al.*, 1983).

Rural populations typically require various resources for their livelihoods, including food, water, fuel, pasture, fodder, medicines, materials for construction and implements and products to exchange or sell in markets (FAO, 1986; Lovtt, 1993; Kothari, 1997). Traditional societies have always met these requirements from natural resources,

renewable and non-renewable, derived in most cases from ecosystems immediately surrounding them. At least, 3000 species of plants have been used throughout history as food alone and some 21,000 species have been used for medicinal purposes (Sharma and Show, 1993; Kothari, 1997). The above authors and some other studies shown clearly that, by having protected common property resources in the alpine areas of Ethiopia, put these resources to a wide range of uses through conducting an appropriate management and conservation systems.

2.5. Grasses Biomass Production

The value of a pasture is largely determined by three factors: the quantity /biomass production/, the energy and the protein content of forages that are eaten by livestock (Soneji and Musangi, 1972; Boudet, 1975; Field, 1976). In general, both quantitative yield of forages and chemical composition are important determinants of grassland production (Soneji and Musangi, 1972). Since diet selection by large herbivores is aimed at obtaining adequate quantity and maximum quality (Senft *et al.*, 1987), it is important to understand the potential of an area to support grazers. Ben-Shahar (1994) suggested that differences in quantity and nutrient levels among the available species in different seasons could be used to indicate nutritious forage species particularly at the peak of the dry season.

One of the criteria for pastureland development planning is assessment of the carrying capacity of the community to meet the feed requirements of the animals at any point in

time and on a long-term sustained basis (Lehouerou *et al.*, 1988). Especially for a proper management of an area that is primarily maintained for its population of large herbivores, it is important to understand the availability of resources for grazing (Ridder *et al.*, 1982) Thus, biomass production is considered as an important ecological characteristic since it reflects the function as significance of grass species in a plant community. Determination of biomass production of species in different areas is a pre-requisite to identify the ecologically important grass species of the area (Theunissen, 1995). Therefore, a study on total biomass production of an area will give information on the capacity of the area since grazing animals adjust their densities in relation to grassland productivity (Mcnaghton, 1985). However, in tropical African highlands, there have been few studies of primary production and there is a lack of quantitative information on the contribution of individual species to the primary production (Kinyamario and Imbamba, 1992).

The primary determinants of the quantity and quality of pasture in East African highlands are the long and short rains which are in turn determined by the pattern of movement at a low pressure system known as the Inter-Tropical Convergence Zone (Heslu *et al.*, 1985; Boutton *et al.*, 1988a; Daniel Gumachu, 1986). However, the on set, magnitude and duration of these rains vary greatly between years and locations (Boutton *et al.*, 1988b; Veenedaal *et al.*, 1996). The amount of these two rains structure both the plant and animal components of East African highlands (Boutton *et al.*, 1988a). Thus, variation in primary production is closely linked to variation in the amount of rainfall and its distribution (Lehouerou *et al.*, 1981b). Moreover, because of the rarefied

and clean atmosphere at high level less of the incoming radiation is absorbed above the ground, so that under a clear sky the intensity of sunshine is greater than in the lowlands. Under the same conditions the relative amount of ultraviolet light is considerably higher at high altitudes than at sea level. Another important aspect of the afroalpine temperature climate is the high incidence of days with changes from frost to thaw and the reverse, they are essential for the development of solifluction (Hedberg, 1964; Smith, 1987; Rundel, 1994).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

The study was conducted at Guna massif, which is located in the north Ethiopia between latitudes $11^0$42" N and longitude 41-42^0 E. It covers approximately 25 km^2 and its altitude ranges between 3010 and 4041 meters. The area is found in eastern and western direction from Nefasmewucha and Debre Tabor towns, respectively and which about 30 kms from both directions. Moreover, the study area is found along Woreta - Woldiya road in the south direction one who takes the Golegie River as a reference point. The area is boarded to the east by Beshlo depression and to the southwest by Fogera plain area (figure 1)

3.1.2 Climate

3.1.2.1 Rainfall and Temperature

The data collected at Debre Tabor and Nefasmewcha Meteorological Stations show that the mean annual rainfall is 1068.45mm. The least rainfall occurred during November, December, January and February and maximum rainfall occurred during the months of June, July, August and September. There is only one really distinct dry season in which

there is usually no or low rainfall recordings. This extends from late December to February. Since the rainfall data for Guna Massif was not available at the site. Extrapolation from the two nearby Metrological Stations (DebreTabor and Nefasmewucha) was undertaking for the establishment of climate diagram (Figures 2 & 3).

Like the rainfall, the temperature data for the study area is extrapolated from the two meteorological stations. Thus, the average temperature data for Debre Tabor is15.6 °c whereas it is 13 °c for Nefasmewucha station (figures 2 and 3).

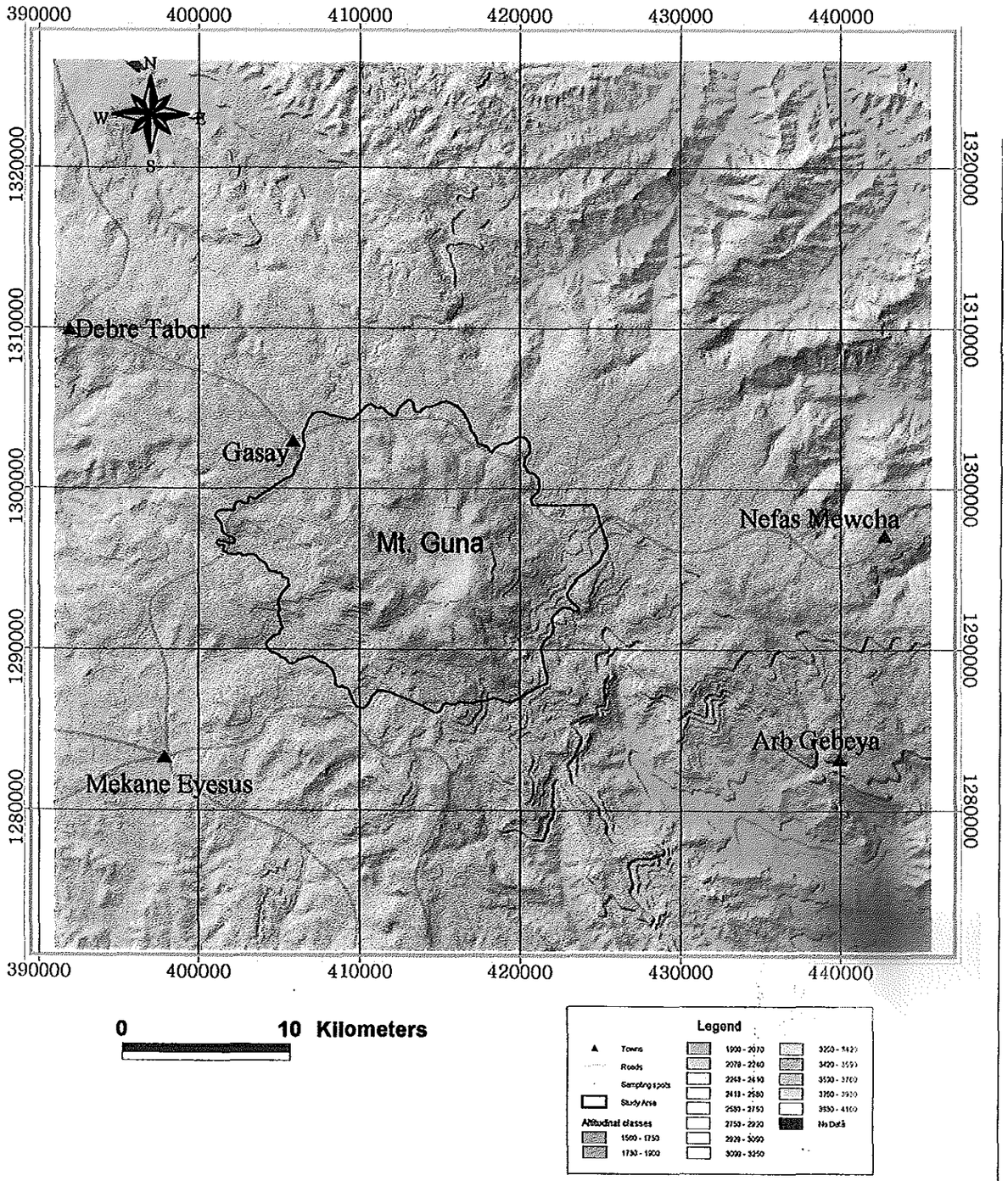

Figure 1. Digital Elevation Model of Guna Mountain and its environs

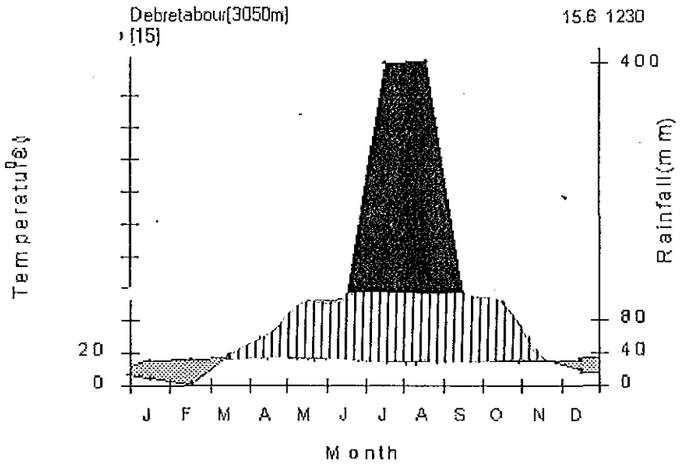

Fig. 1 Climate diagram for Debretabour meteorological station

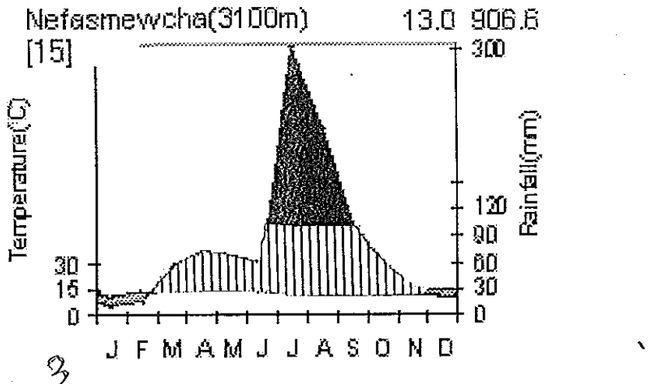

Fig.2 Climate diagram of Nefasmewcha meteorological station

3.1.3 Geology and Soils

The geology of Simien Mountains of Begemidr is the trap series (immense mass of flood basalts and other lavas) of Magdala group, compact and rarely amygdaloidal basalts, with numerous inter-bedded flows of trachyte (Mohr, 1963). According to the same source, the lavas of Simen are composed of almost entirely of porphritic basalts, where the phenocrysts are 60%. Nilsson (1935 and 1952 cited in Mohr 1963) considered the Simien Mountains including Guna to be the denuded remnants of a huge Hawaiian - type volcano, with a crater, lying at the top of a gently sloping cone of stratoid basalts. The same source further pointed out in the Simien Mountains of Beghemeder the trap series reach its maximum development, a total of at least 3000m of lavas being exposed. The present landscape of Guna and its environs is the result of volcano tectonic events and subsequent denudation processes that mainly took place after the Mesozoic time (Mohr, 1963). The weathering and erosion processes, which continuously acted in the study area, have modified the ancient relief of the area by peneplaining some of the elevated lands and creating gullies and gorges. Inselbergs that are commonly erected in the vicinity of the study area are good witnesses of this process.

The dominant soil type in Guna massif and its environs is a basaltic and residual soils, respectively. It is derived from the underlying basaltic rock through weathering process. The topography, the climate together with nature of the rock units had favored formation of thick soil cover especially on the northern extension of the study site (Mohr, 1963)

3.1.4 Population and Land Use

According to the population census of 1994 conducted by Central Statistical Office (CSA, 1995) the total rural population of South Gonder was 1, 652, 030, of which 852,582 were males and 799, 448 were females. Further, the Guna Massif adjoining Woredas' rural population was 695, 023 in which 41.2%, 36.7% and 22.1% contributed from Estie, Farta and Laygaint Woredas, respectively.

In most rural areas of these Woredas, especially Guna massif adjoining "Kebeles" barley and potato are the staple food items. However, the available farmland is limited due to long-aged traditional land management system. The continued divisions of farming land from generation to generation have gone to such an extent that most of the holdings are less than half a hectare. People don't have enough land to cultivate other food crops except few villagers living at the lower part of Guna Massif who cultivate fava beans, field peas and wheat to some extent.

Due to lack of cash crops in the area, all of the community members were involved in illegal deforestation to generate income of the family, which led to some extent loss of biodiversity. People living around Guna Massif already destroyed the vegetation 30 years ago. Moreover, to compensate the low income of the family large number of livestock was herded beyond the capacity of the available pastureland. Thus, over grazing was also a phenomenon in the study area (Personal Observation)

3.1.5 Description of the Study Grasses

***Festuca richardii* Alexeev**

According to Hedberg and Sue Edwards (1995), *F. richardii* is a perennial forming dense tussocks; culms erect up to 45 cm high, culm-sheaths inflated, leaf-blades stiff, acicular, smooth, up to 20 cm long, 0.5 mm wide. Panicale linear, up to 15 cm long, stiff with few spiculate, erect, appressed branches becoming recemose upwards. Spikelets 3-4 flowered, lanceolate, 13-15 mm long (including awn points), violet-tinged, glumes large and enveloping 3/4 as long as the spikelet, actue, 3-nerved lemmas narrowly elliptic, 7-9mm long, scaberulous above the middle, tip extended into an awn point 2.-4 (-8) mm long, anthers 1.5 -2.8 mm long, ovary glabrous or occasionally sparsely hairy.

The species is found in montane grassland and moorland, and on stony mountain tops ranging from 3800-4370m. A high mountain segregate from the *F. abyssinica* complex, whose separate specific status rests mainly on its slightly different leaf-anatomy.

***Andropogon amethystinus* Steud**

A. amethystinus is tufted perennial, sometimes with wiry rhizomes, culms erect to laxly ascending, 10-50 cm high. Leaf-blades flat, 2-3 mm wide, usually pilose, acute racemes terminal, paired, 3-8 cm, often purplish, rhachis internodes and pediceles slender, ciliate to villous, internodes linear, pedicel linear clavate. Sessile spikelet 5-8 mm long,

includes an oblong callus to 1 mm long. Lower glume narrowly elliptic, firmly membranous or papyraceous glabrous to villous, flat or slightly concave and 5-7 nerved between the lateral keels, these narrowly winged upwards or occasionally wingless; nupper glume with an awn 2-6 mm long, upper lemma bifid to the middle, its awn 9-18 mm long. Pedicelled spiklet narrowly elliptic-oblong, 4-8 mm long, lower glume with an awnlet up to 2.5 (-4) mm long, upper glume sometimes with a macro to 2 mm long. The species is abundant in upland and montane grassland, open places among *Erica* bushes and in rock crevices, often in moist situations (Hedberg and Sue Edwards, 1995).

3.2 Methods

3.2.1 Vegetation Data

A reconnaissance survey of the study area was made in August 2002 while sampling (actual data collection) was conducted in February, 2003. The vegetation of Guna Massif was studied along an altitudinal gradient ranging from 3481 m up to the summit of "Beredo Mefia" (4041 m), at 50 meters altitude interval using systematic sampling. Vegetation compositions were studied from quadrats (10 m x 10 m) while quadrat size 1 m x 1 m was used for herbaceous vegetation. From each quadrat species presence or absence and percent cover were recorded. For all species the cover-abundance values were taken following the cover-abundance scale of Braun Blanquet modified by Vandeer Maarel (1979). According to this method the cover-abundance value was

converted into 0-9 scales. A total of 45 quadrats were systematically selected and 56 plant species were recorded.

Voucher specimens were collected, pressed, dried and coded for identification at the National Herbarium, AAU. Plant specimens were identified by comparing with the previously identified specimens in the Herbarium and with reference to the published volumes of Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989, 1995; Edwards *et al.*, 1995, 1997, 2000).

Vegetation data were analyzed following Gauch (1982), Jongman *et al.* (1987) based on species abundances. Cover-abundance values were used as class labels or entities to classify vegetation data. The computer programme used to classify vegetation data was SYNTAX: Programme NCLAS Hierarchical clustering by distance optimization (Podani, 1988). Dissimilarities among the different quadrats were quantified using object group averages, product moment correlation and squared distance or dissimilarities. The different clusters were then arranged hierarchically.

Species richness is one of the widely used approaches in measuring diversity of species (Paul, 1993). Shanon and Wiener (1949) index of species diversity was used to quantify species richness.

Shannon and Wiener (1949) species diversity index is expressed as:

$(H' = -\sum_{i=1}^{k} Pi \ln Pi)$ Where, **H'=** index of species diversity derived from information statistics

Pi=the proportional abundance of the i^{th} species (ni/N)

3.2.2 Environmental Data

Soil samples were taken from a depth of 20 cm, at five points in each quadrat. Four samples were taken from each corner and one from the center in each quadrat. Composite samples, each weighing about 0.5 kg, were then taken for laboratory analysis. Samples were air dried in the laboratory and passed through a 2 mm sieve before the analysis was conducted. The soil samples were analyzed in the Ecology and Eco-physiology Laboratory at the Department of Biology, AAU. The soil tests were carried out following the methods stated in Jackson (1973), Etherington (1975), Juo (1978), Cottenie (1980), and Sahlemedhin Sertsu and Taye Bekele (2000).

Soil environmental factors including Texture, pH, Electric Conductivity, Moisture Content were determined in samples collected from all quadrats. However, NPK were not studied due to lack of proper equipment in the Eco-physiology laboratory.

Texture (particles size analysis). The texture of the soil samples was determined following Hydrometer Method of Mechanical Analysis (Juo, 1978; Sahlemedhin Sertsu and Taye Bekele, 2000). Forty gm of sodium hexametaphosphate and 10 gm of calcium carbonate used as dispersing agent along with 100 ml of distilled water were added to 51gm of 2 mm sieved soil samples. While stirring, the suspension was allowed to stand for 30 minutes. The soil suspension was stirred for 15 minutes by mechanical multi-mix machine and then transferred to one litter volume-measuring cylinder. Then the cylinder was filled with distilled water up to the line mark. This was mixed by covering the top of the cylinder with hand and inverting several times (40-50) until all

soil particles were in suspension. The first hydrometer and temperature readings were taken in 40 seconds after the cylinder was put on the table. The second hydrometer and temperature readings were taken three hours later. The percentage of various soil separates was determined by the following formulae of Juo (1978).

% sand = 100-[H_1+0.2(T_1-68)-2.0]2

% Clay=H_2+[0.2 (T_2-68-2.0]2

%Silt=100-(% Sand +% Clay), where H_1 and H_2 are first and second hydrometer readings, and T_1 and T_2 (in F^o) are first and second temperature readings, respectively. The percentage of soil separates using textural triangle was used to determine the textural classes of soil samples (Donahue *et al.*, 1983).

Soil pH- the pH of the soil was determined using a 1:1 soil-water ratio (Jackson, 1973; Juo, 1978). Twenty-five gms of soil, passed through a 2 mm sieve was mixed with 25 ml of distilled water in 50 ml beaker. The suspension was stirred occasionally and then after 30 minutes the pH was determined using Jenway pH meter (Mode 3071 EC, UK made) after standardizing with buffer solutions of pH 4 and 7.

Electric conductivity (EC)- is a measure of soluble salts. To measure soil electrical conductivity, a soil-water suspension in a ratio of 1:2.5 was prepared following Sahlemedhin Sertsu and Taye Bekele (2000). In this case soil-water suspension was made by dissolving 10 gm of soil by 25 ml of distilled water and stirred for 30 minutes

with glass rod. Then electrical conductivity was determined by using YIS model 5000 and 5100 (USA made) conductometer.

Soil moisture- air-dried soil samples were oven dried at 105 ^{0}c for 24 hours. Percentage moisture was calculated using the formula of Sahlemedhin Sertsu and Taye Bekele (2000): % moisture = wt. Of moist soil – wt. of oven dried soil / wt. Of oven dried soil *100.

One-way analysis of variance (ANOVA) was used to test for significant differences among plots in environmental values and with plant communities and Tukey test for determination of mean differences followed by multiple responses.

3.2.3. Socio-Economic Data

Socio-economic data were obtained through questionnaire, on site observation as well as 1984 and 1994 population census results. Twenty informants were selected in each "Kebele" in order to respond to the questionnaire using systematic random sampling. To determine the relation of the Guna area with respect to common resources to the users were using the statistical package SPSS 10.01, Chi-squire test as well as Pearson correlation coefficient were used to determine whether the people of the surrounding area have a relationship or not with the Guna area in terms of utilization for grazing, thatching and fire wood supply.

3.2.4 Grasses Biomass Data

At the beginning of the study, February 2003 four 6 m x 4 m quadrats were established and fenced at "Guassa" area in the eastern part of Guna Massif at 3663 m altitude. Above ground seasonal and annual biomass productions of the grass species were estimated following Singh and Yadava (1974). Each of the three quadrat was established systematically in such a way that it included mixed stands of the two dominant grass species whereas one quadrat was established in such a way that only pure stand of the individual grass species was included. Each quadrat was divided in into 24,1 m x 1 m sub-quadrats, in which 8,1 m x 1m sub- quadrats were randomly selected on each sampling occasion. At the start of the experiment, mowing was performed manually with the help of sharp sickles at 2 cm level from the ground. Portions of the sub-quadrats were mowed at four months interval (based on the rainfall distribution of the area) to estimate the seasonal and annual biomass productions of the grass species. Sampling was done in such a way that it allowed four, eight and twelve months of growth for each species. The harvested grass from each plot was packed in plastic bags and brought to Ecophysiology Laboratory, AAU for analysis. Then the samples were dried in an oven at 80 °c for 48 hours and then dry - matter was determined. The collected data were analyzed using the MINITAB statistical package version 10. Variance analysis (one way ANOVA) using Tukey's family error rate.

4. RESULTS

4.1 Description of Plant Community Types

In the 45 quadrats a total of 56 vascular plants were identified, which belonging to in 17 plant families. With regard to habit, tree like species was represented by 1 species; shrub by 2 species and the rest were represented by perennial and annual herbs. Lichens and ferns were also recorded (Appendix 1).

4.1.1 Community Types

A total of 6 community types were identified from the analysis of clustered at dissimilarity level ranges from 0.25 to 0.55, which was based on cover –abundance value of the 48 plant species. The rest 8 annual plant species were not classified since they were lately collected from the study area

Table 1 The Distribution of Community Types and their Altitudinal Range

No.	Community Types	Altitudinal Range
1	*Hypericum revoltum- Carex echinochloe-Satureja paradoxa*	3480 m-3600 m
2	*Erica arborea-Hypericum revoltum-Dipsacus pinnatifidus*	3500 m-3700 m
3	*Festuca richardii-Erica arborea-Festuca macrophylla*	3600 m-3700 m
4	*Festuca richardii-Festuca marcrophyla-Oestospermum vaillantic*	3500 m-4000 m
5	*Festuca richardi-Lobelia rhynchopetallum – Thymus shimperi*	3600 m-4000 m
6	*Lobelia rhynchopetallum-Festuca richardii–Helichrysum formossissmum*	3690 m-4040 m

Analysis of vegetation data collected from the ericaceous and afroalpine zones at Guna resulted in six major plant communities, i.e., clusters designated as 1,2,3,4,5, and 6 (Figure 4). The plant communities were named by the dominant species, which occur in each group, i.e., species with the highest values of plant cover (Table 2). A complete list of plant species is given in Appendix 1. Following is a description of the six major plant communities. The dominant species with mean values in bold were selected for community names.

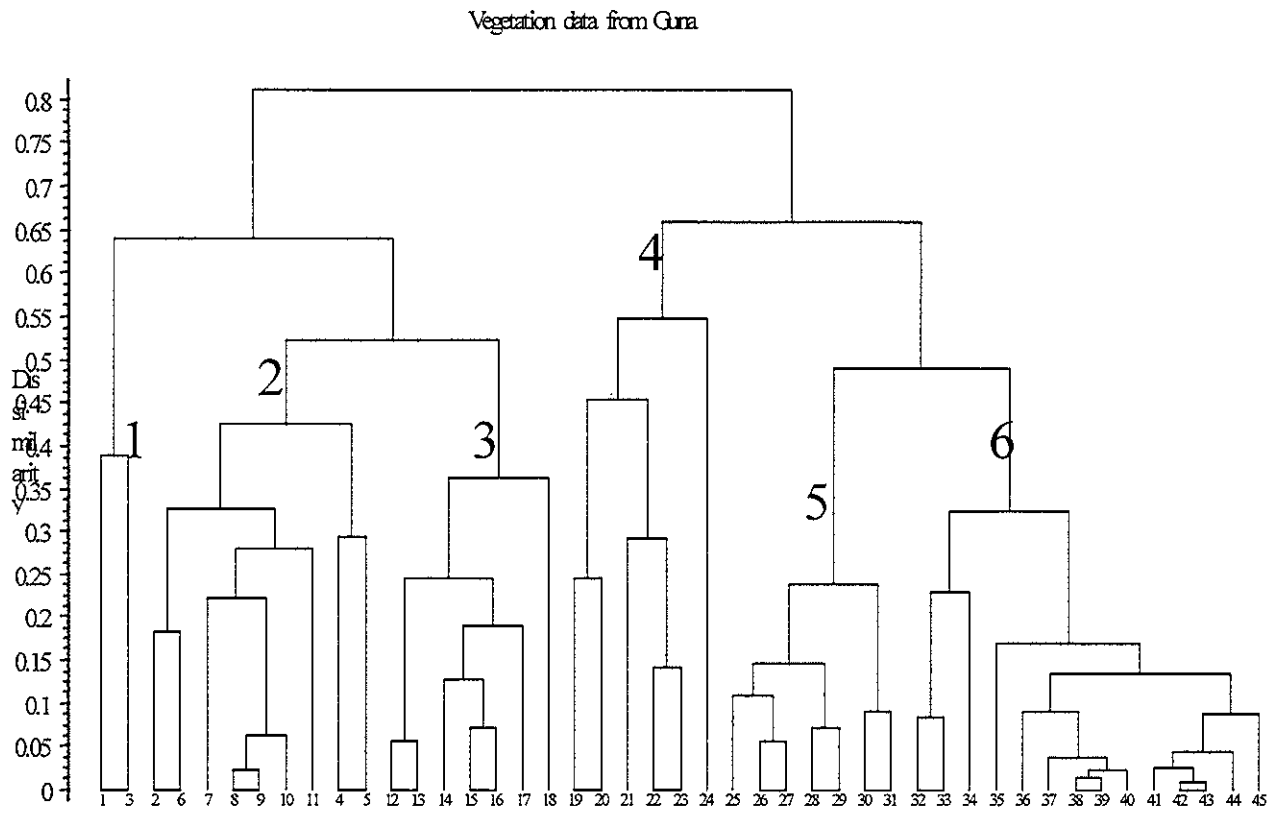

Figure 4. Dendrogram of releve's vegetation cmposition for Guna massif

1. ***Hypericum revoltum-Carex echinochloe-Satureja paradoxa* community type** (3480-3600). The dominant species in this community type based on their respective means cover-abundance value were *Hypericum revoltum* Vahl, *Carex echinochloe* Kunze, *Satureja paradoxa* (Vatke) Engel.ex Seybold, *Rumex nepalensis Spreng* and *Bulbostylis boeckeleriana* (Schweinf). This community separated from the others as a group at medium dissimilarity index (Fig. 4). Typically, this community is found at altitudes ranging from 3481 m - 3600 m. The plant group occurs in association the bush *H. revoltum* with other herbs like *S. paradoxa.* Nineteen plant species were found in this community type (Table 2), most of which were perennial herbs.

2. ***Erica arborea-Hypericum revoltum- Dipsacus pinnatifidus* community type** (3500-3700). Immediately above the tree – line, *Erica – Hypericum* community dominated the area. Many understorey species were observed in association with *Erica* and *Hypericum* bushes. These were *Ferula communis* L., *Carex conferta* Hochst.ex A.Rich, *Conyza abyssinca* Oliv. Hierm, *Carex echinochloe* Kunze, *Thymus shimperi* Ronniger, *Alchemilla abyssinica* Fresen and other herbs. Totally, thirty plant species were found in this plant community type. This community type occupied altitudes ranging from 3500 m – 3700 m.

3. ***Festuca richardii – Erica arborea – Festuca macrophylla* community type** (3600 -3700). This plant grouping was mainly dominated by *F. richardii* Alexeev

Satureja punctata	.00	1.2	2.2	1.6	2.4	7.4
Scabiosa columbaria	.00	1.2	2.4	1.5	2.0	.00
Cardus nyassanus	.00	.55	2.5	1.0	2.1	.00
Malva verticillata	.00	.55	1.1	.50	1.2	.71
Conyza spinosa	.00	.44	1.4	1.3	1.5	.00
Galium spurium	.00	.22	2.5	1.0	.57	.00
Andropogon abyssinicus	.00	.00	**3.5**	2.5	2.1	.00
Salvia merjamie	.00	.00	2.2	1.8	1.7	.00
Thymus serrulatus	.00	1.5	2.4	1.3	1.1	.00
Pentaschistis picigluma	.00	2.2	2.0	2.0	1.7	8.32
Three						
Festuca richardii	.00	1.6	**8.4**	**6.8**	**8.4**	**6.7**
Andropogon pratensis	.00	.00	2.0	**3.1**	3.5	1.6
Dichocephala chrysantthemifolia	.00	.00	.00	**4.3**	1.5	.85
Rumex abyssinica	1.5	.00	.71	2.8	1.4	.71
Dianthoseris schimperi	.00	.00	.00	1.5	1.5	.78
Oestospermum vaillanti	.00	.00	.00	**4.6**	**3.2**	1.5
Haplocarpha rueppelii	.00	.00	.00	**3.3**	2.8	1.7
Senecio ferseni	.00	.00	.71	1.3	1.7	.00
Cardus chamaecephalus	.00	.00	.28	1.6	2.5	.00
Crepis carbonaria	.00	.00	.71	1.1	2.5	.00

Four						
Helichrysum forsskhalii	1.5	1.4	1.5	1.1	.00	**4.0**
Helichrysum splendidum	1.5	1.5	1.1	1.0	.00	**4.5**
Helichrysum gofense	.00	.00	1.1	.16	1.2	1.3
Festuca macrophylla	.00	1.3	**4.2**	**5.3**	**3.2**	**6.0**
Helichrysum cymose	.00	.00	.00	2.0	2.1	**3.2**
Alchemilla cryptantha	.00	.00	.00	1.8	2.7	2.4
Cineraria abyssinica	.00	.00	.00	2.6	2.7	2.2
Haplocarpha schimperi	.00	.00	1.0	2.5	2.5	**3.7**
Helichrysum formossissmum	.00	.00	.00	.50	**4.5**	**6.6**
Lobelia rhynchopetalum	.00	.00	.00	.00	**6.7**	**6.7**

4.1.2 Diversity of Plant Communities

The distributions of the plant community types were found to be related with altitude. Shannon – Wiener diversity index values are shown on Table 3.

Table 3 **Shannon – Wiener Diversity Index**

Community	Richness	Diversity Index (H')	H'Max	Evenness H'/H'Max
1	18	2.744	2.890	0.949
2	29	3.131	3.367	0.930
3	38	3.473	3.638	0.955
4	45	3.574	3.807	0.939
5	32	3.267	3.466	0.943
6	19	2.647	2.944	0.899

Community 4 had the highest diversity index followed by communities 3,5,2,1, and 6. Species evenness shows the relative proportional abundance of a species in quadrats. Low evenness value implies the dominance of the environment by few species. Based on this, community 3 followed by community 1,4, and 2 had the highest evenness value (Table 3).

4.2 Soil Environmental Factors and Plant Communities

Table 4 Mean Values of Soil Properties in Different Plant Communities

Community Type	pH	EC (ms/cm)	Soil moisture (%)	% Sand	% Clay	% silt	Soil Type
1	5.4	0.09	33.3	71.9	5.3	22.7	Sandy loam
2	5.3	0.10	36.5	74.6	1.9	23.6	Loamy sand
3	5.2	0.10	37.3	76.5	0.10	23.4	Loamy sand
4	5.0	0.09	37.5	79.8	0.0	22.9	Loamy sand
5	4.8	0.24	37.3	80.4	0.0	22.2	Loamy sand
6	4.5	0.12	37.1	82.5	0.0	20.7	Loamy sand

Table 5 Summary of ANOVA For Soil Properties

Treatments	Source of variation	Sum of squares	df	Mean square	F	Sig
P^H	Between groups	10.049	5	2.010	21.051	.000
	Within group	14.512	152	9.547E-02		
	Total	24.561	157			
EC	Between groups	6.410E-03	5	1.282E-03	.382	.860
	Within group	.510	152	3.354E-03		
	Total	.516	157			
Soil moisture	Between groups within group	247.780	5	49.556	.372	.326
		20234.018	152	133.119		
	Total	20481.797	157			
% Sand	Between groups	1445.548	5	289.110	3.591	.004
	Within group	12236.822	152	80.505		
	Total	13628.370	157			
% Clay	Between groups	444.804	5	88.961	5.450	.000
	Within group	2481.109	152	16.323		
	Total	2925.913	157			
% Silt	Between groups	126.514	5	25.303	.486	.786
	Within group	7907.498	152	52.023		
	Total	8034.012	157			

Soil pH

The pH values ranged from 4.5 – 5.4. There was statistically significant differences among communities, at F (5,152) = 21.051, (P<0.05). The averaged soil pH values of plant group 1,2,3, and 4 were found to be medium acidic, whereas groups 5 and 6 were relatively strongly acidic (Table 4).

Electrical Conductivity (EC)

The lowest and the highest values of EC were 0.09 and 0.24ms/cm. However, ANOVA result indicated that the values of EC were not statistically significant, at F (5, 125) = 0.382, (P<0.05). Tukey's test also showed that the values of EC among communities were not significantly different (Table 4)

Soil Moisture

Soil moisture content at Guna Massif ranged from 33.3 to 37.5% (Table 4). The moisture content among communities were not significant at, F (5,152) = 0.372, (p<0.05). Moreover, when tested using Tukey's test of mean differences, among communities had also similar result. The result presented in Appendix 4 indicates that with one-meter altitude increment, the moisture content declined by 0.09 percent.

Soil Texture

1. Sand: The proportion of sand in the study area ranged between 71.9-82.5, which was statistically significant among communities, at F (5,152) = 3.591, (P<0.05)
2. Clay: The proportion of clay was the lowest that ranged from 0-5.3, which was statistically significant among communities, at F (5,152) = 5.450, (P<0.05)
3. Silt: Values were not statistically significant, at F (5,152) = 0.486, (P<0.05)

4.3 Socio-Economic Data

The dominant economic activity in Guna and its environs is farming. The size of land holding throughout the study area varies between 0.75 to 1.5 ha. per household with average holding of 1.1 ha. There is one farming season in the area corresponding to the long rainy season (Fig. 2 and 3). The highland population heavily relies on the cropping season in a given year. The dominant crops of the area were barley and polato. The single most important cereal (barley) is for subsistence. Four landraces are recognized from Guna i.e., Senef Kolo, Temej, Kokangent, Gorenge. These are cultivated in the main season.

Peasant associations, which are adjoining Guna, harvest various types of natural resources from the Guna area. Grazing was considered to be the most important followed by thatching and firewood. Most of the livestock that grazes in the Guna Massif originates from the eight peasant associations. The Guna area or locally called "Guassa" area provides a dry season refuge for the livestock of the adjacent

communities. During prolonged drought, livestock from more distant peasant associations stay in the Guna Massif in temporal pens to avoid long journeys from the homesteads on a daily basis. Peasant associations differed ($\chi 2$ = 426, df = 28,P<0.001) in how much importance they give Guna area as a source of grazing.

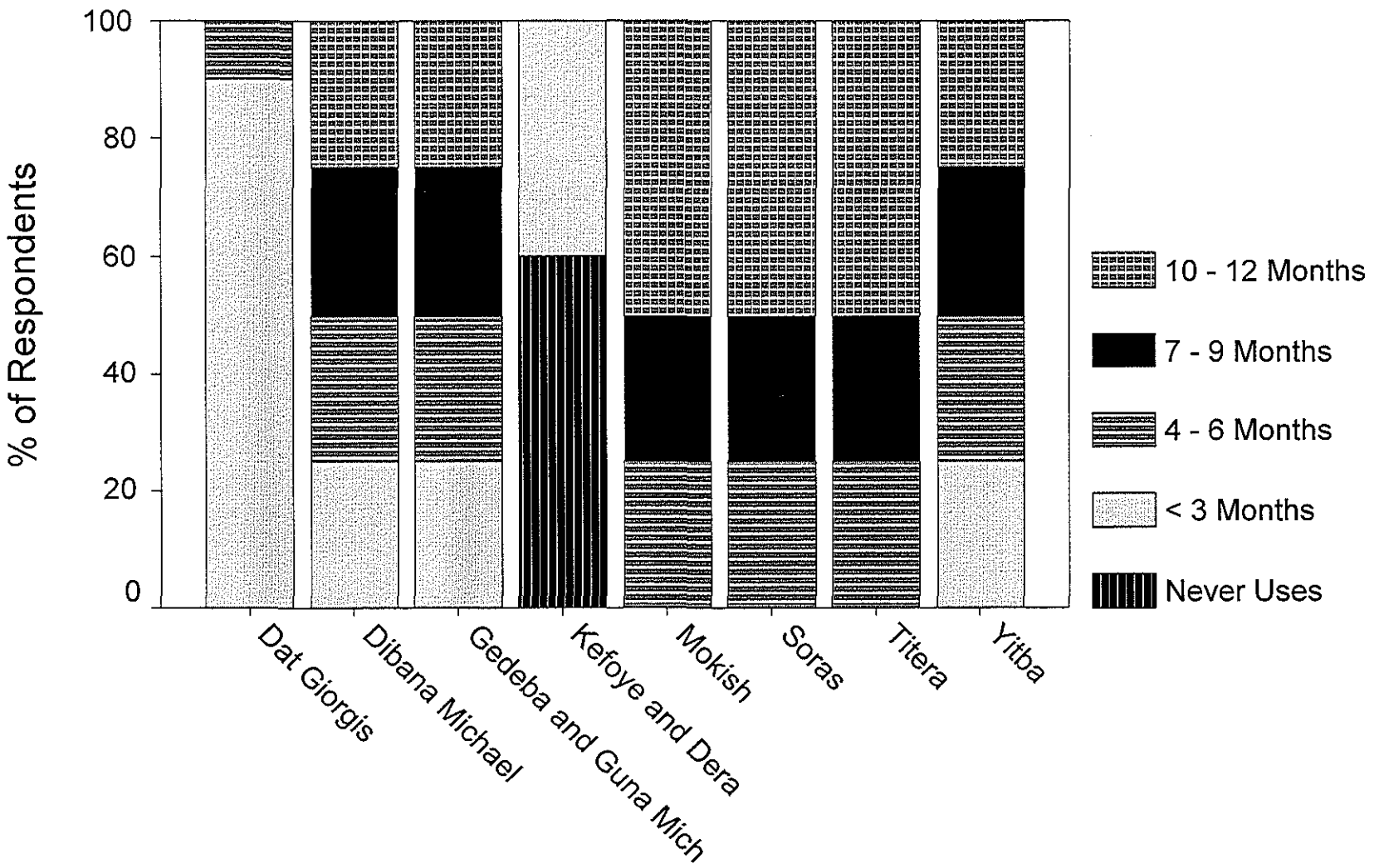

Fig. 6 Degree of Importance Attached to The Guna Area for Grazing

Guna area is used for thatching using the "Guassa" grass (*Festuca richardii*), which makes good thatch. A roof thatched with "Guassa" grasses lasts much longer, up to 14-21 years (Personal Communication) compared with other grasses growing at high altitudes. Peasant associations differed [$\chi 2$ = 326, df = 28, P<0.001] in how Guna area as a source of thatching.

Table 6 The Importance of the Guna Area for thatching by Different Peasant Associations.

Peasant Association	N (Interviewee)	Very Important	Important	Less Important	Not Important
Dibana Michael	20	58%	32.4%	6.6%	3%
Dat Giorgis	20	62%	28.6%	5.4%	4%
Mokish	20	70.2%	20.6%	8.8%	2%
Soras	20	69.8%	19.6%	5.6%	5%
Titera	20	68.9%	23.4%	4.7%	3%
Yitba	20	66.5%	25.8%	4.3%	3.4%
Kefoye and Dera	20	58.6%	27.2%	8.2%	6%
Gedeba and Guna	20	57.1%	33.2%	6.3%	3.4%

Firewood is also an important resource collected from the Guna area. Many respondents indicated that they collect shrubby vegetation in the Guna area as firewood. The most commonly collected plant generas were *Erica* (Asta), *Hypericum* (Amja) and tree like *Lobelia* (Gibra) to some extent. Peasant associations differed in [$\chi 2$ = 336, df = 28, P<0.001] how they use Guna area as a source of firewood.

Table 7 **Percentage of Respondents Who Use the Guna Area as a Source of Firewood.**

Peasant Association	N (Interviewee)	Firewood From Guna	Not from Guna
Dibana	20	90%	10%
Mokish	20	84.6%	15.4%
Soras	20	92.7%	7.3%
Titera	20	90.2%	9.8%
Yitba	20	50.7%	49.3%
Kefoye and Dera	20	62%	38%
Gedeba and Guna	20	0.0	100%
Dat Giorgis	20	57.8%	42.2%

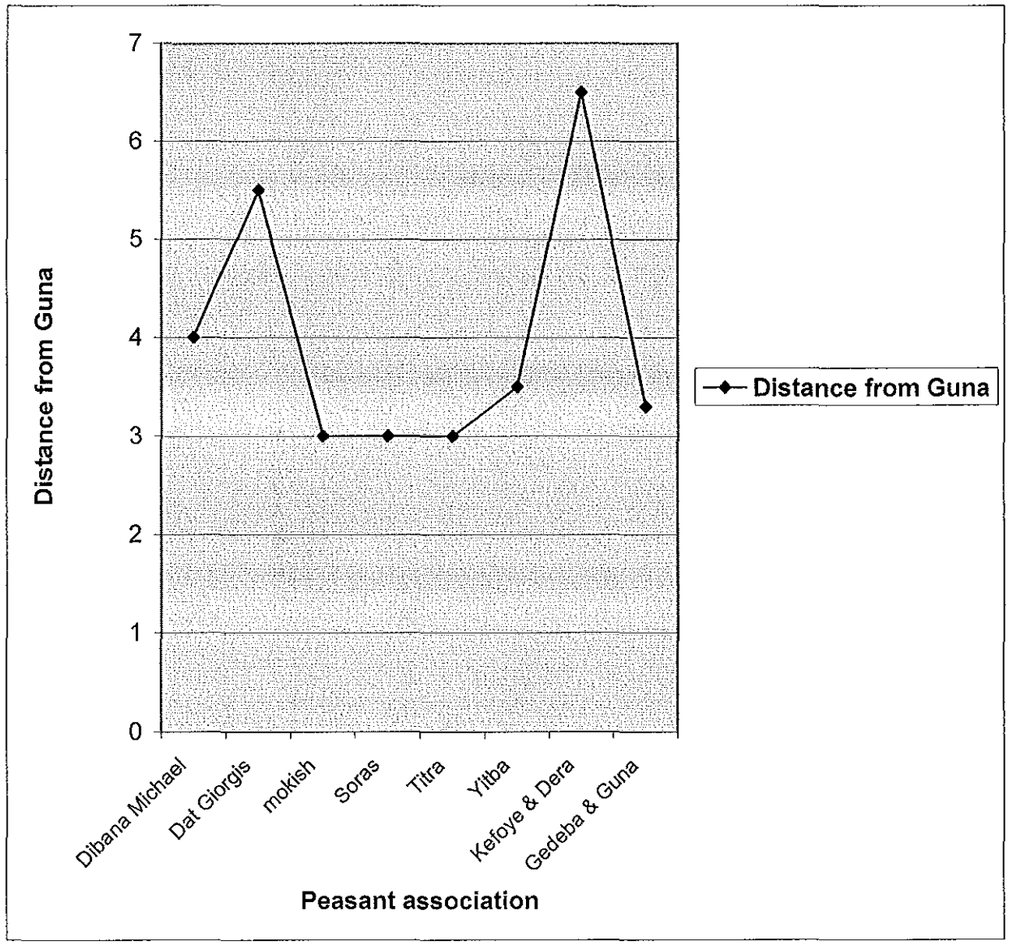

Figure 6. Distance of the study area (Guna) from the adjoining peasant associations

4.4. Grasses Biomass Data

The quantity of seasonal biomass production of grasses at Guna area varied in different periods of the year in response to the seasonal variation in rainfall amount (Fig. 7 and Appendix 5). The seasonal variation in aboveground biomass production of the grasses was estimated after removing all the grasses at 2cm aboveground at the start of the experiment. Rainfall at Guna Massif as it was extrapolated from Debre Tabor and Nefas Mewucha meteorological stations during the study period is shown in Figures 2 and 3. The highest rainfall was recorded in July and August whereas there was very little rainfall from December to February. Maximum values of biomass were obtained during the period from June to October (within a period of four months). These values ranged from 145.7±71.4 gm^{-2} to 120.8±38.2 gm^{-2} from mixed (*Andropogon amethystinus* + *Festuca ricardii* stands) and *Festuca richardii* pure stand, respectively. During the dry period (from October to January) accumulated biomass was 93.4±28.4 gm^{-2} and 102.0±26.7 gm^{-2} for mixed stands and *Festuca richardii* pure stand, respectively.

The increase in biomass production of the grasses from all the four types of stands at different growth intervals (i.e. after 4,8 and 12 months of growth) is shown in Fig. 7. The biomass produced in the second period (June to October) was significantly different from the first (February to June) and third (October to January) periods at $p < 0.05$. However, the biomass production between the first and third periods was not significantly different at $p < 0.05$ (Appendix 5).

The annual biomass production was estimated after removing the biomass produced at January 2004 that allowed all the stands to grow for 12 months. The annual biomass

production of the different stands is shown in Fig. 8. It ranged from 115.2 $\pm$ 73.4 gm^{-2} for mixed stands to 95.6$\pm$ 29.4 gm^{-2} for *Festuca richardii* pure stand. As it can be seen from Fig. 8 and Appendix 6 the biomass production of *Festuca richardii* was significantly lower than that of mixed stands.

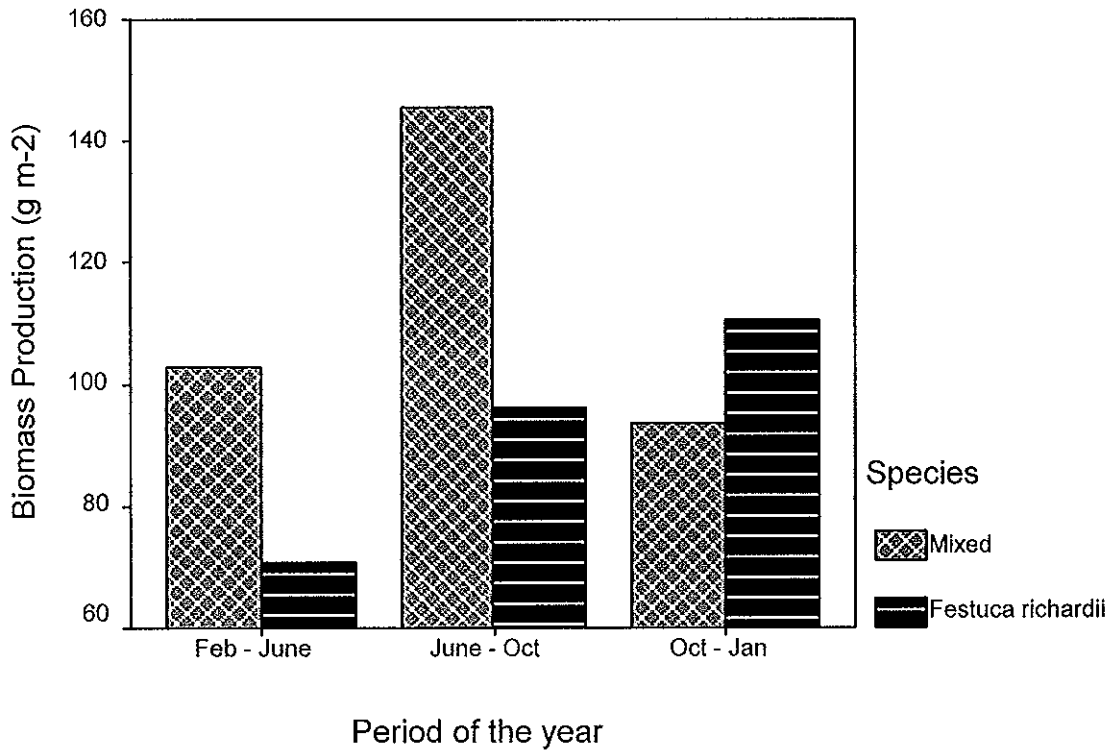

Fig. 7. Seasonal biomass production of the two grass species

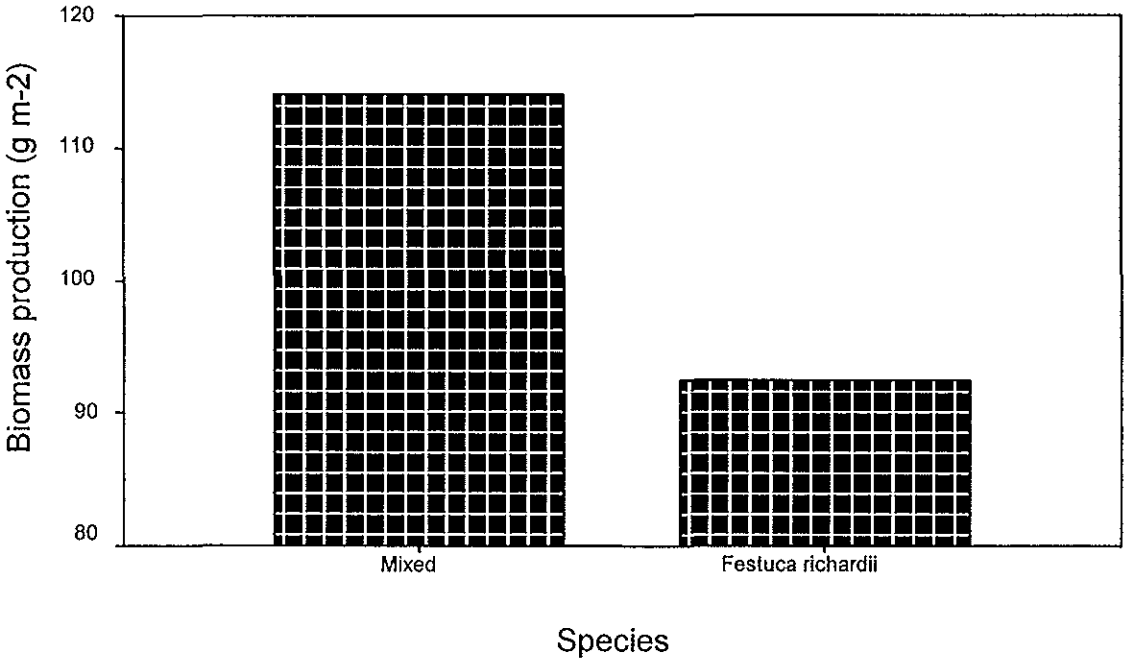

Fig. 8. Annual production of the two grass species

5. DISCUSSION

5.1 Floristic Composition and Plant Communities

The vegetation zonation of Guna Massif seems to agree fairly well with the scheme outlined for the mountains of Tropical East Africa. In Tropical East Africa afroalpine and subafroalpine vegetation are evident and which the characteristic species are *Lobelia rhynchopetalum* (in Kenya and Ethiopia) and *Erica arborea*, respectively (Hedberg, 1951, 1964). This agrees with the afroalpine and subafroalpine areas in the study area (Table 2). The afroapline region of the study area is dominated by various grass and herbaceous species, but the really landmark species were *Lobelia rhynchopetalum, Helichrysum* scrub, *Carex* species at the bog site. *Festuca* grasses were important plant species in the communities (Table 2). The ericaceous scrub, in this community, appears to cover practically all ground with reasonably deep and well-drained soil at this altitude. The result agrees with the investigation of Hedberg (1951, 1964), Coe (1967), Menassie Gashaw and Masresha Fetene (1996) and Mekonnen Biru (2003).

The intensively grazed area showed differences in cover-abundance of their constituent species. The reasons for such variation were due to the differences in the population of livestock and soil factors (Appendix 11). This agrees with the result obtained by Yemane Asgedom (1991). Herbivores selectively graze when offered a given mixture of plant species, and this result in considerable damage to those plants, which are palatable under intensive grazing pressure. On the other hand, sever grazing allows

unpalatable species to gain foothold (Zerihun Woldu, 1980). The intensively grazed sites, in the study area, were dominated by less palatable genera like *Lobelia, Helichrysum and most Asteraceae* while the protected sites were dominated by *Andropogon, Thymus* and other palatable plant species (Table 2 and Fig.1).

In this study the analysis of diversity using the Shannon-Wiener (1949) index showed differences between the groups, the highest species richness was found in the protected area where the species grazed once in a year (Table 3). The high species richness is probably due to relatively low grazing effect and soil factors, i.e., medium pH and relatively high moisture content (Table 4). Low species richness was observed in the intensively grazed areas and at higher altitudes (Table 3 and Appendix 11). The very low species richness in the intensively grazed sites (Community 1) was probably due to the result of losses of species by selective defoliation and trampling by herbivore and intrusive farming activity. Moreover, low species richness at higher altitudes due to solifluction and frost (Fig. 1). This result agrees with Ellison (1960), Rorison (1970), Yemane Asgedom (1991) and Yoseph Assefa (2001). In this study species rich sites showed higher evenness (Table 3) which has shown disparity from the result obtained by Kershaw (1964), Misra (1974), Mani (1980) and Mekonnen Biru (2003). This could be probably due to different environmental factors and/or the highest value of the experimental error. As it has been shown in Table 3, in general, diversity decreases with increase in altitude. Major causes for the decrease could be solifluction and the harsh climate characterized by lower mean monthly temperatures, decreased

precipitation, frequent frost and relatively strong winds. Similar results were obtained by Hedberg (1964, 1975), Yemane Asgedom (1991), Menassie Gashaw and Masresha Fetene (1996), Yosef Assefa (2001) and Mekonnen Biru (2003).

5.2 Soil Environmental Factors and Plant Communities

Soil provides physical support, anchorage and nutrients to plants. Soil is also a complex medium influencing the life of the plant in many ways, because roots not only live in it but also physical and chemical properties can interact with the living roots. This makes the study of soil physical and chemical properties essential in vegetation studies.

Soil pH is the measure of acidity or alkalinity of soil. It has no direct effect on plant growth but its effect is indirect and nutritional, i.e., it affects the solubility of nutrients, organic matter decomposition, some physical properties of soils etc. (Donahue *et al.*, 1983).

Soil pH in this study was found to be medium acidic to relatively strongly acidic (Table 4). This is probably due to high amount of rainfall in the study area and associated with the high slop of the area, which makes it liable to leaching of water soluble salts (Fig.1, 2 and 3). This result agrees with the study conducted by Buckman and Brady (1969), however, it has some disparity with the result obtained by Menassie Gashaw and Masresha Fetene (1996). The relatively low pH values of plant groups 5 and 6 may be attributed to the low cation content of the soils which corresponds to the medium slope of the area (Table 4 and Fig. 1).

Conductivity gives information on the total amount of water-soluble salts (Thompson and Troeh, 1978). A high conductivity value is expected to be correlated with a high saturation point and higher pH values. Mostly cations such as Na^{+}, Ca^{2+}, Mg^{2+}, and anions like SO_4^{2-} and Cl^{-}, illustrating that the soils support the growth of most plant species. According to Millot (1997), most plants grow well between pH 5.5-8.5. The conductivity results of this study based on the mean values shown that communities 1 and 4 had the lowest and communities 5,6, 2&3 had high values (Table 4). The reason for the relatively higher conductivity value of community 5 is that most of the quadrats in this group were inudated by the Wanka River. This could be influenced by the deposition of clay and humus materials, which are rich in nutrients. On the other hand, low conductivity may be attributed to the low cation content of the soils. As there was only insignificant differences among communities, conductivity did not have a significant effect on distinguishing different communities (Table 5).

The survival of plant species is determined by mechanisms that ensure occurrence of germination at a time when the seedling would be established itself. The amount of moisture available in a soil at a given time in a season, in combination with other climatic factors, notably temperature determines germination and establishment of seedlings (Went, 1957, cited in Kennenni, 1990). However, the actual soil moisture content varies with the structure and texture of the soil, as well as precipitation and evapotranspiration (Kenneni, 1990). The soil moisture in the study area was not statistically significant among the communities (Table 5). The result disagrees with trends reported by Menassie Gashaw and Masresha Fetene (1996) and Yoseph Assefa

(2001). The probable reason would be dissimilarity of the rainfall and soils of the respective study sites. As a result the contribution of soil moisture for the establishment of different communities in the study area was not obvious. However, it declined gently with an increase in altitude (Appendix 4). Though in the higher elevations at Guna Massif where annual rainfall was relatively low and erratic, low or high moisture content might not be a major factor that limits the growth and establishments of different plant species (Fig. 4 and Table 2).

Particle size distribution has considerable interest since the dominant particle size present in an area has an effect on the flora of the region (Etherington, 1974). It affects soil aeration, water movement, root penetration and water holding capacity. Furthermore, particle size affects the cation holding capacity and cation saturation point of soils. In this study, sand and clay showed statistically significant variation among plant communities. The sand content seems to be higher and the soil type in most plant communities was Loamy Sand (Table 4). The presence of coarse texture in the study area indicates the capacity of the soil to hold more air (good aeration), better water movement and root penetration. As a result ploughing and cultivation could be easier. The mean value for clay particle was very low, however, the values differed among the plant communities in the study area (Table 4). Even though the mean value of silt was relatively high, it did not differ among the different plant communities. This condition agrees with the result obtained by Menassie Gashaw and Masresha Fetene (1996), and Mekonnen Biru (2003). The probable reason could be the fact that the dominant soil particle in the respective study sites was sand.

5.3 Socio-Economic Data

In Guna Massif the "Guassa" area is an important grazing land which helps as a refuge for the livestock population when pasture and cultivated fields become devoid of any grazing resource, particularly during drought. Cattle, sheep and equines all graze in the area. Most of the respondents from Mokish, Soras and Titera Peasant Associations grazed their livestock for most of the year. In contrast, the respondents from Dat Giorgis, and Kefoye and Dera used the Guna Massif for less than four months and respondents in Dibana, Yitba, and Gedeba and Guna Michael, used the area for grazing equally in all months. Most respondents from Kefoye and Dera never used the Guna Massif for grazing purpose (Fig. 5). The reasons why some peasant associations, which are adjoining Guna Massif, never used the area for grazing were the relatively long distance of the villages from the area, and problem of accessibility (Fig. 6 and Appendix 9).

Peasant associations have different views about the value of the Guna area as a source of grass. Peasant associations near Guna need the grass mainly for thatching and report that a house thatched with *Festuca* grass lasts for several years (Personal Communication). However, peasant associations further away rarely need the grass since they do not have to thatch their houses very often (Fig. 6 and Appendix 9). Generally, most respondents from different peasant associations, 60-70%, considered the Guna area as a very important thatching area, whereas some respondents in respective peasant associations considered the area was being important for thatching

(Table 6). Few respondents in different peasant associations said that *Festuca* grass in Guna Massif was not important for thatching purpose.

The Guna communities depend on the Guna area as a source of fuel wood. The bushy vegetation occurring at high altitude is the only plant matter that can be collected as a source of fuel. *Erica* was the most common shrub used as firewood in Guna (Table 7). The plant is usually collected by uprooting using a small axe or by pulling it out of the ground by hand. However, very little *Erica* bush was left in the area and the little left is continuously used now by the community. It is usually collected in the wet season since it has a capacity to burn quickly even when it is wet. *Hypericum* is another bush collected as firewood and can grow up to the height of a small tree, but it never has the chance to grow to that height in the Guna area, so it is always found as a bushy thicket. *Hypericum* is also collected to make brooms or various households. However, since the firewood plant species collected in the alpine area have a low caloric value and do not provide constant heat (Abbot and Homewood, 1999; Zelalem Tefera, 2001), a mixture of livestock dung and the bushy vegetation from Guna are commonly used to get long-lasting heat by the local community.

5.4. Grass Biomass Production

Many investigators from various parts of the world have attempted to relate biomass production to rainfall, either on a seasonal or on annual basis (Soneji and Musangi, 1972; Button *et al.*, 1988a; Kinymaria and Imbamba, 1992). They obtained strong correlation between biomass and rainfall. Negligible rainfall during dry periods limits

production through reduced soil moisture (Kinyamario and Imbamba, 1992). Further they stated that the amount of rainfall received in one month not only affects production in the same month but also in the following month.

The biomass production (*Andropogon amethystinus* + *Festuca richandii* mixed stands and *Festua richardii* pure stand) of Guna Massif grassland showed significant seasonal and annual differences. All the stands supplied a highest production peak during the rainy seasons and the lowest during the dry seasons (Fig. 7). The highest biomass production was recorded during the June-October period. During October - January the biomass produced was relatively low. The biomass production had relationship with seasonal changes in the amount of rainfall. As indicated in Appendices 5 and 6 and Figs. 7and 8, the seasonal and annual biomass production estimated from *Festuca richardii* stand was significantly lower than that of the mixed stands in all growth periods. This indicates that the contribution of *F. richardii* to the area's primary production was relatively lower than that of the mixed stands. Moreover, biomass value after 12 months growth was slightly lower than the biomass obtained after 8 months growth for all the stands due to defoliation. However, the mixed stands relatively showed higher biomass value during low rainfall periods may be due to require low moisture content by the plant species (*Andropogon amethystinus*). Moreover, the perennial grass species (*Festuca richardii*) relatively supplied low biomass value due to most of the biomass found in under ground part (Kershaw, 1964).

The seasonal and annual biomass productions of grasses in the Guna area were low as compared to the value obtained in Awash National Park range grass species. The

seasonal biomass values ranged from 93.4 gmm^{-2} to 145.7 gmm^{-2} for *Festuca richardii* and mixed stands, respectively, while at Awash area the value was some what high and ranged from 116 gm^{-2} to 409 gm^{-2} for *Bothriochloa radicans* and mixed species stands, respectively. The annual biomass productions of the two areas were also different. In this study it ranged from 95.6 gm^{-2} to 115.2 gm^{-2} for *Festica richardii* and mixed stands, respectively. The annual biomass production ranged from 397 gm^{-2} to 792 gm^{-2} for pure and mixed stands respectively in Awash National Park range grasses (Almaz Taddesse and Masresha Fetene, 1999). The probable reasons would be attributing their differences in the biomass production due to their differences in the amount and distribution of rainfall and temperature (i.e. average annual rainfall and temperature at Guna and Awash National Park was 1068.45 mm, 14 ^{o}c and 970 mm, 32.17 ^{o}c , respectively).

6.CONCLUSIONS AND RECOMMENDATIONS

In this study the major vegetation compositions on Guna Massif were identified. Based on our result the vegetation of the afroalpine area of Guna Massif can be grouped into six major plant communities. The communities occupied different altitudinal ranges that sometimes overlapped. From the study, variation in the distribution of plant communities along the altitudinal gradient was found. Some of the community types occurred at all altitudinal ranges while others were restricted to certain altitudinal ranges. Some of the typical afroalpine community types were found at much lower altitude than at the expected altitudes. Vegetation cover and species diversity also showed distinct altitudinal variations. At higher altitudes above 3700 m there was only scant vegetation due to reduced soil moisture, frost, freezing temperature and low soil nutrients. At lower altitudes in the ericaceous zone there was better vegetation cover and extensive number of species per community and better climatic conditions than at higher altitudes.

Cattle, equines, and shoats have exerted a heavy pressure on the vegetation of the study site especially on lower altitudes. The e*ricaceous* bushes were cut for fuel-wood, construction materials and were frequently burnt by the local people for various reasons that dates back 30 years from present. This resulted in the destruction of the vegetation and loss of wild animals and hence had significant influence on the biodiversity of the study area. Consequently, rivers, streams and springs that originated from this mountain have been drying up. The devegetation of the mountain had reduced stream and river flows. This in turn reduces potable water supply and interrupt the irrigation

schemes. Moreover, intrusive farming activities in the sub-afroalpine zone have also a negative impact on the development and improvement of the ecosystem.

The study showed the quantitative importance of two grass species as pasture and forage for livestock. Productivity was mainly limited by the amount of rainfall during the dry seasons. The highest value for biomass was obtained during the rainy seasons and these values declined during the dry periods of the year. During the dry periods these two species had values below the required maintenance level. Thus it could be possible to conclude that the livestock in Guna face shortage of feeds during the dry periods.

Finally, the present investigation has gathered some preliminary information on the change in the structure and distribution of vegetation in highly disturbed area. This information will be more comprehensive if a comparative study in the less disturbed vegetation is also made. From the results of the study and experience, some conservation and management strategies can be forwarded although it is difficult to give a strong suggestion due to the limitation of the study. However, it is possible to give some suggestions that might be used as basic information for further study. Some anthropogenic factors such as intrusive farming activities, overgrazing, poor management practices and fire hazards should be reduced. Otherwise, on the long run it could affect the watershed of the area in addition to the loss of biodiversity. Moreover, some soil physical, biological and chemical properties which was not covered in this thesis should be extensively studied. Furthermore, it is also important to increase the awareness of the people especially the younger generations on nature and

conservation through their local schools as this will reduce at least uneconomical use of their resources. It is advisable that before undertaking an intervention in the conservation of this fragile and highly disturbed ecosystem, it requires further detailed studies on the ecology of the area, arrangement of programmes for awareness creation in the local population, social participation in the management of the area and full involvement of the government also should be addressed.

REFERENCES

Abbot, J.I. and Homewood, K. (1999). A history of change: Causes of miombo woods and decline in a protected area in Malawi. *Journal of Applied Ecology*, **36**: 422-433.

Alemaz Taddesse and Masresha Fetene (1999). Biomass production and nutrient status of three tropical range grass species. *SINET: Ethiop. J.Sci.*, 22 (**1**):98-111.

Balmford, A., Mace, G.M. and Ginsberg, J.R. (1998). Putting processes on the map. **In:** Mace, G. M., Balmford, A. and Ginsberg, J.R. (eds). *The challenge to conservation in the changing world.* Cambridge University Press. Pp 1-29.

Barry, R.G. (1992). *Mountain weather and climate*. Routledge, London.

Beals, E.W. (1969). Vegetation of the Erer-Gota plain. *Ethiopian Journal of Ecology*, **57**: 655-667.

Begon, M., Harper, J. and Townsend, C.R. (1996). *Ecology, individual, population and communities*. 3rd ed. Blackwell science, Italy.

Ben-Shahar,R. (1994). Patterns of nutrients in grass of a semi-arid savanna. *African Journal of Ecology*, **32**: 328-333.

Bonne fille, R., Buchet, G., Friis, I., Ensermu Kelbesa and Mohammed, M.U. (1993). Modern pollengrain on altitudinal range forests and woodlands in Southwest Ethiopia. *Opera Botanica*, **121**: 71-84.

Boudet, G. (1975). Pastures and livestock in the Sahel. **In:** The Sahel*: Ecological approaches to land use.* MAB Technical Notes, PP. 24-40. The UNESCO Press, Paris.

Boutton, T.W., Teiszen, L.L. and Imbamba, S.K. (1980). Biomass dynamics of grassland vegetation in Kenya. *African Journal of Ecology*, **26**: 89-101.

Boutton, T.W., Teiszen, L.L. and Imbamba, S.K. (1988b). Seasonal changes in the nutrient content of East African grasslands. *African Journal of Ecology*, **26**: 103-115.

Buckman, N.G. and Brady, N.C. (1969). The nature and properties of soils. 2nd ed. The Mac Millan Company Collier-MacMillan Limited, London.

Burbour, W.A., Burk, J.H. and Pitts, W.D. (1987). Terrestrial plant ecology.2nd ed. The Benjamin Cumming Publishing Company, INK, Tokyo.

Butt, N.and Price, M.F. (1999). Mountain people, forests and trees: Strategies for balancing local management and outside interests. E-conference of the mountain forum and the Mountain Institute, Harrisunburg, USA.

Carl, T. (1992). Poverty, Environment and Development. **In:** Kirdar, O. (ed). *Threat or opportunity for human progress*. Vol. 5. UNDP. New York, Pp. 91-112.

Chapin, F.S. and Whiteman, G. (1998).Sustainable development of the boreal forest, interaction of ecological, social and business feedbacks. *Conservation Ecology*, 2(2):12

Chapman, J.L. and Reiss, M.J.(1992). Ecology principle and application. Cambridge.

Coe, M.J. (1697). *The ecology of the alpine zone of Mt.Kenya*. Monogr. Biol. The Hugue: w. Junk. New York.

Cottenie, A. (1980). Soil and plant testing as a basis of fertilizer recommendations. FAO (Soil Bulletins No. 38/2). Rome.

Crawley, M.J.E. (1997). *Plant Ecology*. Black Well Scientific Publications, oxford.

CSA. (1995). Population and Housing Census Addis Ababa, Ethiopia.

Daniel Gamachu (1977). Aspects of Climate and Water Budget in Ethiopia. Addis Ababa University press, Addis Ababa, Ethiopia.

Daniel Gamachu (1986). Some patterns of altitudinal variation of climatic elements in the mountainous regions of Ethiopia. *Mountain Research and Development* **8:**131-138

Demel Teketay (1994). Floristic composition of Garamuleta and Kundudo Mountains. Southeastern Ethiopia: Implications for the conservation of biodiversity. **In:** Maesen, L.J.A. Burgt, X.M. and Medenbach derooy, J,M. (eds). *The biodiversity of African plants.* XIV AETFAT Congress Wogeningen. Pp 35-35.

Desalegn Wana (2002). Plant communities and diversity along altitudinal gradients from Lake Abaya to Chencha Highlands. MSc. Thesis, AAU.

Digby, P.G.N. (1987). *Multivariute* analysis of ecological communities. Cambridge University Press. Cambridge, London.

Dingby, P.G.N. and Kempton, R.A. (1994). *Multivariate analysis of ecological communities: population and community biology series* Chapman and Hill. London.

Donahue, R.L., Miller R.W. and Shikluna J.C. (1983). Soils: *An Introduction to soils and plant growth*. Prestice Hall of India, New Delhi.

Duffey, E., Morris, M.G. Sheail J. and Wells T.C.E. (1974). Grassland ecology and wildlife management Hampman and Hall London.

Edwards, S., Mesfin Tadese and Heberg, I. (eds) (1995). Flora of Ethiopia and Eritrea Vol.2, part2. Canellaceae to Euphorbiacea. Addis Ababa Ethiopia Uppsala, Sweden.

Edwards, S. Sebsebe Demissew and Hedberg, I (eds) (1997). Flora of Ethiopia and Eritrea. Vol6. Hydrocharitaceae to Arecaceae. Addis Ababa, Ethiopia. Uppsala, Seweden.

Edwards, S., Mesfin Tadese, Sebsebe Demissew and Hedberg, I. (eds). (2000). Flora of Ethiopia and Eritrea. Vol.2 part 2 Magnoliaceae to Flacourtiaceae. Addis Ababa, Ethiopia Uppsala, Sweden.

EFAP (1994). Ethiopia Forestry Action Program. Vol.2. The challenge for developmebt Addis Ababa, Ethiopia.

Ellison, L. (1960). Influence of grazing on plant succession of range lands. *Botanical Revision*, **20:** 1-78

Etherington, J, R. (1975). *Environment and Plant Ecology*. John Wiley and Son's Ltd. Company London.

Ethiopian Mapping Authority (1988). National Atlas of Ethiopia, Berhanena Selam Printing Press. Addis Ababa, Ethiopia.

FAO (1986). Food extraction with oxen and agricultural tractors. Forestry, Paper No. 79 Rome.

Feoli, E, Vuerich, L.G. and Zerihun, W. (2001). Evaluation of environmental degradation in Northern Ethiopia, Using GIS to integrate vegetation, geomorphological erosion and socio-economic factors. Agriculture, Ecosystems and Environment **1815:** 1-13

Fernande-Palecius, J.M. and de Nicolas, J.P. (1995). Altitudinal pattern of vegetation in Tenerife. *Journal of Vegetation Science* **6:**183-190

Ferreya, M., Ana, C., Cecilia, E. and Donaldo, B. (1998). High □entat vegetation and environmental gradients in Northwestern Patagonia, Argentina. *Journal of vegetation science*, **9:**307-316.

Field, C.R. (1976). Palatability factors and nutritive values of the fodder of Buffaloes in Uganda. *East African Wildlife Journal*, **14:**181-201.

Fitz Patrick, E. A. (1986). *An Introduction to Soil Science.* Longman.

Forman, R.T.T. and Godron, M. (1986). *Landscape Ecology*. John Wiley and Sons, New York.

Friis, I.(1986). The forest vegetations of Ethiopia. *Acta Univ. Ups Sym. But.Ups*, **26:** 31-47

Friis, I. and Mesfin Tadese (1990). The evergreen forests of tropical Northeast Africa. Proceedings of the 12th planetary meeting of AFTAT. Pp 249-263

Friis, I. and Sebsebe Demissew (2001). Vegetation maps of Ethiopia and Eritrea. A review of Existing Map and the need for the flora of Ethiopia and Eritrea. **In** Friis, I.B and ryding, U. (eds). Biodiversity research in the Horn of Africa Regions.Proceedings of the third international symposium on the Flora of Ethiopia and Eritrea.

Gabelnick, T., Hogan, D., Okuizma, K., Preuffer, P. and Pisani, K. (1997). Managing fragile ecosystems. Sustainable Development.

Gauch, H.G. (1982).*Multivariate Analysis in Community Ecology*. Cambridge University press Cambridge, London. At Carlsberg Copenhagen, Pp 399-439.

Gauch, H.G. and Whittaker, R.H. (1985). Hierarchical classification of community data. *Journal of Ecology*, **69:**135-152.

Greig-Smith, P. (1964). *Quantitative plant ecology*. 2nd ed. Butter worths, London.

Greig-Smith, P. (1980). *Quantitative plant ecology*. 3rded. Butter worths, London

Greig-Smith, P, (1983). The development of numerical classification and ordination, *Vegetatio*, **42:**1-9

Grosjean, M. and Messerli, B. (1998). African mountains and highlands: Potentials and constraints. *Mountain Research and Development,* 213: 111 – 122.

Haile Leul Tebicke (2002). A Scan of sustainable energy, Environment and development in Ethiopia. **In:** Tibebua Hectett (ed). *Ethiopian Civil Society*. Preparation for riotio. Book two. Berhanena Selam Printing Enterprise Pp 12-45. Addis Ababa, Ethiopia.

Hailu Sharew (1982). An Ecological study of a forest in Jemjem, Sidamo. M Sc Thesis, AAU. Addis Ababa, Ethiopia.

Harper, J.L. (1977). *Population Biology of Plants*. Academic press. London.

Hedberg, O. (1951). Vegetation belts of the east African Mountains. Svensk Botanisk *Tidskrift*, **451:**140-204

Hedberg, O. (1962). Mountain plants south southern Ethiopia collected by Dr John Erikson.

Hedberg, O.(1964). Features of afroulpine ecology. *Actaphytogeographica Suecicia* **49:**1-144

Hedberg, O. (1975). Studies of adaptation and speciation in the afro-alpine flora of Ethiopia. *Boissiera,* **24:**71-74

Hedberg, O. and Hedberg, I. (1979). Tropical alpine life-forms of vascular plants. *Oikos,* **33:**297-307

Hedberg, O. (1986). The Afro-alpine flora of Ethiopia. *SINET. Ethiopian Journal of Science,* **9:**105-110

Hedberg, O. (1992). Afro-alpine vegetation compared to the paramos. Convergent adartation and divergent differentiations. **In:** paramo. An Indian ecosystem under human influence, Pp 15-29 (Balslev, H. and Luteyn, J.J. eds). Academic press. London.

Hedberg, I. and Edwards, S. (eds) (1989). Flora of Ethiopia Vol.3 Pittosporaceae to Araliaceae. Addis Ababa, Ethiopia. Uppsala, Sweden.

Hedberg, I. and Edwards, S. (eds) (1995). Flora of Ethiopia and Eritrea. Vol.7. Addis Ababa, Ethiopia. Uppsala, Sweden.

Hesla, B.I., Tieszen, H.L and Bouttun, T.W. (1995). Seasonal water relations of savanna shrubs zones of Nigerian in relation to season and site. *Tropical Agriculture,* **60:**48-52

Hill, M.O., Bunce, R.G. and Shaw, M.W. (1975). Indicator species analysis. A divisive polythetic method of classification and its application to a survey native pine woods in Scotland. *Journal of Ecology,* **63:**597-613.

Hurni, H. (1986). Management plan Bale mountain national park and surrounding rural areas-wildlife conservation organization. Ministry of agriculture Ethiopia.

Hurni, H. and Ludi, T. (1998). Re-conciling conservation with sustainable development center for development and environment. University of Berne, Switzerland.

Huston, M.A. (1994). *Biological Diversity.* The coexistence of species on changing landscape Cambridge University Press. London.

Jackson, M.L. (1973). *Soil chemical analysis.* prentice-Hall of India Private Limited. New Delhi.

Juo, A. (1978). *Selected methods for soil and plant analysis.* Institute of Tropical Agriculture, Ibadan, Nigeria.

Kennenni, L. (1990). On the ecology of acacia tortillas in the Sudan. Comprehensive summaries of Uppsala dissertations from the faculty of science, Uppsala.

Kershaw, K.A. (1964). *Quantitative and dynamic plant ecology.* Edward Arnold limited London.

Kersahw, K.A. (1973). *Quantitative and dynamic plant ecology.* 2nd ed Edward Arnold limited. London.

Kershaw, K.A. (1980). Quantitative and dynamic plant ecology. 3rd ed. Edward Arnold London.

Kinyamario, J.L. and Imbamba, S.K. (1992). Savanna at Nairobi park. **In:** Long S.P. Jones M.B. and Roberts, M.J. (eds). *Primary productivity of grass ecosystems of Chapman and Hall,* London the tropics and sub-topics

Konemund, T., Hiwete Teshome and Samson Tolessa (2002). What alternatives do we have to bridge the gap between fuel-wood demand and supply in Ethiopia? **In:** Tibebura Hectett (ed), *Ethiopian civil society Preparation for riotio.* Book Two Pp44-60

Kothari, A. (1997). Biodiversity and rural livelihood. **In:** Borrin Feyerabend a. (ed) *Beyond fences: sealing social sustainability in conservation,* IUCN, Switzerland.

Kumar, H.d. (1981). *Modern Concepts of Ecology.* 2nd ed Vikas Publisher New Delhi

Kumilachew Yeshitila (1997). An ecological study of the afromontane vegetation of the southwestern Ethiopia. MSc. Thesis, AAU

Lagonegro, M. and Feoli, E. (1984). *Three package for classification and ordination of multivariate data* .Liberia Goliardica, Trieste.

Lambert, J.M and Dale M.B. (1964). *The use of statistics in phytosociology.* Advances in ecological research, Academic Press. London and New York, Pp 59-98

Landon, J.R. (1996). Booker tropical soil manual. A hand book for soil survey and agricultural and evaluation in the tropics and sub-tropics. Longman.

Le Houerou, H.N., Bingham, R.L and Skerbak, W. (1998). Relationship between the variability of primary production and the vriability of annual precipitation in world arid lands. *Journal of arid environments,* **15:**1-18

Lewis, M.A. and Taylor, L.R. (1979). *Introduction to experimental ecology.* The □entate language book society and academic press. London.

Lind, E.M and Marrison M. (1974). *East African Vegetation.* Longman. London.

Lisanwork Nigatu (1987). An ecological study of the vegetation of the Harena Forest. M Sc. Thesis, Addis Ababa University (Unpublished)

Lovett, J.C. (1990). Altitudinal variation in large tree community associations on the west Usabara mountains. **In:** Hedberg, I. and Pearson, E (eds). *Research for conservation of Tanzanian catchment forests,* Pp134-135.

Lovett, J.C. (1993). Temperate and tropical floras in the mountains of eastern Tanzania. *Opera Botanica* **121:**217-227

Lovett, J.C. (1996). Elevation and latitudinal changes in tree associations and diversity in the eastern arc mountains of Tanzania. *Journal of ecology*, **12:**629-650

Lundgreen, B. (1971). Soil studies in a mountain forest in Ethiopia. Stockholm.

Mani, M.S. and Giddings, L.E. (1980). *Ecology of high lands.* The Hague. Bosten. Londen.

Mashalla, S. K. (1988). The human impact on the natural environment of the MBEYA highlands, Tanzania. *Mountain Research and Development,* 4 : 283 – 288.

Mcintosh, R. P.(1967). The continnum concept of vegetation. *Bot. Rev.* **33:** 103-187

Mclean and R.C and Ivimer-Cook. J.W.R (1973). *Practical field ecology 2nd ed.* George Allea and Un win limited. London.

Mcnaghton, S.J. (1985). Ecology of grazing ecosystems: The Sergenti. *Ecological Monograph*, **55:** 259-294.

Mekonen Biru (2003). An Ecological study of the Biteyu forest, along the western escarpment of the Gurage Mountain Chain, Ethiopia. M Sc Thesis (unpublished).

Menasie Gashaw and Masresha Fetene (1996). Plant communities of the afroalppine vegetation of Sanetti Plateau, Bale Mountains: *SINET ETHIOP.J.Sc*: **19 (1)**: 65-86.

Mesfin Wolde-Mariam (1991). Suffering under GOD'S environment: A Vertical Study of Predicament of Peasants in North Central Ethiopia.University of Berne, Berne, Switzerland.

Michaelson, A., Lisanework Nigatu and Friis, I. (1993). Impacts of tree plantation in Ethiopian Highlands on soil fertility, shoot and root growth, nutrient utilization and mycorrhizal colonization. *Forest Ecology and Management,* **61:** 229-324.

Millot, G. (1997). Soil colloids and chemical properties, **In:** *Soil in our environments,* 7th ed. (Miller, R.W. and Donahue, B. L. Ed.).Printce Hall of India, New Delhi.

Misra, K.C.(1974). *Manual of plant ecology.* Oxford and IBH Publishing Company. New Delhi.

Mohr, P.A.(1963). *The geology of Ethiopia.* University College of Addis Ababa, Ethiopia.

Mooney, H.(1963). An account of the journeys to the Araena Mountains in Bale province(Southeast Ethiopia) 1958 and 1959-60, Proc. *Linnean Soc.*, **172:**127-147.

Mueller-Dombois, D. and Ellenberg, H. (1974). *Aims and Methods of Vegetation Ecology.* John Wiley and Sons Inc. USA.

Noy-Meir, I. (1987). Grazing and production in seasonal pastures: Analysis of Simple Model. *Journal of Ecology*, **15:** 809-835.

Palmer, M.W. and Dixon, P.M. (1990). Small scale environmental □entate□neity and species distribution along gradients. *Vegetation Science*, **1:** 57-65.

Paul, C. (1993). *Ecology*. John Wiley and Sons Inc. New York.

Pearcy, R.W., Ehleriger, J., Mooney, H. A. and Rundel, P.W. (1994). *Plant Physiological Ecology*. Field methods and instrumentation. Chapman and Hall. London; New York.

Pielou, E.C. (1984). *Mathematical ecology*. John Wiley and Sons Inc., New York, Toronto.

Podani, L. (1988). Syn-tax III Users manual. *Abstracta Botanica*, **12:** 1-183.

Polunin, N. (1960). *Introduction to plant geography and some related sciences*. Longmans, New York.

Pritchard, N. M. and Anderson, A. J. B. (1971). Observations on the use of cluster analysis in botany with an ecological example. *Journal of Ecology*, **59:** 727-747.

Rickleftis, E.R. (1997). *The Economy of nature*. 4th ed. W.H. Freeman and Company. USA.

Ridder, N., Stroonjder, L., Cisse, H. M. and Van Keulen, H. (1982). *Study of soils.* Wageningen Agricultural University, the Netherlands.

Rorison, I. H. (1970). The use of nutrients in the control of the floristic composition of grassland. **In:** Duffey and Watt (eds), *The scientific management of animal and plant communities for conservation*. Blackwell Scientific Publication Oxford, London and Edinburgh. Pp 106-123.

Rundel, P.W.(1994). Tropical alpine climates. **In:** Meinzer, F. C.; Goldstein, G. and Rundel, P.W.(eds). *Tropical Alpine Environments*, Pp 21-44. Cambrige University Press, Cambridge.

Sahlemedhin Sertsu and Taye Bekele (2000). Procedures for soil and plant analysis. National Soil Research Organiozation, Ethiopia.

Sebsebe Demissew (1998). A Study of vegetation and floristic composition of southern Wollo, Ethiopia. *Journal of Ecological Science*, **31(1):** 118-141.

Senft, R.L., Coughnour, M. B., Bailey, D. W., Rittenhouse, L.R., Sala, O.E. and Swift, D.M. (1987). Large herbivores foraging and ecological hierarchies. *Bioscience*, **37:** 789-799.

Shannon, C. E. and Wiener, W. (1949). The mathematical theory of communication. University Illinois.

Sharma, U.R.O. and Shaw, W.W. (1993). Role of Nepal's Royal Chitwan National Park in meeting the grazing fodder needs of local people. *Environmental Protection,* **20:** 139-142.

Shimwell, D.W. (1971). *The description and classification of vegetation.* Sidgwilk and Jackson, London.

Simon Shibru (1999). Comparative study of the vegetation composition of Mt. Alutu and Mt. Chubbi atitudinal gradient. M Sc Thesis. Addis Ababa University.

Singh, J.S. and Yadava, P. S. (1974). Seasonal variation in composition, plant biomass, and primary productivity of tropical grassland at Kurukshetra, India. *Ecological Monographs*, **44:** 351-376.

Smith, A.P. (1987). Tropical alpine plant ecology. *Rev. Ecol. Syst.*, **18:** 137-158.

Soneji, S.V. and Musangi, B.S.(972).Digestibility and feed intake investigation at different stages of growth of plants: Chemical composition and yield. *East African Agricultural and Forestry Journal*, **37:** 267-271.

Stiling, P.D. (1996). *Ecology.* Theories and application. 2nd ed. Simon and Schuler. A Viacom company, New Jersey.

Tamrat Bekele (1993). Vegetation ecology of remnant afromontane forests on the central plateau of Shewa, Ethiopia. *Acta phytogeogr.suec.* **79:** 1-59.

Taylor, J. A. (1984). *Biogeography*: Recent advances and Future Directions. Barnes and Noble Book Adams Drire, Totowa, New Jersey.

Tesfaye Awas, Tamrat Bekele and Sebsebe Demissew (2001). An ecological study of the vegetation of Gambela Region, Southwestern Ethiopia. *SINET: Ethiop. J.Sc:.* **24:** 213-228.

Teshome Sormesa (1997). Ecological study of lowland vegetation. Key-Afer Shal Luqua and Southwest of Lake Chammo. M Sc Thesis, AAU.

Tewode Berhane Gebre Egziabher (1986). Vegetation and environment of the mountains of Ethiopia and their implications to economic use and conservation. Addis Ababa University Press. Addis Ababa, Ethiopia.

Tewode Berhane Gebre egziabher (1991). Management of mountain environments and genetic erosion in tropical mountain systems: The Ethiopian Example. *Mountion Research And Development* **11(3):** 250 - 230

Theunissen, J.D (1995). Biomass production of different ecotypes of three grass species of the semiarid arasslands of southern Africa. *Journal Of Arid Environments* **29:**439-445.

Thompson, L.M.And Troeh, F.R (1978). *Soils and soil fertility* Mcgaw-Hill Company. New York

Van Breitenbach, F. (1963). *Plant sociology.* The study of plants 2nd Ed. Addis Ababa, Ethiopia.

Veenedaal, E.M Ernst, W. H.O And Modise, G.S (1996) Effect of seasonal rainfall pattern seedling emergence and establishment of grasses : A savanna in south eastern Botswana. *Journal of Arid Environments* **32:**305-317

WCMC 1992 *Global Biodiversity*: Status of the earth's living resources Chapman and Hall, London.

Westheff, V. And Vander Maarel. (1978). The Braun Blanquet Approach. **In:** Whittaker, R.H And Junjunk, W.M.U (Eds), *Classification of plant communities* Pp 287 - 399 The Hague

Whittaker, R.H (1962) Classification of national communities. Bot. Rev. **1:**281-289.

Wildi, O.And Orloci, L. (1989) Mulva-4 A program package for multivariate data analysis in vegetation science.

Williams W.T And Lambert, J.M. (1961) Multivariate methods in plant ecology V. Similarity analyses and information analysis *Journal Of Ecology* **54 (2):** 427-442

Willson, R.T (1977) The Vegetations of central Tigere Ethiopia in relation to land use *Webbia* **32:**235-270

Yalden, W. (1983) The extent of high ground in Ethiopia compared to the rest of Africa *SINET Ethiop J.Sci* **6:**35-39

Yemane Asgedom (1991) An ecological study of the grassland vegetation in some parts of Gojam MSc Thesis, AAU

Yonas Yemshaw (2002) Overview of forest policy and strategy issues in Ethiopia **In:** Demel Teketay and Yonas Yemshaw (eds). *Forest And Environment.* Proceeding of 4th annual conference of forest society of Ethiopia Pp 8 - 15.

Yosef Assefa (2001) Distribution and structure of tree line species in ericaceous vegetation of Harrena escarpment, Bale Mountains MSc. Thesis, AAU.

Young, A.R And Giese, L.R (1990). *Introduction to forest.* 2nd ed. Johns Wiley and Sons USA

Zelalem Tefera (2001) Common property resource management of an afroalpine habitat: Supporting a population of the critically endangered Ethiopian Wolf (Unpublished Document)

Zerihun Woldu (1980) An ecological study of the montane grassland vegetation in Wolmera Woreda, Ethiopia. M.Sc. thesis, Addis Ababa, Ethiopia

Zerihun Woldu (1985) Variation in grassland vegetation of the central plateau of Shewa, Ethiopia in relation to edaphic factors and grazing condition. *Diss Bot* **84:**1-114

Zerihun Woldu (1999) *Forests in the vegetation of Ethiopia and their status in the geographical context.* **In:** *Forest genetic resources conservation : Principles, strategies and actions.* Proceedings of the National Forest Conservation Strategy Development Workshop, June 21-22, Addis Ababa, Ethiopia, Pp 1-36 (Edwards, S., Abebe Demssie, Taye Bekele and Hasse, G, eds). Institute of Bio-diversity Conservation and Research (IBCR), Addis Ababa, Ethiopia.

APPENDICES

Appendix 1..List of Plant Species Encountered in the Study Area

Ser.No	**Species name**	**Family name**	**Vernacular name**
1	*Alchemilla abyssinica* (Fressen)	Rosaceae	Yemedirkoso
2	*Alchemilla cryptantha*(A.Rich)	Rosaceae	Yemedirkoso
3	*Alectra vogelii* Benth	Scrophulariaceae	Ekolelye
4	*Andropogon abyssinicus*(Fresen)	Poaceae	Lesesar
5	*Andropogon amethystius* Steud	Poaceae	Lesesar
6	*Bolbostylis boeckelesiana*(Schweinf.Beetle)	Cyperaceae	
7	*Cardus chamaecephalus* (Vatke) Oliv. And Hiern.	Asteraceae	
8	*Cardus nyassanus(*S. moor) R.E.Fries	Asteraceae	
9	*Carex conferta*(Hochst.ex A.Rich)	Cyperaceae	
10	*Carex echinochloe* (Kunze)	Cyperaceae	
11	*Cineraria abyssinica* Schultz-Bip.Ex A.Rich	Asteraceae	
12	*Conyza abyssinica* Oliv. Hierm	Asteraceae	
13	*Conyza spinosa* Sch.Bip	Asteraceae	
14	*Crepis carbonaria* Sch. Bip.	Asteraceae	
15	*Cynoglossum geomerricum* Baker and Wright	Boraginaceae	Shewtamedhanit
16	*Dianthoseris schimperi*(Sch.Bip.exA. Rich)	Asteraceae	
17	*Dichocephala chrysanthemifolia* DC	Asteraceae	
18	*Dispacus pinatifidus*(Steud.ex.A.Rich)	Dipsacaceae	Ezohamebrat
19	*Erica arborea* (L.)	Ericaceae	Asta
20	Ferns		
21	*Ferrula communis*(L.)	Apiaceae	Gudie
22	*Festuca macrophylla*(Hochst ex. Rich)	Poaceae	Chima
23	*Festuca richardii*(Alexeev)	Poaceae	Guasasar
24	*Galium spurium*(L.)	Rubiaceae	Ashikt
25	*Habenstreitia □entate(*L.)	Scrophulariaceae	Keberojirat
26	*Haplocarpha rueppelii* (Schultz-Bip)P.Beauv	Asteraceae	
27	*Haplocarpha schimperi(*Sch.Bip.)Beauv.	Asteraceae	
28	*Helichrysum cymosum* (L.)Less	Asteraceae	Toncha
29	*Helichrysum formossissmum(*Sch.bip.)A.Rich	Asteraceae	Toncha
30	*Helichrysum forsskhalii* (J.F.Gmel)Hilliard and Burtt	Asteraceae	Toncha

31	*Helichrysum splendidum*(Thunb) Less	Asteraceae	Toncha
32	*Helichrysun gofense* Cuf.	Asteraceae	Toncha
33	*Hypericum revoltum* Vahl	Hypericaceae	Amja
34	*Laggera pterodenta* Sch.Bip.	Asteraceae	
35	Lichens		
36	*Lobelia rhynchopetallum* (Hochst .) Hemsl.	Campanulaceae	Gibra
37	*Malva verticillata*(L.)	Malvaceae	Tult
38	*Oestospermum Vaillanti*(Decene Norlindh)	Asteraceae	
39	*Pentaschistis pictigluma*(Steud. Pilger)	Poaceae	
40	*Rumex nepalensis*(Spreng)	Polygonaceae	Yewushamilas
41	*Rumex abyssinica* Jacq.	Polygonaceae	Mekmeko
42	*Salvia merjamie* Forsk.	Lamiaceae	Dabie
43	*Saturaja punctata* (Banth.)Briq.	Lamiaceae	
44	*Satureja paradoxa* (Vatke)Engen.ex Seybold	Lamiaceae	
45	*Satureja simensis*(Benth.) Briq.	Lamiaceae	
46	*Scabiosa columbaria* L.	Dipsacaceae	Yedmetayene
47	*Senecio ferseni*(Sch.bip.ex.oliv.)and Herm.	Asteraceae	
48	*Thymus serrulatus(*Hochst ex. Berth)	Lamiaceae	
49	*Thymus shimperi* (Ronniger)	Lamiaceae	Tosign
50	*Vernonia shimperi* DC	Asteraceae	
51	*Bidens prestinaria* (Sch.Bip) Cuf	Asteraceae	
52	*Agrostis gracilifolia* C. E.Hubb.	Poaceae	
53	*Helictotrichon elongatum* (Hochst.ex A.Rich)	Poaceae	
54	*Plantago afra* L.	Plantaginaceae	
55	*Agrostis quinquesta* (Hochst.ex Steud.)Hochst	Poaceae	
56	*Anthemis trigrensis* J .Gay ex Rich	Asteraceae	

Appendix 2 Meteorological Data of Nefas Mewucha and Debre Tabor Stations

Monthly Min.temp, Nefas mewcha Station												
Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov	Dec.
1987	-1.5	0.1	2.5	6.1	6.9	7.9	7.7	6.7	6.8	6.2	5.7	5.7
1988	6	7.4	9.2	9.9	9.6	9.5	8.5	8.1	7.7	6.7	6.2	5.8
1989	6.2	6.8	7.4	7.4	8.4	8.3	7.8	7.5	7.2	6.7	7.2	6
1990	5	5.4	4	7.2	8.4	8	6.5	7.8	6.5	7.1	6.7	6.2
1991	6	7.3	6.8	8.6	9.6	8.6	7.2	8.4	5.3	7.6		6.5
1992	7	8	10	9.3	10	10	8.1	7.9	7.5	6.8	6	6.9
1993	6.4	7.2	8.1	8.1	8.8	8.8	8.1	8.2	7.6	7.7	7.3	7.1
1994	7.7	8	8.5	9.3	9.3	7.9	8.9	8.9	7.8	6.8	7.8	8.7
1995	6.5	8.4	7.9	9.4	9.5	10	8.4	8.5	8.1	6.9	7.2	7.3
1996	7.5	8.8	9.2	9.5	9.2	8.8	12.1	8.1	8.3	6.9	6.7	6.9
1997	7.5	7.5	8.9	8.8	8.8	9	8.3	8.3	8.7	7.7	8.1	7.8
1998	8.1	8.5	9.5	10.5	10	10.4	8.1	8.4	8.3	7.6	6.3	6.1
1999	7.9	8.6	8.5	9.3	9.1	9.3	7.6	7.6	7.6	7	5.9	6.3
2000	6.8	7.3	8.7	8.2	9.5	9.7	8	7.7	7.8	7.2	6.8	6.8

	Monthly Max. temp., Nefas Mewucha											
Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1987	18.3	19.3	19.2	22.6	20	19.8	18.7	16.1	18.1	19.9	20.6	19.3
1988	20.3	18.2	23.3	22	22	20.3	16.5	16	17.4	20.4	20	19.3
1989	20.2	19.6	18.3	18	20	19.2	16.4	15.9	18.9	20.8	21.4	19.4
1990	21	20	19	17.8	21	20	15.8	16.5	18.4	18.9	21	19.5
1991	21.8	21	21.3	21.7	20	20.3	15.8	16.7	17.6	17.4	17.8	18
1992	17	19	20.2	20	20	19.7	15.4	13.6	14.9	15.2	14.9	16.3
1993	16.9	16.8	18.6	16.4	17	17.2	15	14.9	15.5	16.6	17.6	17.8
1994	18.6	19.2	19.2	20.2	21	19.5	16.2	15.1	15.2	17.4	17.9	18.3
1995	19.1	19.6	20.9	22.3	21	20.5	16.5	15.8	16.5	18.5	17	17.3
1996	18	19.7	19.6	19.2	18	16.2	15.6	14.8	16.7	17.4	17.4	16.3
1997	17.1	19.1	19.2	18.8	20	18	15.5	15.6	17.5	17.3	16.8	17.9
1998	18.4	19.3	20.1	21.2	20	19.4	14.4	14.9	16.2	16.9	17.4	17.9
1999	17.5	20	20.7	20.8	20	19.7	13.8	14.7	15.8	15.9	17.2	17.2
2000	18.2	19.7	21.3	18.2	20	19.5	15.8	14.8	15.9	16.5	16.8	17.3
Monthly Min. temp. , Debretabour												

12. The status of crop yield per unit area of land of this year when compared to the previous years

Year	Much better	Netter	Bad	Worse	No change
Before 1975					
1975-1984					
1984-1994					
1994-2002					

13. What are major factors affecting your crop yield in 2002 (put in order)

a) Flooding (run-off)

b) Insufficient/absence of rain

c) Frost

d) Hail storm

e) Weed

f) Birds

g) Decline of soil fertility

h) Lack of oxen

i) Others specify _____

14. Your cropland to the fertility, in your opinion, when compared to the previous years

a) Increased

b) Declined

c) No change

Give reasons for any choice_____

_____

16. Do you use fertilizer? _____ if yes, to which crop /plot do you apply? _____, since when? _____, how much?_____ , per unit of fertilizer _____,without fertilizer _____.

17.What other methods do you employ to restore soil fertility?

a) fallowing

b) crop rotation, state the crops rotated _____

c) others, specify _____

18. Concerning pasture and /or grazing land availability to the community of this area

Year	Enough	Medium	Most enough
Before 1975			
1975-1990			
1990-2002			

19. Information on the quality/palatability of grasses/woody plants of this area.

- Dominant grasses

  name_____

- " woody plants used for browsing _____
- " shrub plants used for browsing _____

20. At present, number of livestock in this area.

    a) Increased when compared to the last 20 years

    b) Declined when compared to the last 20 years

    c) No change

21. What is your opinion about livestock population of this area when compared to the availability of grazing land and feed?

    a) too large

    b) medium

    c) low

22. If you answer to question '21; above is 'a' what do you suggest to make the number of livestock in accordance with the available feed and grazing land?

    a) reducing number of livestock

    b) increasing the grazing land by reducing the cultivated land

    c) intensification of livestock rearing using modern systems

    d) other solutions, specify _____

23. List number of livestock your own

    Ox_____; Cow_____; Heifer_____; Bull _____;

    Horse _____; Mule _____.

24. What do you feed your livestock in addition to pasture? (put in order)

Feed	'Kiremt' (summer)	'Bega' (Winter)
Hay		
Freshcut grass		
Straw		
'Atela'		
Other, specify		

25. Specify the forest areas of this locality

a) if natural, name the area_____

b) if manmade, name the area _____

26. How is today's coverage of the forest when compared to the condition before 1974?

a) declined

b) increased

c) no change

Explain _____

27. If you answer to question '26' 'a' what were the major causes of deforestation? (put in order)

a) forest clearing to get additional crop land;

b) cutting of trees for fire wood;

c) burning /clearing to get better and additional grazing land/ pasture land;

d) cutting of trees for house and fence constructions;

e) clearing of forests to control enemies

f) Wildfire

g) forest clearing to control cultivated land from wild animals

h) cutting of trees for farm implements

i) browsing

j) others, specify _____

28. The rapid deforestation, in your knowledge, was observed in _____.

The reasons were_____

29. What are the consequences of deforestation seen in this area?

a) soil erosion and flooding

b) lack of fire wood, construction materials, etc.

c) micro climatic changed

d) others, specify _____

30. Have you observed soil erosion in your locality and crop field?

a) yes, very often

b) sometimes

c) not at all

31. If the answer to question '30' or 'a' or 'b', what are the causes? (put in order)

a) deforestation

b) up and down ploughing

c) overstocking of livestock

d) repeated ploughing

e) others, specify _____

32. What type of fuel do you used household needs? (list them in order)

Description	Before 1975	1975-1990	1990-2002
a) 'Asta' and 'Amja' (Erica and Hypericum)			
b) 'Beharzaf' /Eucalyptus			
c) other trees, specify_____			
d)crop residue			
e)dung cake			
f) charcoal			
g) kerosene			
h) others, specify _____			

33. Where are the fuel wood sources?

a) Near the locality area

b) At homesteads?

c) At Guna Mountain shrubs and herbs

d) Others,

specify_____

34. Do you have an interest to plant trees in this are? a) If yes _____;

Where?_____;

Why? _____;

by whom_____.

b) If no, reasons

1. Lack of land for afforestation
2. Lack of labour
3. Others, specify _____

35. Have you ever planted trees?_____

if yes, when _____; where_____; reasons

of planting _____.

36. Have you owned trees by now? _____

IF yes, type of trees_____ Number of

trees _____; purpose _____

37. What methods do you use to control soil erosion and flooding in your crop field?

---

38. Do you have an interest to protect Guna Mountain's wild animals and vegetation?

    a) IF yes, reasons _____

    b) IF no, reasons _____

39. Do you feel that the community should participate in wild life and forest conservation? _____

40. What are your final conclusion about Guna Mountain?

    a) It should be protected

    b) It should be used for as pasture land

    c) It should be used for as cultivated land

    d) IT should be used for as fuel wood land

Appendix 4. Regression Model Showing relationship between altitude and present soil moisture content at Guna Massif

MODEL: MOD_1.

Independent: ALTITUDE

Dependent Mth	Rsq	d.f.	F	Sigf	bo	b1
MOISTURE LIN	.026	43	1.13	.293	70.9574	-.0093

The Following new variables are being created:

Name	Label
FIT_1	Fit for MOISTURE with ALTITUDE from CURVEFIT, MOD_1 LINEAR
ERR_1	Error for MOISTURE with ALTITUDE from CURVEFIT, MOD_1 LINEAR

Appendix 5. Seasonal biomass production (gm $^{-2}$) of the two grass species in different periods of the year (n=6, mean ± sd)

Species	**Growth Periods**		
	Feb - June	June - Oct	Oct - Jan
Festuca richardii	86.7 ± 59.3 aA	120.8 ± 59.3 bA	102.0 ± 26.7 aA
Mixed	109.9 ± 59.3 aB	145.7 ± 71.4 bA	93.4 ± 28.4 aB

Appendix 6. Annual biomass production (gm $^{-2}$) of the two grass species

Species	**Biomass Production (gm $^{-2}$)**
Festuca richardii	95.6 ± 29.4 A
Mixed	115.2 ± 73.4 B

Means followed by the same lower case letter in rows and mean followed by the same upper case letters in columns are not significantly different at $p \leq 0.05$ as determined by Tukey's Family Error Rate.

Appendix 7. Soil Data in the Study Area

RELEVE	Sand(%)	Clay(%)	Silt(%)	Soil moisture content(%)	pH Reading	Conductimeter (milimhos/cm)
1	68.2	16.8	14.9	34.6	5.59	0.2
2	63.16	14.8	22	29.6	5.33	0.2
3	64.24	12.84	22.92	48.9	5.12	0.06
4	68.2	12.84	18.96	25	4.94	0.14
5	74.24	10.84	14.92	57	5.5	0.08
6	57.16	13.76	29.08	48	5.36	0.07
7	82.24	2.76	15	27.2	5.55	0.07
8	77.24	0.24	22.52	28.8	5.46	0.06
9	67.24	1.72	31.04	45.8	5.63	0.11
10	60.24	9.72	30.04	42.8	6	0.08
11	76.24	0	23.76	16.6	5.33	0.18
12	78.24	0	21.76	25	5.39	0.06
13	84.24	0	15.76	22	5.49	0.05
14	72.24	1.76	26	32	5.25	0.05
15	69.24	0	30.76	37.2	5.25	0.08
16	81.24	0	18.76	22.8	5.15	0.07
17	79.24	0	20.76	22.8	5.05	0.01
18	78.24	0	21.76	40	5.14	0.1
19	80.24	0	19.76	22.8	5.12	0.06
20	78.24	0	21.76	40	5.28	0.04
21	64.24	0	35.76	59	5.36	0.04
22	69.24	0	30.76	42.8	5.31	0.1
23	66.72	0	33.28	20.6	5.2	0.04
24	79.24	0.24	20.52	59	5.16	0.25
25	77.24	0	22.76	23.6	5.06	0.2
26	87.76	0	12.24	42.8	5	0.2
27	87.24	0	12.76	45.8	4.95	0.07
28	81.76	0	18.24	45.8	4.9	0.07
29	85.24	0	14.76	46.3	4.88	0.17
30	99.24	0	0.76	46.3	4.88	0.14
31	72.72	0	27.28	44	4.88	0.16
32	75.76	0	24.24	40	4.72	0.1
33	86.24	0	13.76	34.6	4.55	0.04
34	83.24	0	16.76	59	4.49	0.16
35	85.76	0	14.24	36.5	4.33	0.06
36	85.76	0	14.24	37.6	4.34	0.18
37	97.24	0	2.76	32	4.37	0.16
38	93.76	0	6.24	34	4.38	0.1

RELEVE	Sand(%)	Clay(%)	Silt(%)	Soil moisture content(%)	pH Reading	Conductimeter (milimhos/cm)
39	79.24	0	20.76	37.2	4.45	0.09
40	75.24	0	24.76	40	4.47	0.09
41	86.28	0	13.72	27.2	4.52	0.07
42	63.24	0.76	36	26	4.56	0.2
43	79.76	0.76	19.48	35.5	4.57	0.06
44	83.24	0	16.76	28.6	4.52	0.09
45	70.24	0	29.76	23.3	4.49	0.11

Appendix 8. Grasses Biomass Data in the Study Area

	February-June	June-October	October-January
	Mixed species (gm/m2)	Mixed species (gm/m2)	Mixed species (gm/m2)
R1	107.8	250	101.8
R1	269.9	120	113.6
R1	163.2	104.6	62
R1	271	188.4	106.7
R1	73.5	405.7	188.2
R1	80	280.5	118.8
R1	63.7	266.6	112.3
R1	78.9	189.9	104.6
R2	*63.1*	96.8	92
R2	151.4	210	66
R2	61.4	173.7	71.5
R2	134.4	96.6	62
R2	19.9	77	116.2
R2	0	107	80
R2	21.2	98.9	72.3
R2	20.3	110.2	81.9
R3	107.9	82	98
R3	0	156	101.5
R3	88.3	35.3	90
R3	152.7	33	79.9
R3	45.7	129.3	37.5
R3	63	11.4	98
R3	53.6	88.6	68.9
R3	62.4	77.7	73.7
	Festuca richardii	*Festuca richardii*	*Festuca richardii*
	51.9	93.7	98
	97.2	106	113.8
	130.5	93	126.5
	38.9	96	95.3
	37.7	92	80
	67	95.7	150
	65	97.2	120.8
	58.9	95.2	133.6

Appendix 9. Show Correlation between the common resources consumption from Guna area and distances from the adjoining peasant associations.

Name of peasant Association	Average common resources consumption from Guna area (%)	Average distance from Guna at tree line (Km)
Dibana	79.4	4.0
Dat Giorgis	57.8	5.5
Mokish	92.7	3.0
Soras	90.2	3.0
Titera	89.7	3.0
Yitba	80.6	3.5
Kefoye and Dera	10.0	6.5
Gedeba and Guna	83.4	3.3

Correlations

Correlations

		Percentage of Average Resource Consumption From Guna Area	Average Distance From Guna Area (Kilometer)
Percentage of Average Resource Consumption From Guna Area	Pearson Correlation	1.000	-.956**
	Sig. (2-tailed)	.	.000
	N	8	8
Average Distance From Guna Area (Kilometer)	Pearson Correlation	-.956**	1.000
	Sig. (2-tailed)	.000	.
	N	8	8

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 10. Soil Analysis Based on Multiple Response

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	pH - EC	4,9100	,3698	,1510	4,5220	5,2980	32,527	5	,000
Pair 2	pH - Soil Moisture	-31,4667	1,8228	,7442	-33,3796	-29,5537	-42,285	5	,000
Pair 3	pH - % Sand	-72,5833	4,3079	1,7587	-77,1042	-68,0625	-41,272	5	,000
Pair 4	pH - % Clay	3,8183	1,9232	,7852	1,8000	5,8366	4,863	5	,005
Pair 5	pH - % Silt	-17,5500	,7765	,3170	-18,3649	-16,7351	-55,360	5	,000
Pair 6	EC - Soil Moisture	-36,3767	1,5878	,6482	-38,0429	-34,7104	-56,119	5	,000
Pair 7	EC - % Sand	-77,4933	3,9588	1,6162	-81,6478	-73,3388	-47,949	5	,000
Pair 8	EC - % Clay	-1,0917	2,1593	,8815	-3,3578	1,1744	-1,238	5	,271
Pair 9	EC - % Silt	-22,4600	1,0693	,4365	-23,5821	-21,3379	-51,452	5	,000
Pair 10	Soil Moisture - % Sand	-41,1167	2,9253	1,1943	-44,1866	-38,0467	-34,428	5	,000
Pair 11	Soil Moisture - % Clay	35,2850	3,7285	1,5221	31,3722	39,1978	23,181	5	,000
Pair 12	Soil Moisture - % Silt	13,9167	2,0034	,8179	11,8142	16,0191	17,015	5	,000
Pair 13	% Sand - % Clay	76,4017	5,9076	2,4118	70,2020	82,6013	31,679	5	,000
Pair 14	% Sand - % Silt	55,0333	4,7610	1,9437	50,0370	60,0296	28,314	5	,000
Pair 15	% Clay - % Silt	-21,3683	2,1500	,8777	-23,6246	-19,1121	-24,345	5	,000

Appendix 11. Number of Estimated Human and Livestock Populations in Guna Massif Adjoining Areas.

Peasant Association	Human Population	Livestock population Excluding Poultry
Dibana	4600	5000
Dat Giorgis	5500	6200
Mokish	4900	5300
Soras	4820	5000
Titera	3500	4200
Yitba	3890	4400
Kefoye and Dera	4500	5010
Gedeba and Guna	4490	5320
Total	36200	40430

Source: Farta, Estie and Lay Gaynt Woredas' Agricultural Development Offices, February 2 003