ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DIVERSITY, REGENERATION STATUS AND SOCIO-ECONOMIC IMPORTANCE OF THE VEGETATION IN THE ISLANDS OF LAKE ZIWAY, SOUTH-CENTRAL ETHIOPIA

BY

HAILEAB ZEGEYE

Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Biology (Botanical Sciences)

JUNE 2004

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ABSTRACT

The study was conducted in the islands of Lake Ziway located in the Main Ethiopian Rift part of the Ethiopian Rift Valley in south-central Ethiopia. The main objective of the study was to investigate the diversity, regeneration status, socio-economic importance and the factors that cause degradation of the plant resources in the islands. Vegetation and socio-economic data were collected between 18 September and 7 November 2003. A total of 73 relevés, measuring 20 m x 20 m (400 m^2), were established along line transects laid from central part of each island to the lake edge in eight aspects. Herbaceous species were sampled by using a 2 m x 2 m (4 m^2) sub-relevé laid within each relevé. In each relevé, the cover/abundance of each species was estimated, woody species were counted, diameter at breast height of trees and shrubs and environmental variables (altitude, slope, aspect and position) were measured. Participatory Rural Appraisal method was employed to generate the socio-economic information. A total of 141 species belonging to 113 genera and 55 families were identified, of which 18.4% were trees, 21.3% trees/shrubs, 12.1% shrubs, 3.5% lianas, 4.3% herbaceous climbers and 40.4% herbs. The overall diversity and evenness of woody species in the islands were 2.60 and 0.62, respectively. The number of species on the islands correlated with island's size, degree of human disturbance as well as habitat diversity. The similarity in species composition between the islands was low, indicating that each island has its own unique flora. Nine plant communities were recognized and described. The total density and basal area of the vegetation were 2979 individuals ha^{-1} and 191 m^2ha^{-1}, respectively. The importance value index and the diameter class distribution revealed that some species are threatened and need the highest priority for conservation. The socio-economic survey showed that the island communities are highly dependent on the natural vegetation for various

purposes. On the other hand, the islanders have maintained the soil and vegetation resources for several years through their indigenous resource management systems and practices. Human population growth coupled with farmland expansion, soil erosion, free grazing and cutting trees for various purposes are the major threats to the vegetation resources in the islands. The implications of the results are discussed and recommendations are suggested for conservation, management and sustainable utilization of the fragile island ecosystems.

Keywords: Diversity, regeneration, conservation, plant community types, socio-economics, islands of Lake Ziway

1. LITERATURE REVIEW AND JUSTIFICATION

1.1. Concepts and Levels of Biodiversity

The Earth holds a vast diversity of living organisms and an immense variety of habitats and ecosystems. All of this variation in species, habitats and ecosystems is referred to as biological diversity/biodiversity (Ricklefs and Miller, 2000). Biodiversity includes a number of different levels of variation in the natural world. The most commonly encountered measures of biological diversity are genetic diversity, species diversity and ecosystem diversity. These three main components of biodiversity are inextricably interlinked.

Genetic diversity is the variation in the genetic makeup of organisms. It refers to the genetic variability within species, i.e. the genetic variation between individuals within populations and between populations within species. In a broader sense, genetic diversity exists at various taxonomic levels such as species, genera, families, orders, phyla and kingdoms. Species diversity is the diversity of species in a given area. Species diversity contains two quite distinct concepts, species richness and species evenness (Krebs, 1989; Begon *et al.*, 1996; Barnes *et al.*, 1998). Species richness refers to the number of species in a given area. Species richness is the most fundamental component and commonly used measure of biological diversity. Species evenness (equitability) is the relative abundance of species in an area. Relative abundance can be measured by number of individuals, cover, biomass, productivity, or any measure that quantifies the importance of the species. Ecosystem diversity is the diversity of habitats and ecosystems in an area. It refers to the variety of terrestrial ecosystems (forests, woodlands, grasslands, wetlands, deserts, etc.) and aquatic ecosystems (marine and

freshwater ecosystems). Ecosystems consist of biotic and abiotic components and the interactions and processes that take place within and between these components.

Biodiversity is dynamic and varies in space and time. At spatial scales, biodiversity can be measured as alpha diversity, beta diversity and gamma diversity (Bisby, 1995; Rosenzweig, 1995; Ricklefs and Miller, 2000). Alpha diversity (local diversity) is the diversity of species at local spatial scales. It refers to the number of species in a single site or habitat (WCMC, 1992; Rosenzweig, 1995; Ricklefs and Miller, 2000), or the number of species occurring within an area of a given size (Bisby, 1995). It is a measure of within-area diversity. Gamma diversity (regional diversity) is the species diversity at regional spatial scales. It is the total number of species in all habitats within a region (Rosenzweig, 1995; Ricklefs and Miller, 2000). Gamma diversity is also a measure of within-area diversity like alpha diversity. However, it most often refers to overall diversity within a large region (Bisby, 1995). Beta diversity, also known as species turnover or differentiation diversity, is the degree of change in species composition across a region or landscape along major environmental gradients such as latitudinal, altitudinal and ecological gradients (WCMC, 1992; Bisby, 1995). It is a measure of the difference in diversity from one habitat or area to the next. Beta diversity is a measure of between-area diversity.

Biodiversity also includes the human dimension and this aspect of biodiversity is referred to as cultural diversity (Heywood and Baste, 1995). There are innumerable interactions between human society and biodiversity. The different cultural dimensions in different parts of the world have played a major role in the conservation, management and sustainable use of biodiversity.

1.2. Values of Biodiversity

Biodiversity has fundamental importance in the maintenance of environmental stability and well-being of human society. It has ethical, social, cultural, economic, medicinal, scientific, educational, aesthetic and ecological values. Biodiversity is part of our daily lives and livelihoods, and constitutes the resources upon which families, nations and future generations depend (Heywood and Baste, 1995). Biodiversity is the source of economic and ecological security of present and future generations (ICRAF, 2000).

Biodiversity plays a fundamental role in sustainable development since it is the main source of raw materials for agricultural, medicinal and industrial innovations (Fassil Kebebew, 2002). Biological resources, as represented by the wide array of plants, animals and microorganisms, provide the basic materials for development and sustenance of humanity. They provide food, feed, wood, medicine, fibre, dye, resin, oil, gum, spice and industrial raw material. Moreover, ecosystems provide a range of ecological services and functions that are vital to the maintenance of all forms of life vis-a-vis soil stabilization, watershed protection, regulation of the hydrological cycle, nutrient cycling, energy flow, control of pollution, maintenance of climate, etc.

1.3. Threats to Biodiversity

Globally, humans are the dominant agents influencing biodiversity. The influence of humans on the Earth's biological systems is increasing exponentially (Heywood and Baste, 1995). The increased human interference has resulted in destruction of the environment and, consequently, disruption of evolutionary and ecological processes. The world's terrestrial and

aquatic ecosystems have been so significantly modified by human activities. As a result of heedless human actions, biodiversity is being lost at an alarming rate (Heywood and Baste, 1995; Jeffries, 1997; Tadesse Woldemariam, 1999; Engels and Engelmann, 2002). There is a rapidly accelerating loss of populations, species, habitats and ecosystems. The major factors that cause degradation of ecosystems and loss of biodiversity are rapid human population growth, agricultural expansion, urbanization, incidence of fire, inappropriate policies, inequity in natural resource ownership and utilization, lack of adequate scientific knowledge, introduction of species, genetically modified organisms (GMOs), pollution and global climate change.

1.4. Strategies for Biodiversity Conservation

There are several methods for conservation of biological diversity. The different conservation methods can be broadly divided into two approaches, *in situ* and *ex situ*. Conservation methods are not exclusive, but complement each other (Wolf, 1999). In order to ensure the conservation of the widest possible range of biodiversity and to minimize the risk of genetic erosion, the various conservation methods should be combined in an integrated approach (IPGRI, 1993; Miller *et al.*, 1995; Jeffries, 1997; Wolf, 1999). There is no universal method that can cover all conservation purposes. Thus, integrated or complementary conservation is required for effective conservation of biodiversity.

Due to the complexity of biodiversity, rapid loss of biodiversity, and increased realization of the importance of undertaking cost-effective programmes, developing realistic and viable strategies and establishing priorities for effective conservation and management of genetic

resources will always be necessary (IPGRI, 1993; Miller *et al.*, 1995; Vane-Wright, 1996; Kigomo, 1999; Wolf, 1999; ICRAF, 2000; Coates and Atkins, 2001; Engels and Engelmann, 2002). There is a need for identification of action priorities both in geographical space and biological importance (Jarvis *et al.*, 2002). The choice of suitable conservation methods depends on the objectives of the envisaged genetic conservation and the ecological requirements of the species in question. Conservation is a dynamic process, which requires continuous evaluation based on newly acquired research results.

1.4.1. *In Situ* Conservation

In situ conservation is the conservation of genetic resources within the natural ecosystem in which they occur. It maintains species in dynamic relationships with the habitat and allows gene flow and geographical distribution (Edwards and Ensermu Kelbessa, 1999). Ecosystems, species and populations are dynamic and, hence, are variable in space and time. *In situ* conservation allows evolutionary and ecological processes to take place and promotes genetic variability and adaptability of species to changing environmental conditions. Therefore, conservation of biodiversity is best achieved in natural ecosystems (WCMC, 1992; Heywood and Baste, 1995). In addition, the *in situ* conservation approach allows the conservation of a large amount of genetic, species and ecosystem diversity in a very extensive and cost-effective manner (Wolf, 1999).

In situ conservation is most often achieved by establishment and management of protected areas, defined as geographically delineated areas that are designated or regulated and managed to achieve specific conservation objectives (Miller *et al.*, 1995). Protected areas should have

sufficient size that can allow the maintenance of a given ecosystem or species (IUCN, 1990; Jeffries, 1997; Wolf, 1999). In addition, there is a need to have protected area systems that are representative of major landforms, habitats or ecosystems. Protected areas play a great role in the conservation of biodiversity, and have ecological, scientific, educational, aesthetic and long-term socio-economic values.

The sustainability of *in situ* conservation in protected areas depends on the long-term protection and effectiveness of management (IUCN, 1990; IUCN, 1992; Miller *et al.*, 1995; Jeffries, 1997; Wolf, 1999). It is necessary to provide adequate budget and qualified manpower in order to ensure the effectiveness of protected areas for maintaining biodiversity. In addition, the development and management of protected areas need the participation of the local people in making decisions and undertaking conservation measures. The conservation of biodiversity in protected areas requires the generation of appropriate incentives from international, regional and national agencies for resource users both inside and outside the protected areas. It is important to provide incentives of various forms (tax breaks, subsidies, etc.) for the local people in order to ensure the sustainability of protected areas. There is a need to have appropriate mechanisms for sharing benefits that are generated from the conservation and sustainable use of biodiversity within protected areas. For instance, in Cameroon and Zimbabwe, the involvement of local people in conservation activities and sharing of benefits derived from the protected areas have been found most effective (Jeffries, 1997). However, in Ethiopia and many other African countries, protected areas have failed to meet their conservation objectives mainly because of the exclusion of local people from participation and lack of appropriate mechanisms to provide incentives.

Another dimension of *in situ* conservation is on-farm conservation. On-farm conservation is the conservation of crops and their wild relatives, livestock and the agroecosystems in which they occur. *In situ* conservation on-farm is important for maintenance of agricultural biodiversity/agrobiodiversity. Indigenous/traditional resource management systems and agricultural practices play an important role in the maintenance and diversification of domesticated plants and animals (McNeely *et al.*, 1995). Low-input agricultural systems are important sources and custodians of biodiversity. Farmers and pastoralists maintain a tremendous diversity of crop and livestock varieties around the world. Indigenous knowledge, skills and practices of farmers play an important role in the conservation, management and sustainable utilization of agricultural biodiversity. They are better options for building the scientific basis of *in situ* conservation of agrobiodiversity on-farm (Shewaye Deribe *et al.*, 2002). For instance, the farmers' indigenous knowledge and practices in germplasm selection, storage and exchange are major elements in the conservation of agricultural biodiversity through community genebanks.

The expansion of large-scale/modern agricultural systems, in which relatively a few improved varieties have replaced many farmers' varieties, has caused erosion of agricultural biodiversity. Therefore, there is a need for basing the rural development strategy on traditional farming systems, knowledge and agroecological techniques in order to ensure the maintenance and continual use of the diverse genetic resources associated with traditional agricultural systems (Miller *et al.*, 1995; Fassil Kebebew, 1997). Farmer-based on-farm conservation of agrobiodiversity has been found a more successful approach.

1.4.2. *Ex Situ* Conservation

Ex situ conservation is the conservation of genetic resources outside the natural ecosystem in which they occur. It interrupts evolutionary processes and limits genetic variability and adaptability of species to changing environmental conditions. If *in situ* conservation is not feasible due to various reasons, threatened species can only be conserved *ex situ* (Jeffries, 1997; Wolf, 1999). *Ex situ* conservation could be instrumental in maintaining the sources of materials for restoration of genetic diversity. It is also useful for research purposes. *Ex situ* conservation methods include zoos, botanical gardens, arboreta, field genebanks and genebanks. The costs required for *ex situ* conservation are significantly higher than those required for *in situ* conservation (Wolf, 1999).

1.4.3. Environmental Education

Environmental education is a dimension within the educational system that deals with the environment. It helps to understand the impact of human activities on the environment. Environmental education is a multidisciplinary approach that helps to create awareness in the society and the government about the environment so that they can be actively involved in solving environmental problems. It enables people to acquire knowledge, attitudes and skills in order to analyze issues, assess benefits and risks, make informed decisions and take responsible actions to achieve and sustain environmental quality (Tefera Wogderesegn, 1999). Therefore, there is a need to create awareness about issues of the environment and consequences of environmental degradation at local, national and global levels. Creating environmental awareness at various levels helps for the development of truly participatory conservation systems (Frison *et al.*, 2002). Environmental education is indispensable for

creating awareness and promoting public participation in the conservation, management and sustainable utilization of biodiversity.

1.5. Biodiversity and Its Conservation in Ethiopia

1.5.1. Biodiversity in Ethiopia

Ethiopia is endowed with immense wealth of biological resources. It is recognized internationally as a major centre for biodiversity (Edwards and Ensermu Kelbessa, 1999; Yonas Yemshaw, 2002). The diversity of biological resources in Ethiopia is due to its diverse topography, climate and edaphic (soil) factors. The complex topography and environmental heterogeneity in the country have resulted in ecosystem diversity. The country possesses most of the major ecological systems in the world. Due to its diversified terrestrial and inland aquatic ecosystems, Ethiopia is rich in floral, faunal and microbial diversity. The enormous ecological diversity offers suitable habitats for a wide range of lifeforms.

Ethiopia is one of the centres of plant diversity in the world. The Ethiopian flora is very heterogeneous and has many endemic species. Ethiopia possesses over 7,000 species of higher plants, of which about 12% are endemic (IBCR, 2001). The country possesses diverse indigenous tree species (Gebre Markos Wolde Selassie, 1998). Vegetation types in Ethiopia are highly diverse, ranging from afroalpine to desert vegetation. The Ethiopian vegetation is broadly classified into nine major vegetation types: afroalpine and sub-afroalpine vegetation, dry evergreen montane forest and grassland, moist evergreen montane forest, lowland dry semi-evergreen forest, evergreen scrub, *Combretum-Terminalia* (broad-leaved) deciduous woodland, *Acacia-Commiphora* (small-leaved) deciduous woodland, desert and semi-desert

scrubland and wetland vegetation. Because of the variation of agroecological conditions, and social, economic and cultural diversity of the people, Ethiopia is a centre of origin and/or diversity for many crops (IBCR, 2001; Tadesse Woldemariam and Demel Teketay, 2001; Tesema Tanto, 2002; Tesema Tanto and Abebe Demissie, 2002).

Likewise, Ethiopia is known for its faunal diversity, including domestic, wild and aquatic animal genetic resources. The country possesses about 277 species of mammals, 861 species of birds, 201 species of reptiles, 63 species of amphibians and 150 species of fishes, of which about 11.2% of mammals, 3.3 % of birds, 4.5% of reptiles, 38.1% of amphibians and 2.7% of fishes are endemic (IBCR, 2001). Ethiopia has the largest livestock resource in Africa and the tenth largest in the world (Demel Teketay *et al.*, 2003).

Although there are no substantial studies on microbial genetic resources, preliminary assessments show the existence of various types and species of microorganisms in the country (Mulatu Geleta, 1999; IBCR, 2001). The diversity in microorganisms includes bacteria, fungi, algae, protozoa and viruses.

Ethiopia's economy largely depends on natural resources. Most Ethiopians depend entirely on biological resources for their food, clothing, shelter, energy, health care and recreational requirements. In general, Ethiopia's biodiversity constitutes an important resource base that supports, or has the potential to support, important development programmes in agriculture, health and industry (Mulatu Geleta, 1999). The rich biodiversity existing in the country plays a great role in attaining sustainable development.

However, the biological resources of Ethiopia are being destroyed at an alarming rate because of a combination of factors. The major factors that cause degradation of ecosystems and loss of biodiversity in Ethiopia are rapid human population growth coupled with agricultural expansion, overexploitation of natural resources, lack of appropriate policies and strategies, mismanagement, lack of adequate scientific knowledge, introduction of exotic species, low level of environmental awareness, pollution and recurrent drought (IBCR, 2001; Demel Teketay *et al.*, 2003; Ermias Bekele, 2003; Gete Zeleke, 2003).

1.5.2. Status of Biodiversity Conservation in Ethiopia

Biodiversity conservation by government bodies has a short history in Ethiopia (Gebremedhin Hadera, 2000). But it is clear that the traditional resource management systems and practices used by local people have played a major role in the conservation, management and sustainable utilization of natural resources. At present, owing to the increasing realization of the importance of conservation, management and sustainable utilization of biological resources in socio-economic advancement and the gaps that exist in the conservation efforts in Ethiopia, various institutions have been established and a range of endeavours have been underway.

The Institute of Biodiversity Conservation (IBC), formerly known as Plant Genetic Resources Centre/Ethiopia (PGRC/E), Biodiversity Institute and until very recently Institute of Biodiversity Conservation and Research (IBCR), was established with the responsibility to promote the conservation, management and sustainable utilization of the country's biodiversity. IBC has played major roles in conserving the country's biological resources

using *in situ* and *ex situ* conservation methods, including conservation and research in protected areas and on-farm conservation of agricultural biodiversity/agrobiodiversity. It has accomplished a tremendous work in exploration, collection and conservation of plant genetic resources. Genebanks for long-term storage and management of crop and forest germplasm have been put in place, which currently hold about 61,000 accessions of 104 plant species, of which about 53,900 accessions (90%) are field crops and 7100 accessions (10%) are wild plants (IBCR, 2001).

In order to enhance the conservation, management and sustainable utilization of the country's biological diversity, IBC is involved in promoting the indigenous/traditional knowledge and methods, creating awareness among the public and government, encouraging the participation of the community and stakeholders in natural resource conservation and management, collection and documentation of biodiversity information, enhancement of technological capabilities, and collaboration with relevant national, regional and international institutions.

There are also several governmental institutions involved in the conservation, management and sustainable use of biodiversity in the country. The Ethiopian Agricultural Research Organization (EARO), formerly known as the Institute of Agricultural Research (IAR), is a Federal institution legally mandated to carry out agricultural research and coordinate agricultural research activities conducted by other institutions (Demel Teketay *et al.*, 2003). To conserve the remaining natural forests of Ethiopia, 58 National Forest Priority Areas (NFPAs) have been designated. The Ethiopian Wildlife Conservation Organization (EWCO) is concerned with the conservation, management and sustainable use of wildlife resources, primarily large fauna (EFAP, 1994). This has been undertaken by designation of 40 Wildlife

Conservation Areas (WCAs) (National Parks, Wildlife Sanctuaries, Wildlife Reserves and Controlled Hunting Areas). The Ethiopian Environmental Protection Authority (EPA) is an autonomous Federal government authority mandated to undertake the formulation and implementation of environmental policies and laws, development and implementation of environmental standards, awareness creation on environmental issues and environmental monitoring. Higher learning institutions are not only involved in research but also provide training and extension services pertinent to the environment in the country.

There are quite a large number of local Non-Governmental Organizations (NGOs) working on various aspects of environmental management. The Ethiopian Wildlife and Natural History Society (EWNHS), Forum for Environment, Forum for Social Studies (FSS) and Institute of Sustainable Development (ISD) are involved in environmental advocacy and awareness creation. There are also many professional societies/associations concerned with the sustainable management of the environment. The Forestry Society of Ethiopia (FoSE) is involved in addressing threats to forest resources of Ethiopia and creating awareness in order to enhance their conservation, management, development and sustainable utilization. The Biological Society of Ethiopia (BSE) is playing an important role in addressing environmental issues and creating awareness in the public and the government so as to promote the conservation, management and wise use of biological resources in the country.

In addition, there are a number of international institutions relevant to environmental management in Ethiopia. The most important institutions include the International Livestock Research Institute (ILRI), International Union for the Conservation of Nature and Natural Resources (IUCN), World Wide Fund for Nature (WWF), United Nations Environment

Program (UNEP), Global Environment Facility (GEF), Food and Agriculture Organization of the United Nations (FAO) and United Nations Development Program (UNDP).

The National Herbarium (ETH), managed by the Department of Biology of the Addis Ababa University, is being involved in the inventory of the flora of Ethiopia, collection and deposition of plant specimens, documentation and dissemination of scientific information, scientific research, and collaboration and coordination with relevant national and international institutions so as to facilitate the conservation, management and sustainable utilization of the flora in the country.

However, there are many gaps in biodiversity conservation efforts and coordination of the existing conservation activities. Therefore, the conservation, management and sustainable use of the country's biodiversity require proper implementation of the policies and strategies.

1.5.3. Role of Religious Institutions in Biodiversity Conservation in Ethiopia

In Ethiopia, there are remnant forests or woodlands around churches, monasteries and mosques. Sacred groves are patches of natural vegetation conserved on religious grounds and they represent a long tradition of nature conservation based on sound ecological principles as practiced by indigenous people. Despite the tremendous human population pressure on the forest resources, sacred groves have survived in many parts of Ethiopia. In northern Ethiopia, where deforestation is more pronounced, forests around churches are the main remnant patches of natural forests (Alemayehu Wassie, 2002; Alemayehu Wassie *et al.*, 2004a, b). The

Ethiopian Orthodox Church has a long history of protecting the vegetation around churches and monasteries and planting of trees and shrubs.

Sacred groves retain high levels of biodiversity (Regassa Feyissa, 2001), and particularly they contain diverse plant species including endemic and economically important plants (Desalegn Dessisa and Binggeli, 2002). They also harbour animals and microorganisms. Sacred groves have religious, social, cultural, economic and ecological importance. However, many sacred groves are facing serious depletion of resources because of the increased demand for forest products as well as farming and grazing lands (Regassa Feyissa, 2001; Desalegn Dessisa and Binggeli, 2002).

Sacred forests are important sites for *in situ* conservation of forest genetic resources and can serve as sources of seeds or genetic material. However, there is no or very little information on the diversity, dynamics and conservation status of these forests (Demel Teketay, 1999). Shameem and Balakrishnan (2003) suggested that implementation of effective sacred grove conservation with the participation of local people would help in the continued existence of a variety of organisms in the developing tropical nations, which would otherwise be vanished through development processes. Taking this into consideration, studies have been started to generate relevant information on sacred forests (Alemayehu Wassie, 2002; Desalegn Dessisa and Binggeli, 2002). Such works will contribute for the conservation, management and sustainable utilization of sacred forests and enhance their role in the conservation of the country's forest resources.

1.6. Island Biogeography

An island is a self-contained region whose species originate entirely by immigration from outside the region (Rosenzweig, 1995). By self-contained it is meant that each of the species within the region has an average net rate of reproduction sufficient to maintain some positive population size. Islands include the literal oceanic islands but also islands on mainland such as lake islands and separate patches of the same habitat scattered through the landscape.

Islands have distinctive ecological systems. They shelter unusual relicts, strange combinations and extraordinary evolutionary radiations (Jeffries, 1997). There is high endemism on islands (Rosenzweig, 1995; Cook and MacDonald, 2001; Cook *et al.*, 2001). The presence of high endemics on islands is most probably attributed to allopatric speciation, which takes place as a result of geographical isolation, and sympatric speciation. Generally, islands have low species richness (Mooney *et al.*, 1995; Jeffries, 1997; Cook and MacDonald; 2001). However, there are some islands such as Madagascar, Mauritius, Galapagos and Hawaii, which possess high biodiversity (Jeffries, 1997).

The process of plant migration is of crucial importance to island floras, especially those of oceanic islands. Floras of the islands usually comprise a specialized subset of the mainland flora, or evolutionary derivatives of these subsets, members of which have been able to gain access to the islands by means of long-range dispersal and subsequently evolve in the unique habitat conditions and freedom of competition (Kellman, 1980). Many of the species could be more ancient arrivals that have diverged substantially from their early progenitors, and some of the species may be very recent arrivals that are indistinguishable from the mainland species.

The dynamics of island biotas depends on two processes, immigration and extinction (Jeffries, 1997). Island biotas are in a dynamic state in which the number of species depends on the balance between immigration and extinction (Rosenzweig, 1995; Begon *et al.*, 1996; Jeffries, 1997; Ricklefs and Miller, 2000). Species diversity on islands depends on island size, habitat heterogeneity, species interactions like competition and predation, distance from the mainland, richness and dispersal ability of the source pool species, or combinations of these factors. Disturbance regime is also an important factor that determines species richness on islands.

Island ecosystems are extremely fragile. Island biotas are prone to extinction (Begon *et al.*, 1996; Jeffries, 1997; Cook and MacDonald, 2001; Cook *et al.*, 2001). This is because they are vulnerable to natural calamities such as climatic changes, diseases and storms and a variety of anthropogenic disturbances like habitat destruction and fragmentation, overexploitation and species introductions. Deliberate or unintentional introductions of species can be disastrous to island flora and fauna. The islands of Hawaii have lost more than half of their original endemic species due to incautious introductions of other animals and plants (IUCN/UNEP, 1986). Islands of Africa like Mauritius, Reunion and Rodrigues have suffered from a devastating wave of extinctions in historic times, much of which can be attributed to introduced species (IUCN, 1990). To date, there is increasing impoverishment of island biotas.

Islands have a historic role in the understanding of biodiversity. The Galapagos Islands are the lion share examples in understanding and explaining evolutionary processes. In addition, the theory of island biogeography has many implications in the conservation and management of ecosystems. Island biogeography has particular relevance in the design, selection and management of protected areas (IUCN/UNEP, 1986). It is useful for determination of size,

shape and ecosystem coverage of protected areas, since the number of species that a protected area can hold at equilibrium will depend on its size, habitat diversity, distance from other similar habitats and the dispersal powers of the species concerned (IUCN/UNEP, 1986). In addition, protecting islands as nature reserves has several advantages because islands have clear boundaries, have already developed a balance between their size and species number, cannot be easily encroached upon and are relatively independent ecological units (IUCN/UNEP, 1986). The management of island reserves is relatively simple, as it is illustrated in the management techniques developed for measures taken to protect the Galapagos National Park.

1.7. Regeneration Strategies in Plants

Plants maintain and expand their populations in time and space by the process of regeneration. Regeneration is a complex ecosystem process involving sexual and asexual reproduction, dispersal and establishment in relation to environmental factors (Barnes *et al.*, 1998). It is an ecological process that ensures the development of successive generations of plants. There are various mechanisms by which plants regenerate. The regenerative strategies involve soil seed banks, seedling banks and vegetative parts (Grime, 1979; Garwood, 1989; Barnes *et al.*, 1998).

Soil seed banks refer to viable seeds present in or on the soil and associated with the soil litter. Viable seeds that have no dormancy and germinate immediately following dispersal constitute the active seed bank, and viable but dormant seeds that remain in the soil for one or more years constitute the dormant or persistent seed bank (Grime, 1979; Barnes *et al.*, 1998). Soil

seed banks have spatial and temporal dimensions. The inherent properties of seeds such as morphology, dormancy and longevity, the environmental conditions, and the presence or absence of microorganisms and seed predators are important factors that determine the dynamics of soil seed banks (Grime, 1979; Demel Teketay, 1996; Barnes *et al.*, 1998). Soil seed banks play a crucial role in the dynamics of plant populations (Demel Teketay, 1996). They have major contribution for the regeneration of vegetation after disturbances such as fire, herbivory, logging, etc. Persistent seed banks are also important for restoration or rehabilitation of degraded lands.

Seedling banks are important routes of regeneration in plants. In forests, seedling bank, also known as advance regeneration, is a very common regeneration strategy (Grime, 1979; Demel Teketay, 1996). Persistent seedlings play an important role in the regeneration of many forest trees. The seedling bank serves as the source of re-growth following natural or human disturbance of the established vegetation. According to Grime (1979), the reservoir of seedlings functions in a way, which is, in some aspects, analogous to that of a seed bank.

Vegetative regeneration by coppice/stump sprouts is also an important means for survival and regeneration of plants after disturbances. The ability to sprout from damaged roots or shoots is an important adaptation for the persistence and spatial dominance of woody plants. Gardiner and Helmig (1997) pointed out that coppice sprout is an important component of the regeneration pool.

Many plant species possess combinations of regenerative strategies. The existence of multiple forms of regeneration has important roles in the evolutionary and ecological potential of the

plant. Possession of several strategies increases the range of circumstances in which regeneration can occur and this, in turn, widens the ecological range of the plant and confers a greater degree of persistence under fluctuating environmental conditions (Grime, 1979). Physical factors such as light, temperature, moisture, nutrients, wind and disturbance regimes and biotic factors such as competition, herbivory and disease strongly influence regeneration processes and thereby determine the abundance and status of the plant species.

Understanding the dynamics of soil seed banks and seedling banks of forest vegetation helps to assess the natural regeneration potential of plants (Demel Teketay, 1996). Population structure is also an important parameter. The pattern of population structure of woody plants can show the regeneration profile, which is used to determine their regeneration status (Tamrat Bekele, 1994; Demel Teketay, 1996; Alemnew Aleligne, 2001; Alemayehu Wassie, 2002; Getachew Tesfaye *et al.*, 2002; Simon Shibru, 2002). Assessment of soil seed banks, seedling banks and population structure has some practical importance in forest conservation and management. Knowledge of the regeneration status of the plant species is important for developing management strategies and setting priorities.

1.8. Vegetation Description, Sampling and Analysis

1.8.1. Description of Vegetation

Vegetation, defined as the assemblage of plants occupying a given area, is the result of the prevailing environmental conditions. Environmental factors like topography, soil and climate of an area determine the vegetation it supports. Vegetation growing in an area has a definite composition and structure developed as a result of long-term interaction with various biotic

and abiotic factors. Vegetation is dynamic, changing in space and time. Environmental conditions and historical events play important roles in shaping the dynamic nature of plant distributions.

Plants tend to be grouped in different combinations forming more or less definite communities (Daubenmire, 1968). Plant communities are fundamentally the products of interaction between two phenomena: differences in the environmental tolerances (ecologic amplitudes) of the various taxa which comprise the flora and the heterogeneity of the environment. They are interactive groups of plants whose species combinations are selected by the environment.

The description of vegetation is used for the recognition and definition of different vegetation types and plant communities. Since vegetation is a phenomenon of great complexity, simple descriptions of vegetation such as floristic composition (simply expressed as the list of species) and physiognomy (appearance of vegetation) do not permit any exploration of the functioning of the vegetation, which is usually a central objective of vegetation analysis (Kellman, 1980). Thus, there is a need for descriptions of vegetation to include some abundance measure of the species present. In addition, it is important to assess the environmental factors that determine the vegetation type and dynamics. The description of vegetation in relation to the environment allows the comparison and ultimate classification of different units of vegetation (Kershaw, 1973).

1.8.2. Methods of Vegetation Sampling

Collection of reliable vegetation data requires the use of appropriate sampling method. The choice of sampling method depends on the objectives of the study, habitat type, precision and resources available (manpower, cost and time). The most common sampling methods are random sampling, stratified sampling and systematic sampling, and described by Kent and Coker (1994) and Greenwood (1996) as follows. In random sampling, each point within the survey area has an equal chance of being included in the sample. One of the problems with random sampling is that the cover of the area with sample points is not regular, some areas being under-sampled and others over-sampled. Stratified sampling involves sub-dividing the study area into relatively homogenous points and then sampling each sub-division according to its area or some other parameter. Systematic sampling involves the arrangement of samples at regular intervals. Transects are forms of systematic sampling in which samples are arranged linearly and usually contiguously. They are commonly used in vegetation studies.

1.8.3. Multivariate Techniques for Vegetation Analysis

Ecologists have developed a wide array of multivariate methods to characterize and measure the properties of communities of plants and animals (Krebs, 1989). These methods help in the analysis of community patterns and defining the environmental controls of community patterns. Multivariate techniques are normally employed with the primary aim of summarizing large complex data sets obtained from samples. Many studies have shown that among the multivariate methods used to study the complex nature of plant communities, classification and ordination are the two main and basic strategies (Mueller-Dombois and Ellenberg, 1974). Some ecologists believe that vegetation is discrete while others assume that vegetation is

continuous. According to Westhoff and van der Maarel (1978), classification is considered to have stemmed from the concept of discontinuity of vegetation whereas ordination from continuity of vegetation.

Classification involves the arrangement of samples into more or less homogenous categories. Measurement of similarity between communities is the basis of classification, and cluster analysis is one method of objectively defining the relationships among many community samples (Krebs, 1989). Classification of vegetation into types, whose distribution is then compared to environmental conditions in a search for correlations, comprises the vast proportion of analyses to date (Kellman, 1980). There are two approaches in classification, non-hierarchical and hierarchical. Non-hierarchical classification merely groups similar samples together into classes without revealing the pattern of relationship among the samples. In contrast, hierarchical classification involves step-wise arrangement of the samples in a hierarchy by establishing a pattern of closeness of relationship among the samples (Goodall, 1978). Hierarchical classification systems are well known and more widely used in ecological work than non-hierarchical methods. Hierarchical classification methods can be divisive or agglomerative, monothetic or polythetic (Goodall, 1978; Krebs, 1989; Kent and Coker, 1994). Divisive strategy begins with the whole set of samples and proceeds by successive divisions while agglomerative strategy begins with the individual samples and proceeds by successive fusions, in either case ending with hierarchically arranged clusters or classes. Monothetic classification is based on a single attribute, such as presence or absence of species, whereas polythetic classification is based on many attributes.

Ordination, on the other hand, seeks major dimensions of change or clines of variation in vegetation (Kellman, 1980). Generally, the purpose of ordination is to reduce the multidimensional system into a small number of dimensions or components, which have a greater indicative value (Zerihun Woldu, 1985). Thus, it is used to summarize the continuous variation. According to Mueller-Dombois and Ellenberg (1974), ordination is a technique which aims at description through the arrangement of samples and stands in order of similarity or environmental gradients.

According to Goodall (1978), classification and ordination can be appropriately applied to the same data, and the choice between the two approaches depends on the intended use of the results. For instance, classification is more applicable in vegetation mapping while ordination is more appropriate in assessment of vegetational characteristics in terms of environmental variables. Both classification and ordination of vegetation data represent attempts to identify orderly patterns in vegetation. They contribute to the elucidation of the complexities of vegetation. Although these techniques contain inherent subjectivities, they can provide useful temporary summaries of vegetation patterning (Kellman, 1980).

1.9. Research Methods in Ethnobotany

Ethnobotany is defined as the study of people's classification, management and use of plants (Martin, 1995). It is a multidisciplinary science that requires the application of methods and techniques from several disciplines of which the major ones are botany, ecology, pharmacology, economics, anthropology and linguistics. According to Martin (1995), there are four major interrelated endeavours in ethnobotany: basic documentation of traditional

botanical knowledge, quantitative evaluation of the use and management of botanical resources, experimental assessment of the benefits derived from plants both for subsistence and commercial ends, and applied projects that seek to maximize the value that local people attain from their ecological knowledge and resources.

Ethnobotanical surveys can help to identify the most urgent problems and needs of local communities relating to wild plant use and resource management and suggest appropriate alternatives (Martin, 1995; Cunningham, 2001). They can also help to identify conservation issues, such as cases where rates of harvest of plants exceed rates of regeneration, and undertake practical conservation work. Field researchers have realized the importance of the use of ethnobotanical research methods to generate relevant information in order to explore solutions to conservation and development issues.

There are different methods employed by ethnobotanists for effective interaction with local communities and understanding their indigenous knowledge and uses of the plant world. Participatory methods have been developed from a need to involve local communities in analysing their own circumstances (Cunningham, 2001). One of such approaches is Participatory Rural Appraisal (PRA). PRA brings the researcher and local people closer for sharing experiences and knowledge. Local people are full participants rather than being merely the objects of the investigation. The relationship between the researcher and local people is egalitarian, avoiding the hierarchical or top-down approach common to much research (Martin, 1995). PRA is a field technique that allows the researcher to gather and document indigenous knowledge of local people and reality of rural life. The method is cost-effective, more flexible, applicable in many cultural and ecological conditions, and enables the

researcher to obtain a lot of information within a specified time. PRA methods are one way of documenting how people interact with their environment, especially as a complement to more rigorous methods of data collection (Martin, 1995). Because of its manifold advantages, PRA has become more popular and commonly used method in recent years. PRA involves an array of techniques and methods. According to Martin (1995) and Cunningham (2001), the most important and commonly used PRA methods in ethnobotanical surveys are field observation, structured and semi-structured interviews, discussions with individual resource users or groups of people, direct matrix ranking and scoring and pair-wise comparison. Kessy (1998) pointed out that semi-structured interviews serve the purpose of disclosing the system of knowledge and structuring of ideas central to the respondent's own views of the world. Interviews can also be made with people who are knowledgeable about the topic under study, and such respondents are referred to as key informants (Martin, 1995).

1.10. Causes and Consequences of Deforestation in Ethiopia

Tropical forests are vanishing rapidly due to rapid human population growth, which results in the conversion of forestlands to agricultural lands and overexploitation of forests for various purposes such as fuelwood, construction material and timber (Demel Teketay, 1996; Girma Balcha, 1999; Feyera Senbeta and Demel Teketay, 2002). Reasons for deforestation and modes of deforestation vary between countries (Girma Balcha, 1999). For example, in Latin America, the most important cause of forest destruction is the development of cattle ranching (Girma Balcha, 1999). In Southeast Asia, the major cause for destruction of forests is logging for export of quality timber. In Africa, the main reasons are rapid human population growth, conversion of forests to arable lands, demand for wood products particularly fuelwood, and

lack of or inappropriate land use policy. The destruction of tropical forests has resulted in land degradatiuon, decline or loss of biological diversity and natural calamities such as drought. Furthermore, it has affected the socio-economic conditions of the people. Deforestation is one of the most serious environmental and economic problems in tropical regions.

In Ethiopia, forest destruction is more pronounced and the resulting consequences have become even more serious. In fact, this is the biggest challenge for the country. It is known that the large part of Ethiopia was covered with natural forests. However, the natural forests of Ethiopia have been declining from time to time. The forest cover of the country was 16% in the early 1950s, 3.6% in the early 1980s and 2.7% in 1989 (EFAP, 1994). Most of the remaining natural forests of Ethiopia are found in the southern and southwestern parts of the country, and forests have virtually disappeared from the rest of the country except a few scattered and relatively small areas of forest cover that remained in the northern, central and eastern parts of the country (Tewolde Berhan Gebre Egziabher, 1986). Generally, the remaining forests of Ethiopia are only small remnant patches mostly confined to inaccessible areas such as the steeper hillsides and mountaintops and sacred places. Furthermore, some indigenous treesare threatened as a result of deforestation (Appendix 12).

The major causes for the destruction of forest resources in Ethiopia are agricultural expansion, overexploitation, inappropriate land use policy, incidence of forest fire, lack of proper forest management and destructive investment activities (Gebre Markos Wolde Selassie, 1998; Demel Teketay, 1999; Edwards and Ensermu Kelbessa, 1999; Taye Bekele *et al.*, 1999; Kumilachew Yeshitela, 2001; Yonas Yemshaw, 2001; Feyera Senbeta *et al.*, 2002; Shiferaw Dessie and Taye Bekele, 2002). Furthermore, there is inadequate scientific knowledge on the

conservation, management and utilization of forest resources. The rate of forest destruction is very alarming. With the estimated rate of deforestation 150,000-200,000 ha per year (EFAP, 1994), the remaining natural forests could disappear within a few decades unless appropriate and immediate measures are taken.

Forest destruction has many consequences. According to Legesse Negash (1995, 2002), massive soil erosion has occurred in Ethiopia due to the decimation of its natural forests. The destruction of forests has led to severe wood deficit, land degradation, loss of biodiversity, climatic change, reduction in agricultural productivity, scarcity of water and loss of economic opportunity (Demel Teketay, 1996; Legesse Negash, 2002; Yonas Yemshaw, 2002; Demel Teketay *et al.*, 2003). Deforestation and land degradation have led to ecological and socio-economic crises in Ethiopia (Tewolde Berhan Gebre Egziabher, 1986; Lisanework Nigatu, 1987). This calls for appropriate and immediate solutions so as to maintain the forest resources in particular and the biodiversity in general.

1.11. Vegetation Studies in Ethiopia

Many foreigner and Ethiopian scholars have attempted to describe the vegetation of Ethiopia. Early works include Pichi-Sermolli (1957), von Breitenbach (1963), Mesfin Wolde-Mariam (1972), Daniel Gamachu (1977) and Wilson (1977). The comprehensive survey of the vegetation of Ethiopia made by Pichi-Sermolli (1957) laid the foundation for systematic studies of the vegetation and environmental factors in Ethiopia. Recent studies on vegetation aimed at describing community types and their relationship with some natural and anthropogenic features include Zerihun Woldu (1980, 1985, 1986), Sebsebe Demissew (1980),

Hailu Sharew (1982), Lisanework Nigatu (1987), Zerihun Woldu *et al.* (1989), Zerihun Woldu and Mesfin Tadesse (1990), Friis (1992), Tamrat Bekele (1994), Menassie Gashaw and Masresha Fetene (1996), Teshome Soromessa (1997), Kebrom Tekle (1998), Simon Shibru (1999), Tamrat Andargie (2001), Tesfaye Awas *et al.* (2001), Desalegn Wana (2002) and Kumilachew Yeshitela and Tamrat Bekele (2002). The contributions made by these authors towards the understanding of the vegetation of Ethiopia are of paramount significance.

There are also studies on vegetation that focused on population dynamics and regeneration ecology. Investigations in this direction include Tamrat Bekele (1994), Demel Teketay (1996), Mekuria Argaw *et al.* (1999), Gebremedhin Hadera (2000), Tesfaye Bekele (2000), Alemnew Aleligne (2001), Elias Taye (2001), Feyera Senbeta and Demel Teketay (2001, 2002), Alemayehu Wassie (2002), Feyera Senbeta *et al.* (2002), Getachew Tesfaye *et al.* (2002), Simon Shibru (2002) and Kumilachew Yeshitela and Taye Bekele (2003). The results of these works have provided relevant information on the regeneration status of many plant species, which is paramount importance to undertake appropriate conservation and management measures.

1.12. Justification of the Research Problem

Conservationists require detailed studies as well as comprehensive overviews of structural and functional aspects of ecosystems to make sound proposals for management and development plans that will allow conservation of biologically valuable areas or at least reduce the induced damage. The ever-increasing threat to plant resources calls for proper management and conservation activities so as to ensure the continued productivity and stability of the area.

Vegetation study helps to select and employ the appropriate conservation and management plan for sustainable use of ecosystems. Integrated vegetation management requires an understanding and knowledge of the dynamic processes involved in the vegetation (van Wyk and Smith, 2003).

The Ethiopian vegetation is extremely complex. Therefore, there is a need for detailed studies as well as comprehensive overviews of the vegetation resources in order to develop conservation strategies and set priorities. This arises from the fact that ecological knowledge provides the ground for conservation, management and sustainable use of biological resources. One of the aims of the present study is to investigate the species diversity and plant communities of the vegetation and the regeneration status of woody plants in the islands of Lake Ziway.

Africa's biodiversity is seriously threatened not only on the mainland but also on its islands (IUCN, 1990). This is mainly due to the increased pressure exerted by the rapidly growing human population. The situation is more serious on the islands. This is because islands have their own natural limitations in addition to anthropogenic influences. Therefore, islands need special attention since they are extremely fragile ecosystems.

Islands of Africa possess unique biological diversity. Madagascar, Mauritius, Comoros, Sao Tome and Principe, and Seychelles are important centres of endemism, and Madagascar has the highest level of endemism in Africa (IUCN, 1990). Madagascar is of great global importance in terms of biological diversity. Mauritius is recognized as an oceanic biodiversity hotspot (Jeffries, 1997). Although there are no oceanic islands in Ethiopia, there are lake and

habitat islands. There are islands in Lakes Tana, Ziway, Langano, Shalla, Abaya and others. The biodiversity of the islands in Ethiopia is threatened due to natural calamities and ever-increasing human impacts.

Islands are the least studied ecosystems. Two major reasons for this are their inaccessibility to researchers and lack of recognition. As a result, the information on island biotas is very limited. This is particularly true in Ethiopia whereby the diversity, endemicity, dynamics, conservation status and rate of depletion of island biotas have not been assessed. Furthermore, specific threats to the country's island biotas have not been identified. Except the study by Alemnew Aleligne (2001) on the forests of Zegie peninsula, there are no studies that specifically deal with the vegetation resources of the islands in Ethiopia. Therefore, there is a need to generate scientific information in order to ensure the conservation, management and sustainable utilization of biological resources on the islands.

Information on the extent, distribution, species diversity and rate of depletion of the forest and woodland resources of Ethiopia is very limited (Teshome Soromessa, 1997; Demel Teketay, 1999; Taye Bekele *et al.*, 1999). According to Demel Teketay (1999) and Taye Bekele *et al.* (1999), the taxonomy, reproductive biology, ecology and silviculture of forest and woodland genetic resources should be examined and characterized in order to determine the conservation methods to be applied. In addition, information on socio-economic aspects in relation to the conservation and sustainable utilization needs to be collected, synthesized and documented. The present study stemmed from such a background.

The vegetation in the Lakes Region of the Ethiopian Rift Valley has been studied by Zerihun Woldu and Mesfin Tadesse (1990). Mirutse Giday (1999) did some vegetation study on some shore areas and one of the islands of Lake Ziway in connection with identification of medicinal plants. However, there is no particular and detailed study of the vegetation in the islands of Lake Ziway. This indicates that there is a gap in the knowledge of plant ecology and socio-economic aspects of the vegetation resources in the islands. Therefore, the study will provide ecological and socio-economic information that would help for conservation, management and rational utilization of the vegetation resources in particular and the biodiversity as a whole.

2. OBJECTIVES OF THE STUDY

The present study was undertaken with the following general and specific objectives.

2.1. General Objectives

The main objectives of the study were to:

- investigate the diversity and status of the vegetation in the islands of Lake Ziway;
- generate ecological and socio-economic information that would help for conservation, management and sustainable utilization of the vegetation resources and the associated biodiversity in the islands.

2.2. Specific Objectives

The specific objectives of the study were to:

- assess the species diversity (richness and evenness) and plant communities of the vegetation in the study area;
- determine the population structure and regeneration status of woody plants;
- investigate the socio-economic values of the plant resources for communities in the islands;
- assess the indigenous resource management systems and practices used by the local people and the role of churches in conserving sacred groves and the surrounding vegetation;
- identify the factors that cause degradation of the vegetation.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location and Topography

The study was carried out in the islands of Lake Ziway (Fig. 1). The study area lies in the Main Ethiopian Rift (MER) part of the Ethiopian Rift Valley (ERV), within the Oromia National Regional State. Lake Ziway is one of the seven major lakes situated in the Ethiopian Rift Valley, located close to Ziway town at 7° 52`-8° 8` N, 38° 40`-38° 56` E, about 160 km south of Addis Ababa. It lies east of Ziway town, west of Assela, north of Mount Aluto and south of Mount Bora. Mount Aluto, Mount Chilalo and Mount Bora dominate the landscape south, east and north of the lake, respectively. Lake Ziway has an altitude of 1636 m, a length of 32 km and a width of 20 km, an area of 434 km^2 and an average depth of 2.4 metres. The lake is fed by two major rivers, Meki and Katar Rivers, which drain from the northwestern and southeastern plateaus and enter into the lake in the northern and eastern sides, respectively. Many smaller streams along the shore also contribute to the inflow. The only outlet of Lake Ziway is the Bulbula River, which flows from southwest edge of the lake to Lake Abijata. There are many swampy areas around the lake. Lake Ziway is relatively salt-free with a high concentration of bicarbonate (Makin *et al.*, 1976). It usually has brownish colour due to the organic suspension brought by the rivers and floods in the rainy season. The lake is unsheltered and thus exposed to frequent agitation by wind.

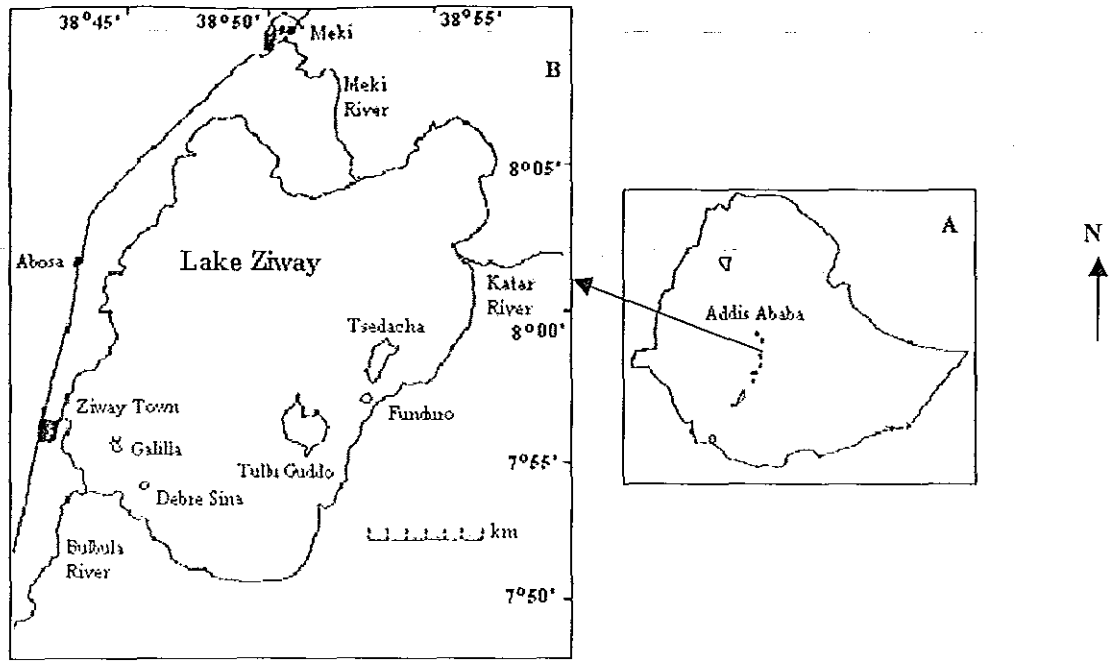


Fig. 1. Map showing: (A) location of the study area and (B) Lake Ziway and its islands (Modified from Makin *et al.*, 1976).

There are five main volcanic islands in Lake Ziway, namely Galilla, Debre Sina, Tullu Guddo (also called Debre Tsion), Funduro and Tsedacha. The names of the latter three islands were derived from the three words of the Oromo language, i.e. "Tullu Guddo" meaning "Big Mountain", "Tsedacha" meaning "*Acacia* Island" and "Funduro" meaning "The Front or Closer Island" to the mainland. There is a church in each island. There are also islets or tiny islands (Table 1). The two islands, namely Galilla and Debre Sina, are found on the southwestern side of the lake, close to Ziway town while the other three islands, namely Tullu Guddo, Funduro and Tsedacha, are found on the eastern side, very near the Arsi mainland. The former two are administered by the East Shewa Zone while the latter three are administered by the Arsi Zone.

Table 1. List of islands, islets and churches in Lake Ziway.

No.	Island/Islet	Church
1	Galilla	Teklehaimanot
2	Yewof Deset, northwest of Galilla	-
3	Debre Sina	Mariam
4	Yewof Deset, north of Debre Sina	-
5	Tilqu Deset	-
6	Tinshu Deset	-
7	Tullu Guddo (Debre Tsion)	Kidist-Mariam
8	Funduro	Arbaitu Ensessa (the four creatures)
9	Tsedacha	Abraham

The five islands are similar in their geological formations. Tullu Guddo and Tsedacha are relatively big. Tullu Guddo is the largest and the highest of all the islands (Fig. 2). Because of its high peaks, locally known as Woizero and Gumarghe, Tullu Guddo is visible from all parts of the Lake Ziway region. Conversely, because of the highest and striking peak Woizero, the lake and the surrounding landscape is visible from any direction. Tullu Guddo is slopy and stony. There are many hot springs in Tullu Guddo, mainly on its western side. The hot springs are used for bathing by the islanders as well as people from the mainland. The altitude of the islands ranges from 1549 m at flat lake edge in Debre Sina to 2033 m at Woizero Summit in Tullu Guddo. The immediate land to the north, east and south of Lake Ziway has slightly undulating terrain dotted with volcanic cinder cones whereas the land to the west of the lake is

relatively flat. Lake Ziway lies within a broad dawn-faulted basin, and there is gently rising landscape around the lake.

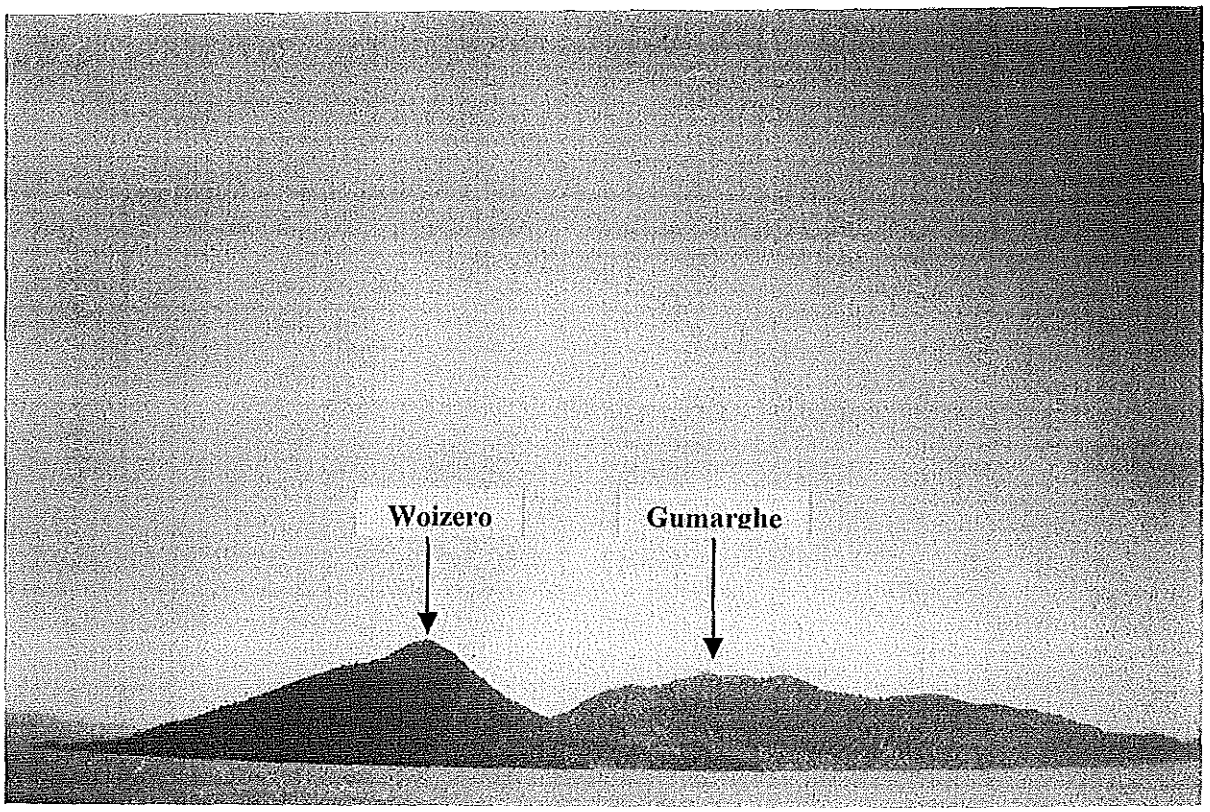


Fig. 2. Vegetation cover and topography of Tullu Guddo.

3.1.2. Geology

The ERV, in which the study site is located, is part of the Great East African Rift System, the longest Rift Valley in the world extending for about 6,000 kilometres from Syria to Mozambique. The MER is the most typically developed part of the East African Rift System (Mohr, 1971). The ERV is roughly a funnel-shaped depression that opens up in the northeast into the Gulf of Aden and the Red Sea. It is aligned in northeast-southwest direction,

dissecting the Ethiopian landmass into northwestern highlands and lowlands and southeastern highlands and lowlands. The ERV has great variation in geomorphology attributed to volcano-tectonic processes and is dotted with numerous volcanic mountains and cinder cones. The rift floor is covered by volcanic rocks, and volcanoclastic, colluvial, alluvial and lacustrine deposits (Tenalem Ayenew, 2001). The major rock types in the Rift Valley are basalt, ignimbrite, tuff, trachyte and pumice. The floor of the rift is marked by local active faulting and volcanic centres, usually associated with the presence of hot springs, fumaroles and geysers (Mesfin Wolde-Mariam, 1972; Tenalem Ayenew, 2001). The presence of hot springs in Tullu Guddo indicates that the study area is still geologically active.

East of Lake Ziway, and determining its shoreline on this side, runs the Wonji Fault Belt (WFB), which is a belt of late Quaternary extensional faulting (Mohr, 1971). The Wonji Fault is characterized by an irregular morphology consisting of narrow uplifted blocks, spatter cones, lava fields, valleys and depressions. According to Mohr (1971), the four ERV Lakes, namely Ziway, Langano, Abijata and Shalla, were united as one megalake during the pluvials, but they were later separated during the early Pleistocene period by volcano-tectonic activities, faulting and shrinkage in water level. This is witnessed by the presence of lacustrine sediments around the lakes.

The islands and immediate areas to the east and northeast of Lake Ziway are similar in geological structure. They consist of basaltic lavas and cinder cones as well as silicic flows and domes formed during the Quaternary age as a result of fissure eruptions (Street, 1979). According to Street (1979), the rocks of the areas to the west of Lake Ziway are composed of alluvium material and lacustrine sediments. The waterbed of Lake Ziway and the swampy

areas around the lake are mainly composed of coarse pumice material (Makin *et al.*, 1976). Most parts of the islands of Lake Ziway are covered by volcanic rocks mainly basalt and pumice. Rock outcrops are common in many areas of the islands. The rocks are light dark, greyish or whitish in colour. Foot slopes are covered with lacustrine sediments and colluvial deposits transported from upper slopes.

3.1.3. Soils

The major soil types in the Rift Valley clearly show the influence of soil parent material and extent of weathering (Street, 1979). The survey made by Makin *et al.* (1976) showed that most of the areas around Lake Ziway have poorly developed soils, quite variable in thickness, texture, alkalinity, salinity and sodicity. Areas around the lake have soils of volcanic, lacustrine and alluvial origin. According to Makin *et al.* (1976), soils affected by both high salinity and alkalinity occur fairly extensively along the northwestern, northeastern and southeastern shores of Lake Ziway.

The soil types found in the islands include arenosols, andosols, regosols, leptosols and cambisols. Soils of volcanic origin, particularly ash, are common on the slopes while soils of colluvial and lacustrine origin are common along the edges of the lake. Generally, the soils are shallow and sandy and are characterized by low organic matter. The steep slopes and hills have extremely shallow to shallow soils while relatively deep soils occur in flat and gently sloping areas. The colour of the soils is mostly grey, whitish and brown depending on location. Compared with the other islands, soils in Tullu Guddo are poorly developed because of slopy

nature of the landscape that induces erosion. As a result, cultivation is mostly undertaken within the plots of land between the terraces at the lower and flat areas.

3.1.4. Climate

Ethiopia possesses diverse climate. A generalized account of the climate of Ethiopia is given by Daniel Gamachu (1977). The climate of the ERV varies markedly over short distances (Zerihun Woldu and Mesfin Tadesse, 1990). Because of the altitudinal variation and positional differences, the climate varies from warm, hot and dry to cool and moderately moist conditions. The Rift Valley is characterized by temperature and rainfall variability, and it is generally an area of low rainfall and high temperature. The dynamics of the environment has been under the influence of increasing aridity for the last 5,000 years (Zemede Asfaw, 1999).

Generally, the Lake Ziway basin is characterized by arid climate. Areas surrounding Lake Ziway have bimodal rainfall distribution with short-term, highly variable, "small" rains from February to June and "big" rains from July to September. The dry season is from October to January. Average evaporation exceeds precipitation in all months of the year (Daniel Gamachu, 1977). Strong and persistent winds are characteristic features of the Lake Ziway area.

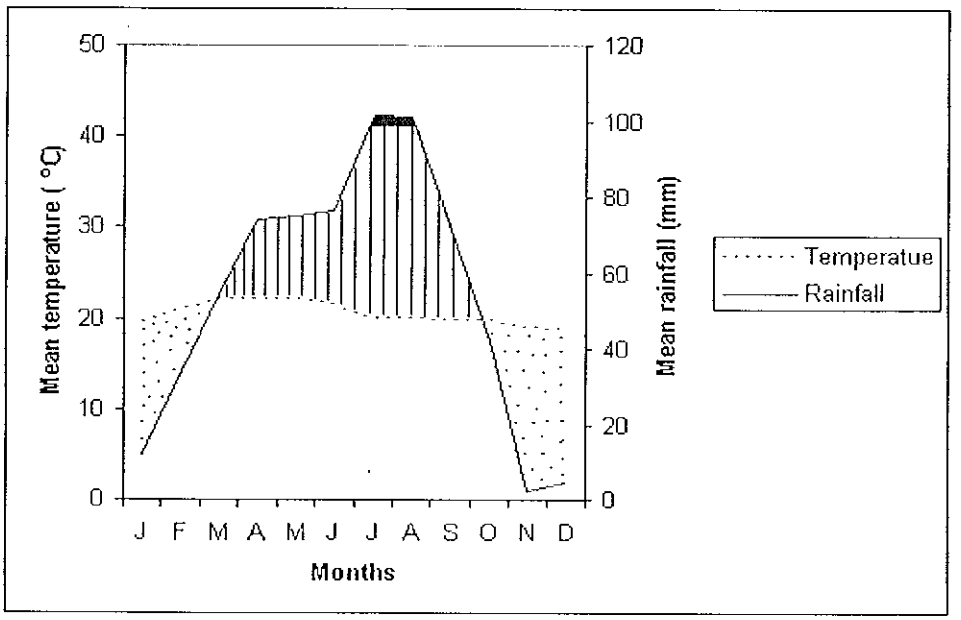
Climatic data of mean monthly maximum and minimum temperature and monthly total rainfall for the years 1982-2002 for Ziway meteorological station, which is the nearest to the study area, were obtained from the National Meteorological Services Agency (NMSA). The mean annual temperature is 20.5°C and the mean annual maximum and minimum

temperatures are 27.1°C and 13.9°C, respectively. The hottest months are March and May with mean maximum temperature of 28.8°C, and the coldest is December with mean minimum temperature of 11.6°C. The total annual rainfall is between 457.6 and 958.9 mm and the mean annual rainfall is 702.1 mm. The wettest month is July and the driest is November. High concentration of rainfall occurs in July and August (Daniel Gamachu, 1977), as witnessed by the climadiagram (Fig. 3).

The agroclimatic classification of Ethiopia based on the characteristics of the growing season shows that there are four major agroclimatic belts and 21 agroclimatic zones (Engida Mersha, 2000). Accordingly, the study area is found in SS32 agroclimatic zone, which has a single growing season.

Ziway (1640 m)

[20] (20.5 702.1)



Source of raw data: NMSA

Fig. 1. Climadiagram of Ziway following Walter (1985).

3.1.5. Vegetation

The ERV has a mosaic of vegetation consisting of woodlands, bushlands, shrublands, grasslands, riparian and swamp vegetation as well as forests. Open *Acacia* woodland vegetation is a characteristic of the Rift Valley area (Zerihun Woldu and Mesfin Tadesse, 1990). The climatic gradient attributed from altitudinal variation has resulted in the development of vegetation zones or belts.

The vegetation of the Lakes Region of the ERV varies with the climate from forested areas on the escarpments to open *Acacia* woodland in the plains of the rift floor. The predominant vegetation types are *Acacia* woodland, bushland, shrubland and wooded grassland (Zerihun Woldu and Mesfin Tadesse, 1990; Friis, 1992). The classification of the vegetation based on the tree and shrub species by Zerihun Woldu and Mesfin Tadesse (1990) showed that four vegetation types exist in the Lakes Region: *Acacia albida* dominated vegetation type; *Olea europaea* subsp. *cuspidata, Acokanthera schimperi* and *Acacia etbaica* dominated high altitude vegetation type; *Acacia tortilis, A. seyal* and *Balanites aegyptiaca* dominated low altitude deciduous vegetation type; and *Euphorbia candelabrum, Croton dichogamus* and *Solanum schimperianum* dominated vegetation type.

The vegetation in the Rift Valley has been greatly influenced by human activities. The depletion of the *Acacia* woodlands and other vegetation types in the Rift Valley has been very rapid (Zerihun Woldu and Mesfin Tadesse, 1990). The area around Lake Ziway, which used to be covered by continuous woodlands, has now been left with remnant woodland and bushland patches mainly on rocky hilltops. At present, the land around Lake Ziway is characterized by almost continuous cultivation. Maize cultivation with scattered remnant *Acacia* trees is

common. The major causes for depletion of the natural vegetation are clearing for cultivation, overgrazing due to increase in livestock population, urban development, fire and tree cutting for construction material, fuelwood and charcoal production. Charcoal production, albeit not sustainable, has become a lucrative activity in the Rift Valley and is a major factor for devastation of the vegetation.

Much of the shoreline of Lake Ziway is covered with a belt of lush marshy vegetation and it is dotted with big *Ficus sycomorus*. *Aeschynomene elaphroxylon*, *Cyperus papyrus*, *Paspalidium geminatum*, *Typha domingensis* and *Nymphaea nouchali* are the most common species (Mirutse Giday, 1999). The islands have vegetation consisting of different trees and shrubs interspersed with herbaceous species. Despite the great destruction of the vegetation around Lake Ziway, the vegetation in the islands is maintained owing to the indigenous resource management systems and practices used by the island communities.

From the nine broad categories of vegetation in Ethiopia, *Acacia-Commiphora* deciduous woodland, *Combretum-Terminalia* deciduous woodland, desert and semi-desert scrubland and wetland vegetation occur in the ERV. Of these, the vegetation of the study area largely belongs to the *Acacia-Commiphora* deciduous woodland. White (1983) classified the vegetation of Africa based on physiognomy, floristic composition and endemism as the main criteria. This author divided the vegetation of northeastern Africa into four major centres of endemism: Sudanian regional centre of endemism, Somalia-Masai regional centre of endemism, Afromontane archipelago-like regional centre of endemism and Afroalpine archipelago-like regional centre of endemism. Accordingly, the vegetation in the study area belongs to the Somalia-Masai regional centre of endemism. This region is one of the major

floristic regions in Africa and extends from Red Sea to central Tanzania. The area is floristically rich with around 2,500 species, of which about 50% are endemic to the region (White, 1983).

3.1.6. Wildlife

The ERV is well known for its rich fauna. There are different kinds of mammals, birds, reptiles and invertebrates, including the endemic species. Most of the country's wildlife conservation areas (national parks, wildlife sanctuaries, wildlife reserves and controlled hunting areas) are found in the Rift Valley.

Lake Ziway, like the other Rift Valley Lakes, is a habitat for a variety of birds including the migratory afrotropical and palaearctic species (Syvertsen, 1995). According to Syvertsen (1995), Great White Pelican (*Pelecanus onocrotalus),* Marabou (*Leptoptilos crumeniferus*), Grey-headed Gull (*Larus cirrocephalus*), Black-headed Gull (*L. ridibundus*), Fulvous Whistling Duck (*Dendrocygna bicolor*), White-faced Whistling Duck (*D. viduata*), White-backed Duck (*Thalassornis leuconotus*), Whiskered Tern (*Chlidonias hybridus*), Egyptian Goose (*Alopochen aegyptiacus*), Spur-winged Goose (*Plectopterus gambensis*) and Black-crowned Crane (*Balearica pavonina*) are some of the most common species. Lake Ziway supports a large number of hippopotamus and Nile monitor. It also harbours the fish species *Tilapia nilotica*, *Barbus* sp., *Clarias garepenus*, *Tilapia zilli* and *Caracies caracies*, of which the latter two are exotic (Meseret Taye in Ziway Fisheries Resources Research Centre, personal communication). The islands are habitats for monkeys, warthog, porcupine and the various kinds of birds. According to local informants, birds were common in the islands of

Lake Ziway until very recently. However, at present, there is reduction in the diversity of birds due to habitat destruction by humans and lack of availability of food, especially fish.

3.1.7. The People, Land Use and Socio-economic Aspects

3.1.7.1. The People and Language

The inhabitants of the islands of Lake Ziway are the Zay People. The Zay People are one of the minority nationalities in Ethiopia. Their language is Zay and belongs to one of the main language groups called Semitic. The words in the Zay Language are derived mainly from Siltigna and also from Amharic, Oromiffa and Tigrigna (key informants, personal communication). They can also speak Amharic and Oromiffa as in the order. The Zay People are christians strongly dedicated to their religion. To the Oromos and other surrounding people, the Zay People are commonly known by the name "Laqi" (Tuma Nadamo, 1982; Tesfaye Edetto, 1988), which means "paddlers or rowers of boat". However, the people identify themselves as Zay.

3.1.7.2. Brief History of the Zay People

There are limited written historical sources about the Zay People, and their history has, thus, remained largely oral (Tuma Nadamo, 1982). Local traditions compiled by Tuma Nadamo (1982) showed that the Zay People are the result of amalgamation of three streams of people who inhabited the islands of Lake Ziway sometime between the early 14^{th} and the middle of the 17^{th} Centuries for different reasons. This compilation further showed that the islands of Lake Ziway had been serving as a safe refuge for people who had a fear of being attacked by

others at different times. The first settlers in the islands are thought to be people who had lived around the lake and, later, were forced to leave the area because of continuous raids from 'unknown' warriors. The second settlers were followers of the Ethiopian Orthodox Church that fled from Menz, North Shewa, to escape the war of Muslims led by Ahmed Gragn. The last settlers in the islands were people called Silte who were living on the shore areas of Lake Ziway but later on forced to leave the area after losing a battle with the Oromo People. Despite their different origins, the settlers in the islands formed a common culture and language, which gave way to the evolution of the Zay People through time.

The other version about the origin of the Zay People obtained from the key informants is as follows. During the reign of Yodit, a certain group of people from the northernmost part of the country, specifically from Axum, fled an attack from pagans led by Yodit who by that time were massacring christians and destroying churches. The people migrated southward and temporarily got a refuge in Menz, which they considered relatively safe from any attack because of the features of its landscape. These people further moved to the Lake Ziway region and, finally, ended up on the islands and ultimately gave rise to the Zay People.

3.1.7.3. Land Use

Despite the land distribution that has been undertaken in the country in the past and the present, the land tenure system in the islands is still through inheritance from parent to children. As a result, there is a gap in land holding among the islanders. The land use systems in the islands can be classified into five major types: cultivated area, forestland (which is also grazing land), settlement area, religious site and fishing area or the lake. Cultivation is mostly

undertaken in lower and flat areas while the slopy areas, hills and rocky lake edges are forest and grazing lands.

3.1.7.4. Settlement

According to the local elders and key informants, the Zay People used to inhabit all the five islands until very recently. Currently, they live on only three of the islands: Tullu Guddo, Funduro and Tsedacha. Tsedacha is the most populated and hospitable island followed by Tullu Guddo. The other two islands (Galilla and Debre Sina) were abandoned for various reasons. According to the local people, the main reason for leaving the islands was over-population that resulted in shortage of land for cultivation. The Zay People who moved out from the islands have settled on some shore areas mainly on the southwestern (locally known as "Bochesa") and northwestern (locally known as "Mekdela") sides of the lake. There is still a continuous influx of people from the islands to the mainland in search of arable land and also for other socio-economic reasons.

3.1.7.5. Economy

The economy of the Zay People is mainly based on traditional fishing and subsistence agriculture. Fishing is widely practiced by the islanders both for subsistence and sale. Boats made from *Cyperus papyrus* and *Aeschynomene elaphroxylon*, locally known as "Yebella", are used as the main means of water transport. In addition to fishing, they are engaged in crop cultivation and animal husbandry, both of which form an important aspect of the Zay economy. However, their agricultural activity is limited by shortage of farming and grazing

lands. They are also involved in trading traditional clothes with the surrounding Oromo and other people.

3.1.7.6. Health Care System

Data obtained from the Adami Tullu Jido Kombolcha Woreda Health Office in Ziway town showed that respiratory diseases, malaria, intestinal parasitiasis, gastritis, skin diseases and tuberculosis are among the diseases that are highly prevalent in the area. According to local informants and personal observation, the main health problems of the Zay People are malaria, schistosomiasis, amoebiasis, giardiasis, diarrhoea, respiratory diseases and mental illnesses. Access to modern health services is very limited. People have to go to health centres in Ziway or other towns to get treatment.

According to data obtained from the Adami Tullu Jido Kombolcha Woreda Agriculture Office, anthrax, black leg, sheep and goat pox and internal and external parasitism are some of the common diseases of livestock in the area. Discussion with local informants indicated that anthrax and parasitic infections are the prevalent livestock diseases in the islands. The Zay People have very limited access to modern health services, and thus they partly depend on traditional medicine to fulfill their health care needs. They use medicinal plants, most of which are harvested from the wild, to treat various human and livestock diseases. The use of medicinal plants by the Zay People was studied and documented by Mirutse Giday (1999).

3.2. Methods

Reconnaissance survey to the study area was made in August 2003 in order to get general information about the physiognomy of the vegetation, socio-economic conditions of the people and accessibility to the islands. Then, vegetation and socio-economic data were collected between 18 September and 7 November 2003.

3.2.1. Vegetation Sampling

Line transect method (Bullock, 1996) was used for inventory of vegetation. In each island, line transects were laid from central part of the island to the lake edge in eight aspects: North (N), South (S), East (E), West (W), Northeast (NE), Northwest (NW), Southeast (SE) and Southwest (SW) determined by using Suunto compass (Fig. 4). Relevés, measuring 20 m x 20 m (400 m^2), were established along the line transects approximately at 100 m intervals. The relevés were delineated by using a measuring tape and polythene strings. A total of 73 relevés (12 from Galilla, 10 from Debre Sina, 28 from Tullu Guddo, 9 from Funduro and 14 from Tsedacha) were sampled. The sampled area is 2.9 ha. Herbaceous species were sampled by using a 2 m x 2 m (4 m^2) sub-relevé laid inside each relevé where the vegetation was assumed to be representative. Floristic data were collected following the Braun-Blanquet (1965) and Mueller-Dombois and Ellenberg (1974) approaches.

In each relevé, all plant species were listed by their local and/or scientific names and identities that help for identification were recorded (Appendix 1). The cover/abundance of each species was estimated visually using the 1-9 modified Braun-Blanquet scale (van der Maarel, 1979). Trees, shrubs and lianas were counted. Diameter at Breast Height (DBH) of trees and shrubs

were measured following the methods described by Martin (1995) and Cunningham (2001). DBH at 1.3 m above the ground of trees and shrubs with DBH ≥ 2.5 cm was measured using diameter tape. For trees whose stem forked below breast height into two or more stems and shrubs, DBH was measured for the largest stem only. Individuals of trees and shrubs with DBH < 2.5 cm were counted by species as seedlings. Plant species that occur outside the sample relevés were also recorded to produce a more complete list of the plants in the islands.

Environmental variables like altitude, slope, aspect and position (latitude, longitude) of each relevé were measured and recorded (Appendix 5). Altitude and position were measured with Magellan GPS (Geographical Positioning System), slope with Suunto clinometer and aspect with Suunto compass.

Plant specimens were collected, numbered, pressed, partially dried and taken to the National Herbarium (ETH), Addis Ababa University. Identification of the plant specimens was made by comparing them with previously identified specimens in the Herbarium and referring the various volumes of Flora of Ethiopia and Flora of Ethiopia and Eritrea. Nomenclature follows the aforementioned volumes. Voucher specimens are deposited at the National Herbarium (ETH).

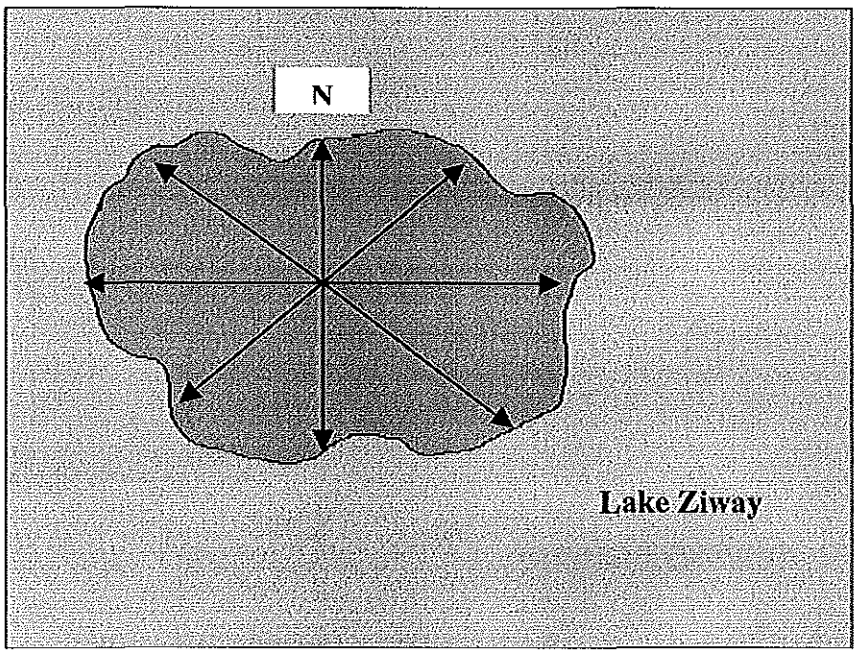


Fig. 4. Design of the study showing transects for vegetation sampling.

3.2.2. Socio-economic Survey

In this survey, PRA method was employed to generate the socio-economic information following Martin (1995) and Cunningham (2001). Primary data were collected by field observation, semi-structured and key informant interviews and group discussion. In addition, secondary sources of data obtained from the local representatives, elders and churches were used in order to get supplementary information.

3.2.2.1. Field Observation

Field observation is one the scientific methods that help to understand the natural environment and get more reliable information through first hand experience. In the present study, field observation was made on land use types, extent of soil erosion and vegetation degradation and soil conservation practices.

3.2.2.2. Semi-Structured Interview

A semi-structured/open-ended questionnaire (Appendix 6) was prepared in advance for undertaking the interview. The questionnaire was designed to solicit socio-economic data, trends in plant products utilization and local people's perceptions of a variety of conservation and development aspects. Prior to the actual survey, the questionnaire was pre-tested and corrections and slight improvements were made.

The list of the households, recorded by the head (which may be male or female), was obtained from the representatives of the local community and random selection was made in order to make the sample representative and avoid biases in the results. From a total of 294 households (130 in Tullu Guddo, 20 in Funduro and 144 in Tsedacha), 60 households (20%) were surveyed. This was determined based on logistic problems and time limitations. Then, the interview was conducted by the researcher with the help of assistants using the questionnaire prepared for this purpose (Appendix 6). Respondents were, in many cases, the husband and wife. Other members of the household, especially the adults, were also involved in the discussion. Data obtained from the respondents were recorded.

Interview was also made with the clergy using a questionnaire (Appendix 6) in order to assess the status and utilization of sacred groves and the role of churches in the conservation of the sacred groves in particular and the vegetation in the islands in general. In addition, six key informants (Appendix 7), which have been suggested by the local guides and representatives, were selected and interviewed informally on socio-economic issues so as to enrich the information. The points for discussion were history of the Zay People including their entry to the islands, settlement, indigenous resource conservation and management systems and major socio-economic problems and solutions. During the interview with key informants, emphasis was given to issues related to the vegetation in order to get in-depth information about the past and present status, traditional vegetation management systems, utilization and major threats.

Discussion was also made with stakeholders relevant for this study using a questionnaire (Appendix 6). Questions were addressed for respective stakeholders. The stakeholders selected for the present study were representatives of the local community, Woreda Administrative Office, Woreda Rural Land and Natural Resources Administration Office, Woreda Agriculture Office, Woreda Health Office, Woreda Church Office, Ziway Fisheries Resources Research Centre and Ziway Fish Production and Marketing Enterprise. The stakeholders were from East Shewa Zone specifically in Ziway town. Because of the limitations of transport, budget and time, it was not possible to include stakeholders from Arsi Zone.

3.2.2.3. Group Discussion

In order to undertake the discussion, group participants were selected by the help of the local representatives. Attention was given to encompass both sexes and different age groups.

Accordingly, a group consisting of women, youths, elders, clergy and representatives of the local community was formulated. At the beginning of the discussion, the aim was explained to the participants by the researcher in collaboration with the representatives so as to ensure openness in the discussion. The actual discussion (Fig. 5) was made on socio-economic issues with emphasis on the conservation, management and sustainable utilization of the vegetation resources in the islands of Lake Ziway. The discussion focused on identifying the major threats to the vegetation and measures that should be taken to alleviate the problems. The ideas and suggestions forwarded by the group participants were registered. Advice on the ecological and long-term socio-economic importance of the vegetation was given by the researcher so as to create awareness among the participants and ultimately in the community. Because of the limitations mentioned previously, it was difficult to mobilize stakeholders for discussion with the local communities.

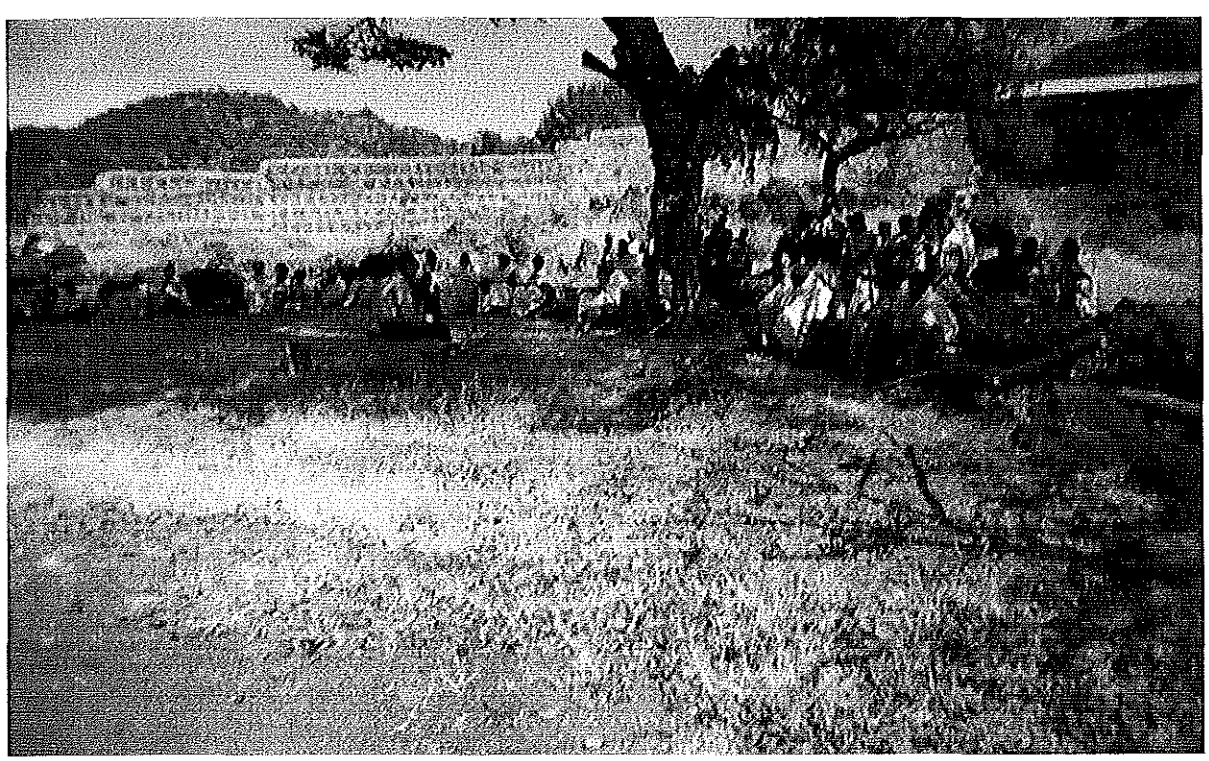


Fig. 5. Group discussion at Kidist-Mariam church compound in Tullu Guddo.

3.2.3. Data Analysis

3.2.3.1. Analysis of Vegetation Data

The following indices and parameters were computed in order to determine species diversity, structure and regeneration status of the vegetation.

1. The diversity of woody species was determined using the Shannon-Wiener diversity index (H) and evenness or equitability index (E) (Krebs, 1989; Barnes *et al.*, 1998), which are computed as:

$$H = - \sum pi \ln pi$$

$$E = H/Hmax = H/\ln S$$

where pi is the proportion of individuals of the i^{th} species; S is the number of species; Hmax is the maximum possible diversity that would occur if all species had equal abundance and appears to be the natural log of S.

2. The similarity in species composition between the islands was computed by using Jaccard's similarity coefficient (Sj) (Krebs, 1989), which is expressed as:

$$Sj = a/(a+b+c)$$

where a is the number of species that occur in both islands 1 and 2; b is the number of species that occur in island 1 but not in island 2; and c is the number of species that occur in island 2 but not in island 1.

3. Analysis of vegetation classification was made using PC-ORD software (McCune and Mefford, 1999).
4. Abundance of woody species was calculated as the total count of individuals of the species in all the relevés sampled (2.9 ha).
5. Density was computed as the number of individuals of a species per hectare.

6. Percentage frequency of the species was calculated as: Frequency (%) = (Number of relevés in which the species occurs/Total number of relevés sampled) x 100.

7. The DBH of trees and shrubs was categorized into nine classes (1 = < 2.5 cm; 2 = 2.5-10 cm; 3 = 10-20 cm; 4 = 20-30 cm; 5 = 30-40 cm; 6 = 40-50 cm; 7 = 50-60 cm; 8 = 60-70 cm; 9 = > 70 cm)

8. Basal area of trees and shrubs with DBH ≥ 2.5 cm was calculated by using the formula:

$$\textbf{Basal area} = (\textbf{DBH}/2)^2 \times 3.14$$

9. The importance value index (IVI) (Lamprecht, 1989; Kent and Coker, 1994) for each species was calculated with three components as follows: Relative density = (Density of a species/Total density) x 100; Relative frequency = (Frequency of a species/Total frequency) x 100; Relative dominance = (Basal area of a species/Total basal area) x 100; IVI = Relative density + Relative frequency + Relative dominance.

3.2.3.2. Analysis of Socio-economic Data

Microsoft Excel Software (Microsoft, 2000) was used for the analysis of the survey data and the results of the analysis were presented using descriptive statistics.

4. RESULTS AND DISCUSSION

4.1. Vegetation

4.1.1. Floristic Composition

A total of 141 plant species belonging to 113 genera and 55 families were identified from the islands of Lake Ziway (Appendix 2). One species was unidentified. 85.5% of the families were dicots, 12.7% monocots and 1.8% gymnosperms. The families with the highest number of species were Asteraceae and Fabaceae (11 species each), followed by Euphorbiaceae (10 species), Poaceae (9 species) and Acanthaceae, Boraginaceae, Capparidaceae, Lamiaceae and Solanaceae (5 species each) (Table 2). Three families were represented by four species, five families by three species, ten families by two species and the rest twenty eight families by one species each. The families with the highest number of genera were Asteraceae (11 genera), Poaceae (9 genera) and Euphorbiaceae and Fabaceae (7 genera each). From the total species, 18.4% were trees, 21.3% trees/shrubs, 12.1% shrubs, 3.5% lianas, 4.3% herbaceous climbers and 40.4% herbs. The herbs had the largest proportion of the lifeforms.

The flora of the islands comprise both lowland and highland species. Data obtained from the Flora of Ethiopia and Flora of Ethiopia and Eritrea showed that the distribution of the species encountered in the islands is in the altitudinal range from sea level to 3400 m. The unique floristic composition of the islands is attributed to habitat diversity and the diverse forms of dispersal agents, which include wind, water and animals, especially birds. Jeffries (1997) pointed out that islands shelter unusual relicts and combinations of species.

Table 2. Comparative distribution of genera and species in each family.

No.	Family	G	S	% S	No.	Family	G	S	% S
1	Acanthaceae	4	5	3.5	29	Fabaceae	7	11	7.8
2	Aloaceae	1	1	0.7	30	Lamiaceae	2	5	3.5
3	Amaranthaceae	1	1	0.7	31	Malpighiaceae	1	1	0.7
4	Anacardiaceae	3	4	2.8	32	Malvaceae	2	3	2.1
5	Apiaceae	1	1	0.7	33	Meliaceae	1	1	0.7
6	Apocynaceae	1	1	0.7	34	Moraceae	1	4	2.8
7	Araliaceae	1	1	0.7	35	Myrtaceae	2	2	1.4
8	Asclepiadaceae	3	3	2.1	36	Nyctaginaceae	1	2	1.4
9	Asparagaceae	1	1	0.7	37	Olacaceae	1	1	0.7
10	Asteraceae	11	11	7.8	38	Oleaceae	2	2	1.4
11	Balanitaceae	1	1	0.7	39	Orobanchaceae	1	1	0.7
12	Bignoniaceae	2	2	1.4	40	Papaveraceae	1	1	0.7
13	Boraginaceae	3	5	3.5	41	Poaceae	9	9	6.4
14	Brassicaceae	1	1	0.7	42	Polygonaceae	3	3	2.1
15	Burseraceae	1	1	0.7	43	Resedaceae	1	1	0.7
16	Cactaceae	1	1	0.7	44	Rhamnaceae	2	2	1.4
17	Capparidaceae	3	5	3.5	45	Rubiaceae	2	2	1.4
18	Caricaceae	1	1	0.7	46	Rutaceae	1	1	0.7
19	Celastraceae	2	2	1.4	47	Sapindaceae	2	2	1.4
20	Chenopodiaceae	1	2	1.4	48	Scrophulariaceae	1	1	0.7
21	Commelinaceae	1	1	0.7	49	Solanaceae	3	5	3.5

(Table 2 Continued)

22	Convolvulaceae	1	1	0.7	50	Tiliaceae	1	3	2.1
23	Crassulaceae	1	1	0.7	51	Typhaceae	1	1	0.7
24	Cucurbitaceae	1	1	0.7	52	Ulmaceae	1	1	0.7
25	Cupressaceae	1	1	0.7	53	Urticaceae	2	2	1.4
26	Cyperaceae	2	4	2.8	54	Verbenaceae	1	1	0.7
27	Dracaenaceae	1	1	0.7	55	Vitaceae	3	3	2.1
28	Euphorbiaceae	7	10	7.1					

G = Number of genera S = Number of species

4.1.2. Species Diversity

The richness of families and species of the islands of Lake Ziway ranged from 24 and 43 at Funduro to 43 and 87 at Tullu Guddo, respectively (Table 3). Tullu Guddo had the highest species richness of all the islands due to its large size, altitudinal variation and ecological diversity. Debre Sina has an area less than that of Tsedacha but it was the second in species richness next to Tullu Guddo. This is because Debre Sina is uninhabited island and thus human disturbance is minimal whereas Tsedacha is the most populated island whereby human disturbance is high. Funduro has the same area as that of Debre Sina but its richness was much lower since it is inhabited and exposed to human interference. Funduro has an area greater than Galilla but its richness was lower than that of the latter. Generally, there is relationship between species richness and size of the islands. It has been reported that the number of species on an island depends on the island's area (Rosenzweig, 1995; Jeffries, 1997; Ricklefs and Miller, 2000). This is because the larger the area the greater the habitat diversity and, thus,

the greater the species diversity. But this is not always true (Rosenzweig, 1995; Jeffries, 1997). The results also indicated that species richness depends on human disturbance regime.

The overall Shannon-Wiener diversity and evenness of woody species in the islands were 2.60 and 0.62, respectively. The results indicated that the diversity of woody species in the islands is relatively high whereas the evenness is low. The low evenness value showed that there is unbalanced distribution of individuals among different species. Debre Sina had the highest diversity and evenness followed by Tullu Guddo (Table 3). The high species diversity and evenness of Debre Sina may be attributed to low human disturbance and also its flatness and relatively well developed soil, which are suitable for growth of immigrant propagules. The equitability for Tsedacha and Funduro were lower than the other islands, indicating that there is unbalanced representation of species because of human disturbance as well as site and species characteristics. According to Alemayehu Wassie (2002), the reason for low evenness can be attributed to excessive disturbance, variable conditions for regeneration and exploitation of some species. The Shannon-Wiener diversity and evenness indices imply the significance of conserving the vegetation in the islands from both diversity and human disturbance perspectives.

Table 3. Comparison of area, richness, diversity (H) and evenness (E) among the islands of Lake Ziway.

Island	Area (ha)*	Richness		H	E
		Families	Species		
Galilla	20	35	57	2.18	0.62
Debre Sina	30	37	78	2.90	0.78
Funduro	30	24	43	1.79	0.57
Tsedacha	210	35	68	1.78	0.58
Tullu Guddo	480	43	87	2.38	0.64

* Soucre: Yared Tigabu (2003)

4.1.3. Similarity in Species Composition between the Islands

From the total species identified, 19 species were found on both the five islands, 3 species on Galilla only, 15 species on Debre Sina only, 20 species on Tullu Guddo only, 1 species on Funduro only and 13 species on Tsedacha only (Appendix 3). The woody species found on all the five islands were *Acacia tortilis*, *Aeschynomene elaphroxylon*, *Caparis fasciculraris*, *Celtis africana*, *Cordia monoica*, *Ehretia cymosa*, *Euphorbia abyssinica*, *E. tirucalli*, *Ficus ingens*, *F. sycomorus*, *F. vasta*, *Opuntia ficus-indica* and *Solanum schimperianum*. *Acacia etbaica*, *Balanites aegyptiaca*, *Barleria eranthemoides*, *Croton dichogamus*, *Dodonaea angustifolia*, *Grewia velutina*, *Juniperus procera*, *Lannea schimperi*, *Olea europaea* subsp. *cuspidata*, *Rhoicissus tridentata*, *Rhus retinorrhoea*, *Senna singueana*, *Withania somnifera and Ziziphus mucronata* were restricted to Tullu Guddo only.

The similarity values in species composition between the islands ranged from 0.30-0.51 (Table 4). The highest similarity (Sj = 0.51) in species composition was found between Galilla and Debre Sina and the lowest similarity (Sj = 0.30) was between Debre Sina and Tsedacha. One of the reasons for this is that Galilla and Debre Sina are close to each other, possibly having similar environmental conditions and exposure to dispersal agents while Galilla and Tsedacha are far apart. Except for one pair, the remaining similarity coefficients were below 0.5, indicating that there is low similarity among the islands and each island has its own unique species composition. Thus, all of the islands are important in terms of floristic diversity and sensitive from a conservation point of view.

Table 4. Similarities in species composition among the five islands determined by Jaccard's similarity coefficient.

	Galilla	Debre Sina	Tullu Guddo	Funduro	Tsedacha
Galilla	1	0.51	0.41	0.41	0.34
Debre Sina		1	0.40	0.33	0.30
Tullu Guddo			1	0.34	0.36
Funduro				1	0.41
Tsedacha					1

4.1.4. Species-Area Curves

The number of species for each island showed a relatively sharp increase initially with increasing area except for Tullu Guddo (Fig. 6). The highest increase in the number of species

with increasing area was observed for Debre Sina. The curves for Galilla and Debre Sina tended to flatten toward the end while those for Tullu Guddo, Funduro and Tsedacha showed increasing trend toward the end. The species-area curves for the latter three islands showed that species diversity increases as area increases. Rosenzweig (1995) pointed out that species-area curves reveal the pattern of diversity with increasing area.

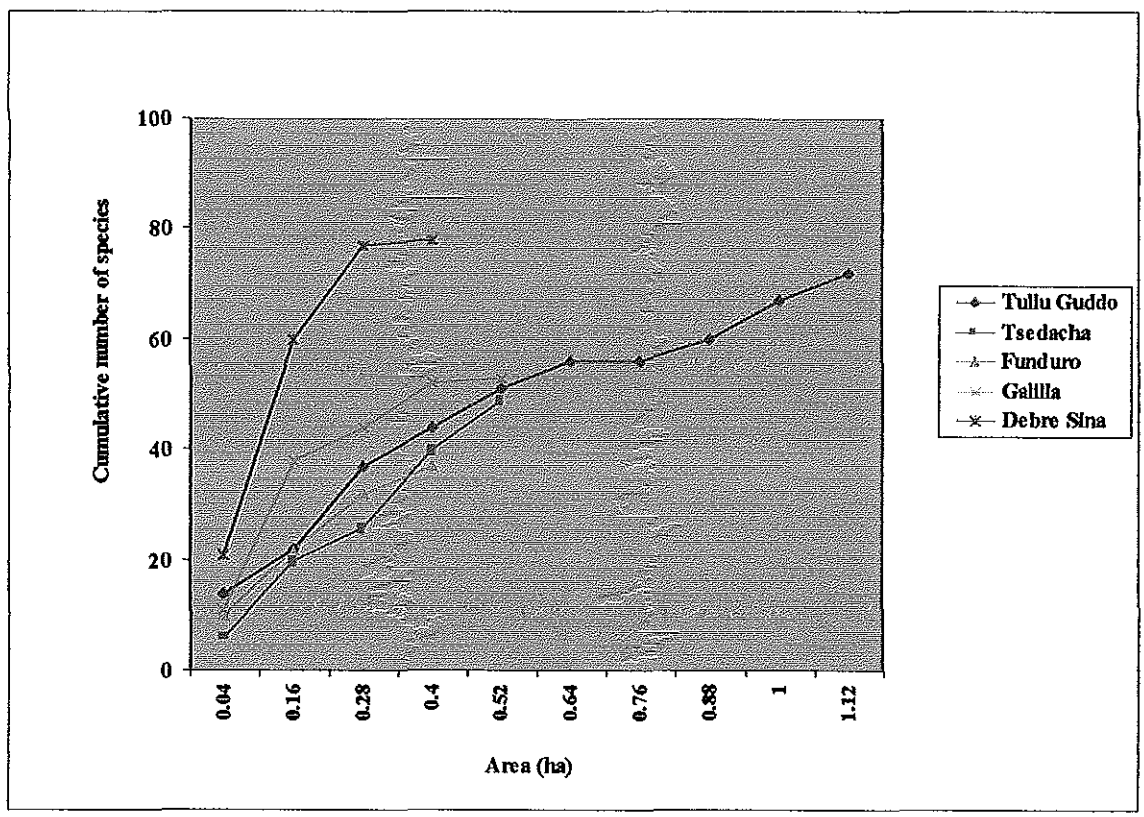


Fig. 6. Species-area curves for the islands of Lake Ziway.

4.1.5. Vegetation Classification

From the analysis of classification, nine clusters were recognized at 50% similarity level (Fig. 7). These clusters were recognized as plant communities and named by using two or three

dominant or characteristic species, which occur in each group. Dominant species are species with the highest cover/abundance values and characteristic species are those which are restricted to one or two relevés. The nine plant communities are described as follows.

1. *Euphorbia tirucalli-Acacia tortilis-Euphorbia abyssinica* community [number of relevés (r) = 20, number of species (n) = 48]

This community occurred at the altitudinal range of 1620-1840 m and slope of 0-55%. *Euphorbia tirucalli, Acacia tortilis, Euphorbia abyssinica, Opuntia ficus-indica and Croton macrostachyus* were the dominant species in this community (Table 5). Shrubs like *Calpurnia aurea* and *Solanum schimperianum*, and the lianas *Capparis fascicularis* and *Cissus quadrangularis* were found. The herbs consisted of *Hyparrhenia hirta, Hypoestes forskaolii, Argemone mexicana, Erucastrum arabicum, Tagetes minuta, Xanthium spinosum* and *Senna occidentalis.*

2. *Ficus vasta-Ficus ingens-Ficus sycomorus* community (r = 12, n = 59)

This community was found at the altitudinal range of 1567-1857 m and slope of 2-40%. *Ficus ingens, F. sycomorus, F. vasta, Euphorbia tirucalli, Acacia tortilis and Maytenus senegalensis* were the dominant trees and *Opuntia ficus-indica, Solanum schimperianum, Acokanthera schimperi, Vernonia myriantha, Phyllanthus reticulatus* and *Pterolobium stellatum* were the dominant shrubs in this community. *Grewia bicolor, Rumex nervosus and Senna didymobotrya* were the characteristic species. The lianas *Capparis fascicularis, Caucanthus auriculatus* and *Cissus quadrangularis* were found. The herbs *Hypoestes forskaolii, Leucas martinicensis* and *Girardinia diversifolia* were common.

3. *Steganotaenia araliacea-Maerua triphylla-Cussonia holstii* community (r = 5, n = 56)

This community was found at the altitudinal range of 1557-1737 m and slope of 12-20%. *Steganotaenia araliacea*, *Maerua triphylla* and *Cussonia holstii* were the characteristic species and *Euphorbia tirucalli*, *Acacia tortilis*, *Euphorbia abyssinica*, *Acacia albida*, *Pappea capensis, Celtis africana and Ehretia cymosa* were the common species in this community. Shrubs like *Vernonia myriantha*, *Solanum schimperianum* and *Asparagus africanus* and the lianas *Capparis fascicularis*, *Caucanthus auriculatus* and *Cissus quadrangularis* were found. The common herbs were *Leucas martinicensis*, *Chenopodium murale*, *Kalanchoe lanceolata, Laggera crispata* and *Girardinia diversifolia.*

4. *Euphorbia tirucalli-Solanum schimperianum-Acacia tortilis* community (r = 5, n = 56)

This community was found at the altitudinal range of 1549-1777 m and slope of 5-20%. *Euphorbia tirucalli*, *Acacia tortilis*, *Euphorbia abyssinica*, *Ficus ingens*, *F. sycomorus* and *F. vasta* were the dominant trees and *Justicia schimperiana*, *Capparis tomentosa*, *Asparagus africanus* and *Lantana camara* were the dominant shrubs in this community. *Commiphora africana* was the characteristic species. The lianas *Cissus quandrangularis*, *Capparis fascicularis and Caucanthus auriculatus* were found in this community. The common herbs were *Ageratum conyzoides*, *Heliotropium aegyptiacum*, *Hypoestes forskaolii*, *Laggera crispata*, *Galinsoga quadriradiata*, *Girardinia diversifolia* and *Kalanchoe lanceolata.*

5. *Justicia schimperiana-Pavetta gardeniifolia-Cordia monoica* community (r = 2, n = 49)

This community occurred at the altitudinal range of 1665-1680 m and slope of 25-27%. *Justicia schimperiana*, *Pavetta gardeniifolia*, *Phyllanthus reticulatus* and *Vernonia myriantha* were the dominant shrubs and *Cordia monoica*, *Euphorbia tirucalli*, *Acacia tortilis*, *Ficus*

thonningii, F. vasta and *Celtis africana* were the dominant trees in this community. *Kanahia laniflora* was the characteristic species. The lianas *Cissus quadrangularis* and *Capparis fascicularis* were found in this community. The herbs included *Ageratum conyzoides, Galinsoga quadriradiata, Achyranthes aspera, Heliotropium aegyptiacum, Cyperus esculentus* and *Cynodon dactylon.*

6. *Olea europaea-Juniperus procera-Dodonaea angustifolia* community (r = 20, n = 57)

This community was distributed at the altitudinal range of 1690-2033 m and slope of 10-80%. *Olea europaea* subsp. *cuspidata, Juniperus procera, Dodonaea angustifolia, Croton dichogamus, Lannea schimperi, Acacia etbaica, Balanites aegypticaca* and *Rhoicissus tridentata* were the characteristic species and *Celtis africana, Euphorbia tirucalli, E. abyssinica, Acacia tortilis, Opuntia ficus-indica, Flueggea virosa, Pavetta gardeniifolia, Solanum incanum* and *Barleria eranthemoides* were the dominant species in this community. The lianas in this community were *Jasminum grandiflorum, Capparis fascicularis* and *Cissus quadrangularis.* The herbs *Hypoestes forskaolii, Plectranthus lanuginosus, Heliotropium aegyptiacum, Erucastrum arabicum, Aloe pubescens, Kalanchoe lanceolata, Tagetes minuta* and *Bidens biternata* were very common.

7. *Senna singueana-Pavetta gardeniifolia-Grewia velutina* community (r = 7, n = 51)

This community was found at the altitudinal range of 1638-1830 m and slope of 16-30%. *Senna singueana, Pavetta gardeniifolia, Opuntia ficus-indica, Rhus natalensis, Calpurnia aurea, Grewia trichocarpa, G. velutina, Flueggea virosa and Barleria eranthemoides* were the dominant shrubs *and Euphorbia tirucalli, Acacia tortilis, Euphorbia abyssinica and Pappea capensis* were the dominant trees in this community. *Rhus retinorrhoea* and *Ziziphus*

mucronata were the characteristic species. The lianas *Capparis fascicularis*, *Cissus quadrangularis*, *Jasminum grandiflorum* and *Caucanthus auriculatus* were found in this community. The common herbs were *Leucas martinicensis*, *Hypoestes forskaolii*, *Plectranthus lanuginosus*, *Erucastrum arabicum*, *Tagetes minuta*, *Achyranthes aspera*, *Chloris pychnothrix*, *Kalanchoe lanceolata* and *Aloe pubescens*.

8. *Aeschynomene elaphroxylon-Sesbania sesban* community (r = 1, n = 31)

This community occurred at an altitude of 1673 m and slope of 5%. *Aeschynomene elaphroxylon*, *Sesbania sesban*, *Euphorbia tirucalli* and *Acacia tortilis* were the dominant species and *Withania somnifera* was the characteristic species in this community. The liana found in this community was *Capparis fascicularis*. Some of the herbs in this community included *Leucas martinicensis*, *Hypoestes forskaolii*, *Achyranthes aspera*, *Galinsoga quadriradiata*, *Cyperus alopecuroides*, *Shoenoplectus confusus*, *Leptochloa fusca* and *Typha latifolia*.

9. *Pappea capensis-Rhus natalensis-Maytenus senegalensis* community (r = 1, n = 25)

This community occurred at an altitude of 1699 m and slope of 30%. *Pappea capensis*, *Rhus natalensis*, *Maytenus senegalensis*, *Ximenia americana*, *Euphorbia tirucalli*, *Acacia tortilis* and *Pavetta gardeniifolia* were the dominant species in this community. The lianas in this community were *Jasminum grandiflorum*, *Caucanthus auriculatus*, *Cissus quadrangularis* and *Capparis fascicularis*. The herbs consisted of *Leucas martinicensis*, *Plecthranthus lanuginosus*, *P. cylindraceus*, *P. minutiflorus*, *Chloris pychnothrix*, *Chenopodium murale*, *C. procerum*, *Girardinia diversifolia* and *Kalanchoe lanceolata*.

Table 5. Tree/shrub and herb species in each plant community type.

Community type	Tree/shrub species	Herb species
1	*Euphorbia abyssinica, E. tirucalli, Acacia tortilis, Opuntia ficus-indica, Croton macrostachyus, Calpurnia aurea, Solanum schimperianum*	*Hyparrhenia hirta, Hypoestes forskaolii, Argemone mexicana, Erucastrum arabicum, Tagetes minuta, Xanthium spinosum, Senna occidentalis*
2	*Ficus ingens, F. sycomorus, F. vasta, Euphorbia tirucalli, Acacia tortilis, Maytenus senegalensis, Opuntia ficus-indica, Solanum schimperianum, Acokanthera schimperi, Vernonia myriantha, Phyllanthus reticulatus, Pterolobium stellatum, Grewia bicolor, Rumex nervosus, Senna didymobotrya*	*Hypoestes forskaolii, Leucas martinicensis, Girardinia diversifolia*
3	*Steganotaenia araliacea, Maerua triphylla, Cussonia holstii, Euphorbia abyssinica, E. tirucalli, Acacia albida, A. tortilis, Pappea capensis, Celtis Africana, Ehretia cymosa, Vernonia myriantha, Solanum schimperianum, Asparagus africanus*	*Leucas martinicensis, Chenopodium murale, Kalanchoe lanceolata, Laggera crispata, Girardinia diversifolia*
4	*Euphorbia abyssinica, E. tirucalli, Acacia tortilis, Ficus ingens, F. sycomorus, F. vasta, Justicia schimperiana, Capparis tomentosa, Asparagus africanus, Lantana camara, Commiphora africana*	*Ageratum conyzoides, Heliotropium aegyptiacum, Hypoestes forskaolii, Laggera crispata, Galinsoga quadriradiata, Girardinia diversifolia, Kalanchoe lanceolata*
5	*Justicia schimperiana, Pavetta gardeniifolia, Phyllanthus reticulatus, Vernonia myriantha,*	*Ageratum conyzoides, Galinsoga quadriradiata, Achyranthes aspera,*

	Cordia monoica, Euphorbia tirucalli, Acacia tortilis, Ficus thonningii, F. vasta, Celtis Africana, Kanahia laniflora	*Heliotropium aegyptiacum, Cyperus esculentus, Cynodon dactylon*
6	*Olea europaea subsp. cuspidata, Juniperus procera, Dodonaea angustifolia, Croton dichogamus, Lannea schimperi, Acacia etbaica, Balanites aegypticaca, Rhoicissus tridentate, Celtis africana, Euphorbia abyssinica, E. tirucalli, Acacia tortilis, Opuntia ficus-indica, Flueggea virosa, Pavetta gardeniifolia, Solanum incanum, Barleria eranthemoides*	*Hypoestes forskaolii, Plectranthus lanuginosus, Heliotropium aegyptiacum, Erucastrum arabicum, Aloe pubescens, Kalanchoe lanceolata, Tagetes minuta Bidens biternata*
7	*Senna singueana, Pavetta gardeniifolia, Opuntia ficus-indica, Rhus natalensis, Calpurnia aurea, Grewia trichocarpa, G. velutina, Flueggea virosa, Barleria eranthemoides, Euphorbia tirucalli, Acacia tortilis, Euphorbia abyssinica, Pappea capensis, Rhus retinorrhoea, Ziziphus mucronata*	*Leucas martinicensis, Hypoestes forskaolii, Plectranthus lanuginosus, Erucastrum arabicum, Tagetes minuta, Achyranthes aspera, Chloris pychnothrix, Kalanchoe lanceolata, Aloe pubescens*
8	*Aeschynomene elaphroxylon, Sesbania sesban, Euphorbia tirucalli, Acacia tortilis, Withania somnifera*	*Leucas martinicensis, Hypoestes forskaolii, Achyranthes aspera, Galinsoga quadriradiata, Cyperus alopecuroides, Shoenoplectus confusus, Leptochloa fusca, Typha latifolia*
9	*Pappea capensis, Rhus natalensis, Maytenus senegalensis, Ximenia americana, Euphorbia*	*Leucas martinicensis, Plecthranthus lanuginosus, P. cylindraceus, P.*

	tirucalli, Acacia tortilis, Pavetta gardeniifolia	*minutiflorus, Chloris pychnothrix, Chenopodium murale, C. procerum, Girardinia diversifolia, Kalanchoe lanceolata*

Fig. 7. Dendrogram showing clusters of relevés sampled from the islands of Lake Ziway.

4.1.6. Population Structure and Regeneration Status of Woody Species

4.1.6.1. Abundance, Density and Frequency

The abundance and density of woody species in the islands ranged from 866-4153 individuals and 298.6-1432.1 individuals ha^{-1}, respectively (Appendix 4). Tullu Guddo had the highest abundance and density and Funduro the least. Tsedacha has greater area than Galilla and Debre Sina but it had less abundance and density. This is due to disturbance of the vegetation in Tsedacha as it is the most populated island and low human pressure in Galilla and Debre Sina as they are uninhabited. By the same token, Funduro had less abundance and density than Galilla.

The total abundance and density of woody species in the islands were 8640 individuals and 2979 individuals ha^{-1}, respectively (Table 6). The species with the highest density was *Euphorbia tirucalli*, followed by *Euphorbia abyssinica*, *Acacia tortilis*, *Opuntia ficus-indica*, *Capparis fascicularis*, *Pavetta gardeniifolia* and *Solanum schimperianum*. Species like *Balanites aegyptiaca*, *Acacia etbaica*, *Grewia bicolor*, *Phyllanthus ovalifolius*, *Ziziphus mucronata*, *Rhus retinorrhoea*, *Rhoicissus tridentata*, *Maerua triphylla* and *Steganotaenia araliacea* had densities of less than 2 individuals ha^{-1} each and were poorly represented in the vegetation. The species with the highest frequency value was *Acacia tortilis* (90%), followed by *Euphorbia tirucalli* (89%), *Capparis fascicularis* (75%) and *Euphorbia abyssinica* (58%). The high frequency indicates regular horizontal distribution of the species in the islands. Some of the infrequent species were *Balanites aegyptiaca*, *Acacia etbaica*, *Grewia bicolor*, *Ziziphus mucronata*, *Rhus retinorrhoea*, *Dodonaea angustifolia*, *Senna didymobotrya*, *Croton*

dichogamus, *Maerua triphylla*, *Steganotaenia araliacea*, *Olea europaea* subsp. *cuspidata* and *Juniperus procera*.

The variation in density and frequency between species may be attributed to habitat differences, habitat preferences among the species, species characteristics for adaptation, degree of exploitation and conditions for regeneration.

In order to assess the distribution pattern and diversity of species, the frequencies were grouped into five classes: 1 = ≤ 20%; 2 = 20-40%; 3 = 40-60%; 4 = 60-80%; 5 = 80-100%; and the percentage of species in each frequency class was calculated (Fig. 8).

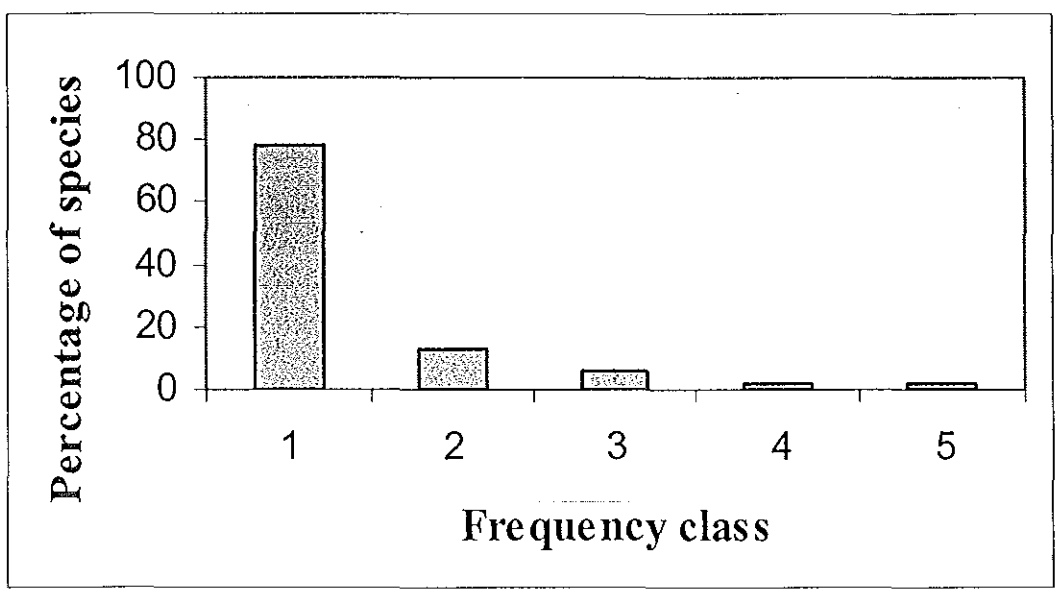


Fig. 8. Frequency distribution of the species in the islands of Lake Ziway.

The frequency reflects the pattern of distribution as well as diversity (Gebremedhin Hadera, 2000; Simon Shibru, 2002). According to Lamprecht (1989), frequency gives an approximate indication of the homogeneity and heterogeneity of a stand. Low values in lower frequency classes and high values in higher frequency classes indicate homogeneity in species composition whereas high values in lower frequency classes and low values in higher frequency classes indicate a high degree of floristic heterogeneity. In the present study, high values in lower frequency classes and low values in higher frequency classes were obtained, indicating that there is a high degree of floristic heterogeneity in the islands. Species-abundance measures are ways of expressing not only the relative richness but also evenness and thereby assessing diversity (Barnes *et al.*, 1998).

4.1.6.2. Basal Area and Importance Value Index (IVI)

The total basal area for the vegetation in the islands was 191 m^2 ha^{-1} (Table 6). The species with the highest basal area was *Ficus vasta*, followed by *F. ingens*, *F. sycomorus*, *A. tortilis*, *Euphorbia abyssinica* and *E. tirucalli*. The high basal area of *Ficus* species was because of their large size. *Euphorbia tirucalli* had the highest density of all the species but its basal area was less than that of the aforementioned species due to its smaller diameter.

The leading species in terms of IVI value was *Euphorbia tirucalli*, followed by *Acacia tortilis*, *F. vasta*, *Euphorbia abyssinica*, *Ficus ingens* and *F. sycomorus*. The high IVI value of *Euphorbia tirucalli* was because of its high relative density and relative frequency though it had low relative dominance/basal area. On the other hand, *Ficus* species had low relative density and relative frequency but high IVI value owing to the contribution of their high

relative basal area. The species with low IVI value were *Olea europaea* subsp. *cuspidata*, *Juniperus procera*, *Steganotaenia araliacea*, *Maerua triphylla*, *Senna didymobotrya*, *Rhus retinorrhoea*, *Rumex nervosus*, *Balanites aegyptiaca*, *Ziziphus mucronata*, *Grewia bicolor*, *Acacia etbaica* and *Dodonaea angustifolia*. In other words, these species were not abundant, frequent and dominant.

IVI is an important parameter that reveals the ecological significance of species in a given ecosystem (Lamprecht, 1989). Species with high IVI are considered more important than those with low IVI. On the other hand, values of IVI can be used for prioritizing species for conservation (Simon Shibru, 2002). Species with high IVI value need less priority for conservation effort while those with low IVI value need high conservation effort. From the results it is possible to suggest that the species listed above and others having low IVI value should be prioritized for conservation.

Table 6. Abundance, density, relative density, frequency, relative frequency, basal area, relative basal area and IVI of woody species.

No.	Scientific name	Abundance *	Density **	Relative density (%)	Frequency (%)	Relative frequency (%)	Basal area ***	Relative basal area (%)	IVI
1	*Euphorbia tirucalli*	2978	1026.90	34.47	89.04	9.55	8.17	4.28	48.30
2	*Euphorbia abyssinica*	1071	369.31	12.40	57.53	6.17	20.39	10.69	29.26
3	*Acacia tortilis*	933	321.72	10.80	90.41	9.70	27.42	14.37	34.87
4	*Opuntia ficus-indica*	457	157.59	5.29	49.32	5.29			
5	*Capparis fascicularis*	370	127.59	4.28	75.34	8.08			
6	*Pavetta gardeniifolia*	363	125.17	4.20	42.47	4.55	0.10	0.05	8.81
7	*Solanum schimperianum*	324	111.72	3.75	38.36	4.11	0.00	0.00	7.86
8	*Aeschynomene elaphroxylon*	298	102.76	3.45	15.07	1.62	3.04	1.59	6.66
9	*Cissus quadrangularis*	265	91.38	3.07	38.36	4.11			
10	*Senna singueana*	130	44.83	1.50	9.59	1.03	0.05	0.02	2.55
11	*Vernonia myriantha*	111	38.28	1.28	8.22	0.88	0.04	0.02	2.19
12	*Grewia velutina*	89	30.69	1.03	24.66	2.64	0.42	0.22	3.89
13	*Rhus natalensis*	74	25.52	0.86	26.03	2.79	0.35	0.18	3.83
14	*Ficus vasta*	73	25.17	0.84	36.99	3.97	54.09	28.35	33.16
15	*Caucanthus auriculatus*	68	23.45	0.79	17.81	1.91			
16	*Ficus ingens*	63	21.72	0.73	26.03	2.79	38.67	20.26	23.78
17	*Croton dichogamus*	60	20.69	0.69	1.37	0.15	0.03	0.01	0.85
18	*Calpurnia aurea*	58	20.00	0.67	10.96	1.18	0.03	0.02	1.87
19	*Acokanthera schimperi*	55	18.97	0.64	10.96	1.18	0.07	0.04	1.85
20	*Phyllanthus reticulatus*	54	18.62	0.63	5.48	0.59			

(Table 6 Continued)

21	*Justicia schimperiana*	52	17.93	0.60	6.85	0.73	0.01	0.00	1.34
22	*Sesbania sesban*	52	17.93	0.60	2.74	0.29	0.01	0.00	0.90
23	*Pappea capensis*	50	17.24	0.58	15.07	1.62	0.98	0.51	2.70
24	*Capparis tomentosa*	46	15.86	0.53	9.59	1.03			
25	*Celtis africana*	45	15.52	0.52	21.92	2.35	1.17	0.62	3.49
26	*Pterolobium stellatum*	44	15.17	0.51	9.59	1.03			
27	*Grewia trichocarpa*	41	14.14	0.47	9.59	1.03	0.11	0.06	1.56
28	*Ficus sycomorus*	32	11.03	0.37	20.55	2.20	30.04	15.74	18.31
29	*Lantana camara*	30	10.34	0.35	8.22	0.88	0.01	0.00	1.23
30	*Maytenus senegalensis*	29	10.00	0.34	12.33	1.32	0.86	0.45	2.11
31	*Flueggea virosa*	28	9.66	0.32	9.59	1.03	0.05	0.03	1.38
32	*Solanum incanum*	24	8.28	0.28	6.85	0.73			
33	*Asparagus africanus*	22	7.59	0.25	12.33	1.32			
35	*Ficus thonningii*	19	6.55	0.22	6.85	0.73	0.59	0.31	1.26
34	*Jasminum grandiflorum*	19	6.55	0.22	4.11	0.44			
36	*Ehretia cymosa*	18	6.21	0.21	10.96	1.18	1.72	0.90	2.28
37	*Erythrococca abyssinica*	16	5.52	0.19	5.48	0.59	0.01	0.00	0.77
38	*Cordia monoica*	15	5.17	0.17	9.59	1.03	0.12	0.06	1.26
39	*Commiphora africana*	15	5.17	0.17	2.74	0.29	0.18	0.09	0.56
40	*Acacia albida*	12	4.14	0.14	6.85	0.73	0.65	0.34	1.21
42	*Ricinus communis*	11	3.79	0.13	6.85	0.73	0.01	0.01	0.87
41	*Ximenia americana*	11	3.79	0.13	5.48	0.59	0.04	0.02	0.74
43	*Maerua angolensis*	9	3.10	0.10	6.85	0.73	0.10	0.05	0.89
46	*Cordia africana*	8	2.76	0.09	4.11	0.44	0.21	0.11	0.64
47	*Croton macrostachyus*	8	2.76	0.09	4.11	0.44	0.01	0.00	0.53
44	*Lannea schimperi*	8	2.76	0.09	2.74	0.29	0.16	0.09	0.48
45	*Olea europaea* subsp. *cuspidata*	8	2.76	0.09	2.74	0.29	0.07	0.04	0.43

(Table 6 Continued)

48	*Kanahia laniflora*	7	2.41	0.08	1.37	0.15			
52	*Cussonia holstii*	6	2.07	0.07	4.11	0.44	0.29	0.15	0.66
50	*Juniperus procera*	6	2.07	0.07	2.74	0.29	0.08	0.04	0.40
53	*Withania somnifera*	6	2.07	0.07	2.74	0.29			
49	*Senna didymobotrya*	6	2.07	0.07	1.37	0.15	0.10	0.05	0.27
51	*Dodonaea angustifolia*	6	2.07	0.07	1.37	0.15	0.01	0.01	0.23
54	*Hibiscus diversifolius*	5	1.72	0.06	2.74	0.29			
56	*Steganotaenia araliacea*	4	1.38	0.05	2.74	0.29	0.06	0.03	0.37
57	*Maerua triphylla*	4	1.38	0.05	2.74	0.29	0.03	0.02	0.36
55	*Rumex nervosus*	4	1.38	0.05	1.37	0.15	0.00	0.00	0.19
59	*Rhus retinorrhoea*	3	1.03	0.03	1.37	0.15	0.19	0.10	0.28
60	*Ziziphus mucronata*	3	1.03	0.03	1.37	0.15	0.04	0.02	0.20
58	*Rhoicissus tridentata*	3	1.03	0.03	1.37	0.15			
61	*Phyllanthus ovalifolius*	3	1.03	0.03	1.37	0.15			
62	*Leucas abyssinica*	3	1.03	0.03	1.37	0.15			
64	*Acacia etbaica*	2	0.69	0.02	1.37	0.15	0.06	0.03	0.20
63	*Grewia bicolor*	2	0.69	0.02	1.37	0.15	0.00	0.00	0.17
65	*Balanites aegyptiaca*	1	0.34	0.01	1.37	0.15	0.00	0.00	0.16
	Total	**8640**	**2979.31**	**100**	**932.88**	**100**	**190.84**	**100**	**258.17**

* = total number of individuals; ** = individuals ha^{-1}; *** = m^2 ha^{-1}

4.1.6.3. Regeneration Status

The size class distributions of species exhibited different patterns (Fig. 9). The DBH class distribution patterns were:

A. Species having high number of individuals in the first class with gradual decrease towards the middle classes: *Euphorbia tirucalli* (Tullu Guddo, Funduro, Tsedacha), *Acokanthera schimperi* (Debre Sina), *Aeschynomene elaphroxylon* (Funduro, Tsedacha), *Pavetta gardeniifolia and Senna singueana* (Tullu Guddo).

B. Species with no or few individuals in the lower classes, missing or few individuals in the middle classes and sharp increase in the higher classes: *Ficus ingens* and *F. vasta* (Galilla), *F. sycomorus* (Tullu Guddo).

C. Species having no or few individuals in the lower classes, increased number of individuals towards the middle classes but declining number at the higher classes: *Acacia tortilis* (Debre Sina, Tullu Guddo, Funduro, Tsedacha), *Celtis africana* (Galilla, Debre Sina), *Aeschynomene elaphroxylon* and *Maytenus senegalensis* (Galilla), *Euphorbia abyssinica* (Debre Sina, Tullu Guddo), *Pappea capensis* (Tullu Guddo).

D. Species with few individuals in the first class and high number of individuals in the second and third classes followed by declining number of individuals at the middle and higher classes: *Euphorbia tirucalli* (Debre Sina), *Grewia velutina* (Tullu Guddo), *Euphorbia abyssinica* (Funduro, Tsedacha).

E. Species with high number of individuals in the first and second classes and a sharp drop in the third class: *Calpurnia aurea* (Tsedacha).

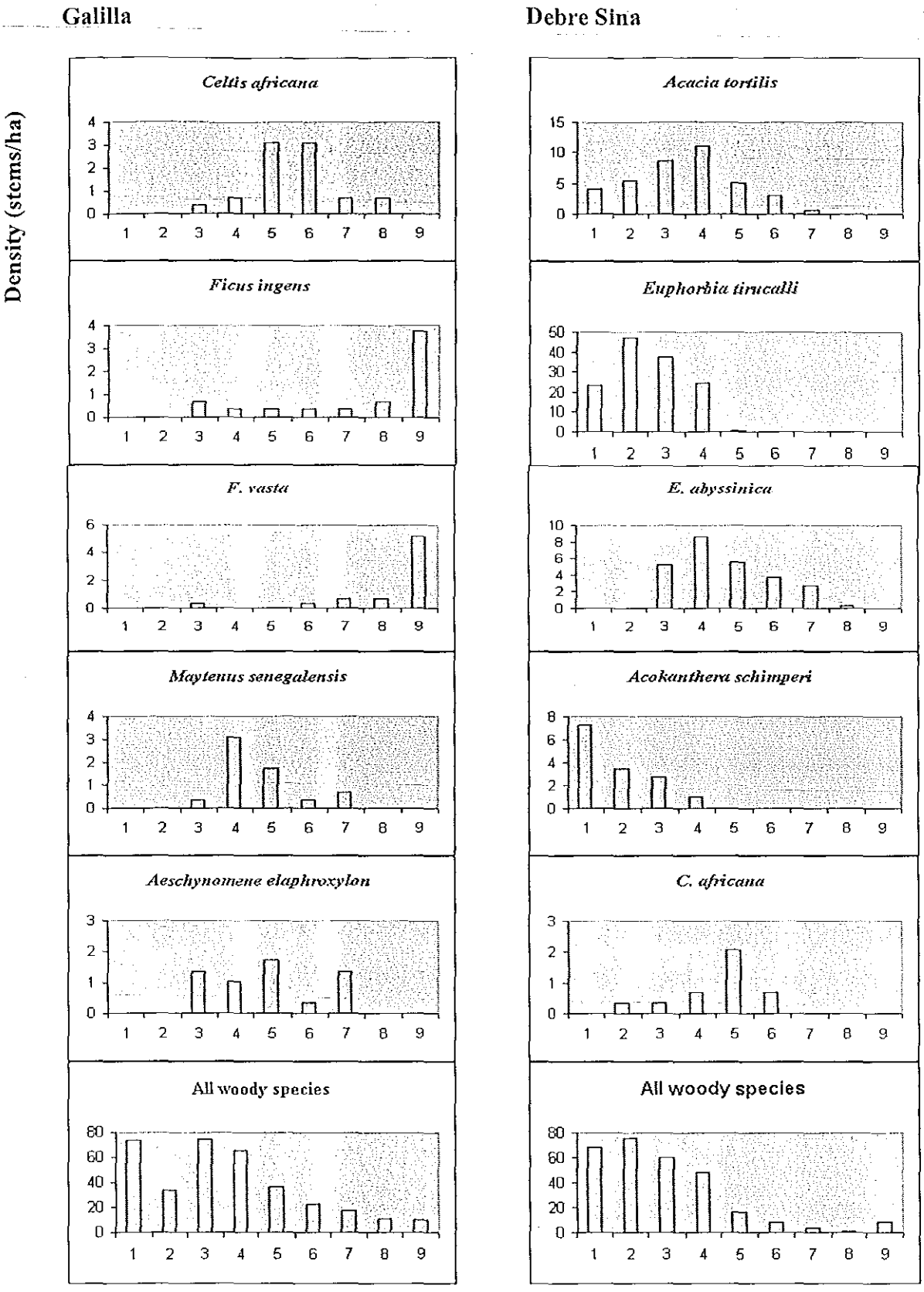
The DBH class distribution patterns showed that there are species with individuals concentrated in the lower classes, some species at the middle and others at higher classes. Only *Euphorbia abyssinica*, *Ficus ingens* and *F. vasta* reached the last DBH class (Fig. 9). Sign of selective removal was observed for *Aeschynomene elaphroxylon* and *Euphorbia abyssinica*. The reason for this is cutting the former for making local boats and the latter for construction purposes.

From the DBH class distributions of the species, two types of regeneration status could be recognized: good and poor regeneration. Some species possessed high number of individuals in the lower DBH classes, particularly in the first class, and this suggests that they have good regeneration potential. This implies that dying adult trees will be replaced by the growth of individuals from the smaller size classes and seems to be a self-maintaining plant population. Other species possessed either no or few number of individuals in the lower DBH classes, particularly in the first class, and this suggests that the species are in poor regeneration status. *Euphorbia tirucalli* showed good regeneration at Tullu Guddo, Funduro and Tsedacha but hampered regeneration at Debre Sina. *Aeschynomene elaphroxylon* showed good regeneration at Funduro and Tsedacha but hampered regeneration at Galilla. Other species, which showed good regeneration, include *Acokanthera schimperi* at Debre Sina, *Pavetta gardeniifolia* and *Senna singueana* at Tullu Guddo and *Calpurnia aurea* at Tsedacha. *Acacia tortilis* and *Euphorbia abyssinica* showed hampered regeneration at Debre Sina, Tullu Guddo, Funduro and Tsedacha. Other species with hampered regeneration include *Celtis africana* at Galilla and Debre Sina, *Ficus ingens*, *F. vasta* and *Maytenus senegalensis* at Galilla, *Pappea capensis*, *Ficus sycomorus* and *Grewia velutina* at Tullu Guddo. This could be due to unfavourable environmental conditions and damage caused by free grazing livestock, particularly goats,

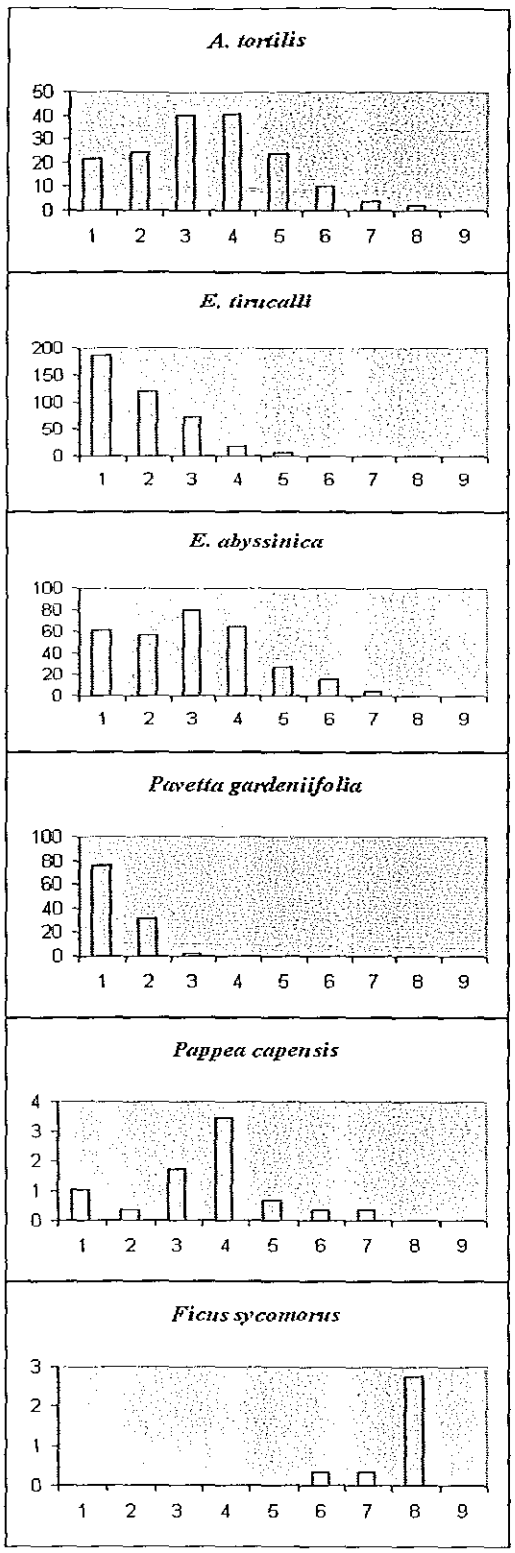
which resulted in hampered regeneration. This leads to the suggestion that limiting the number of goats can improve the regeneration of these and other woody species. Although the IVI value suggested that *Ficus* species need less priority, the DBH class distributions showed that the species are in poor regeneration status and, thus, should be prioritized for conservation.

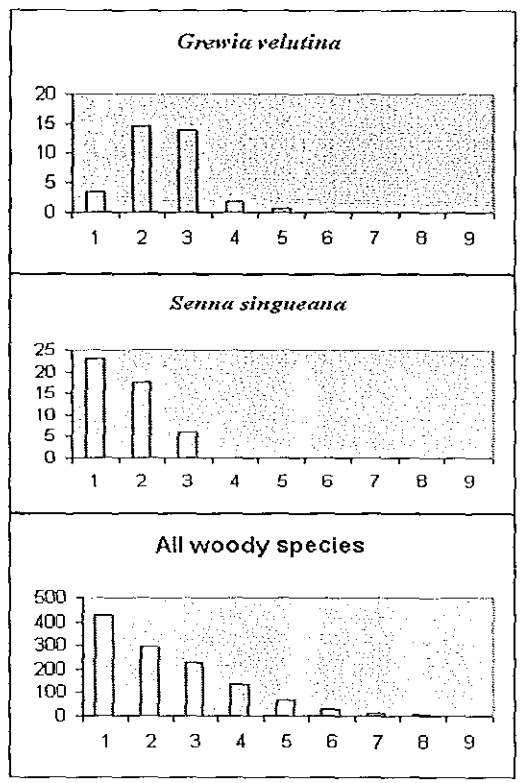
The DBH class distribution of all woody species at Galilla showed U-shaped distribution in the lower classes and reverse "J" distribution in the middle and higher classes. The U-shaped DBH class distribution indicated that there is good regeneration but seedling establishment is hampered due to disturbance caused by free grazing livestock, particularly goats, compounded with unfavouralble environmental conditions like rocky land and poorly developed soil. The vegetation is sensitive to disturbance due to the island's small size. The DBH class distribution of all woody species at Debre Sina showed a reverse "J" distribution with slight deviation in the first class. The DBH class distribution of all woody species at Tullu Guddo, Funduro and Tsedacha showed a reverse "J" distribution.

The cumulative diameter class distribution of all woody plants in all the islands exhibited a more or less reverse "J" type of distribution, which is considered as an indication of stable population structure or good regeneration status (Silvertown, 1982; Silvertown and Doust, 1993; Tamrat Bekele, 1994; Demel Teketay, 1997; Alemnew Aleligne, 2001; Alemayehu Wassie, 2002; Getachew Tesfaye *et al.*, 2002; Simon Shibru, 2002). But here it is important to note that some of the species are not in good regeneration status and thus require due attention.

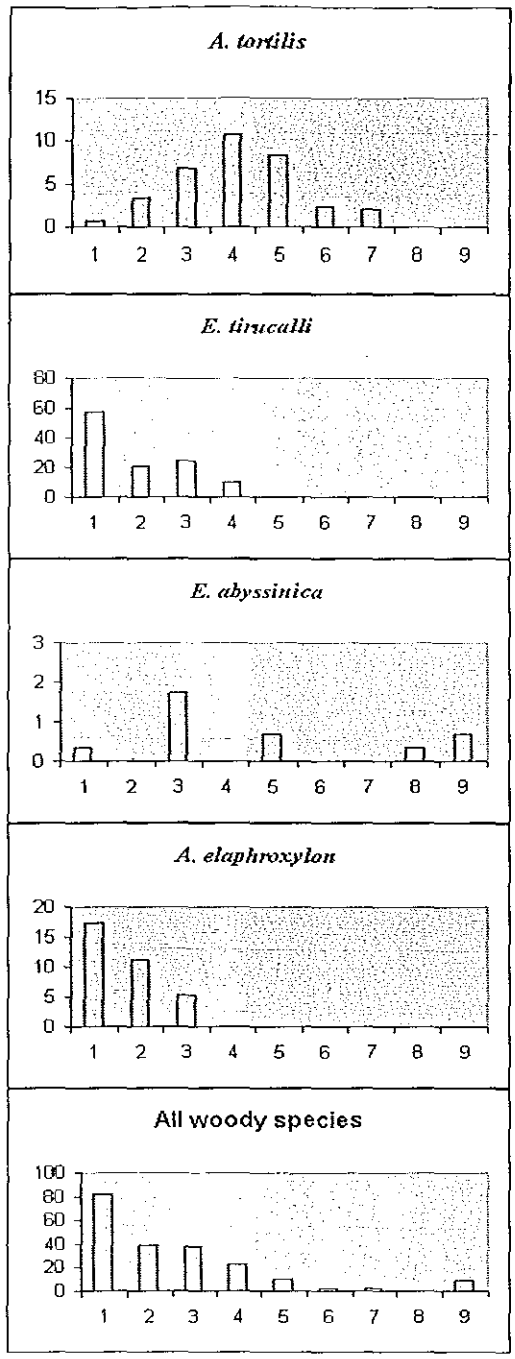

Galilla
Debre Sina
Density (stems/ha)
Celtis africana
Acacia tortilis
Ficus ingens
Euphorbia tirucalli
F. vasta
E. abyssinica
Maytenus senegalensis
Acokanthera schimperi
Aeschynomene elaphroxylon
C. africana
All woody species
All woody species

Tullu Guddo

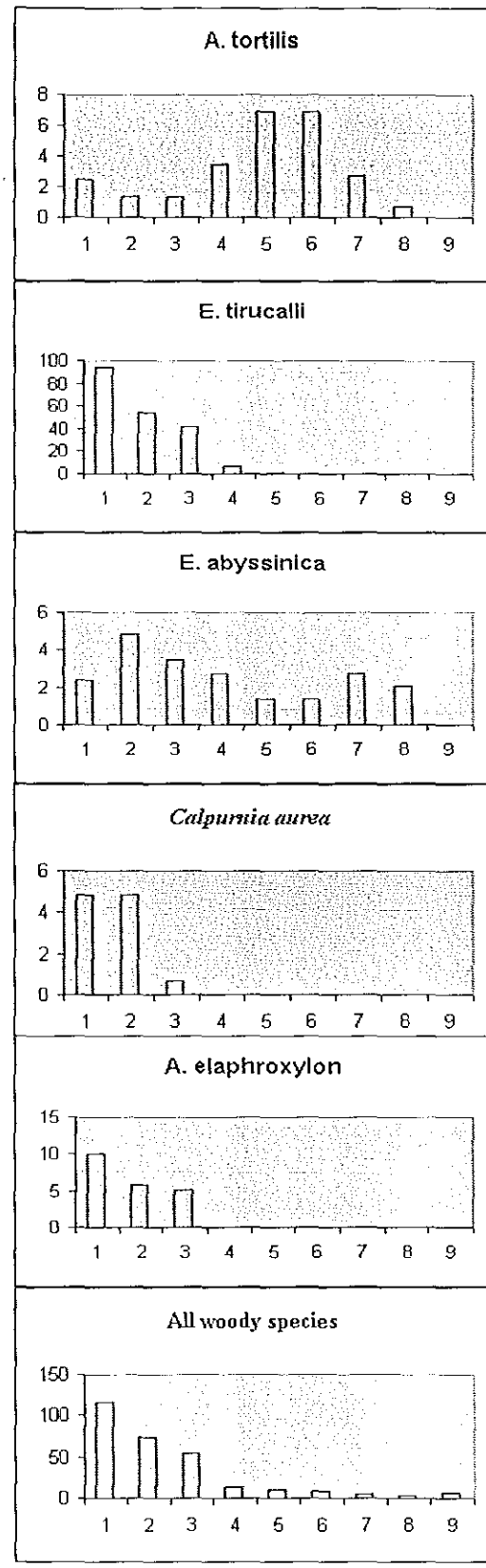

A. tortilis
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9
E. tirucalli
200
150
100
50
0
1 2 3 4 5 6 7 8 9
E. abyssinica
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9
Pavetta gardeniifolia
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9
Pappea capensis
4
3
2
1
0
1 2 3 4 5 6 7 8 9
Ficus sycomorus
3
2
1
0
1 2 3 4 5 6 7 8 9


Grewia velutina
20
15
10
5
0
1 2 3 4 5 6 7 8 9
Senna singueana
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9
All woody species
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9

Funduro



Tsedacha



All Islands

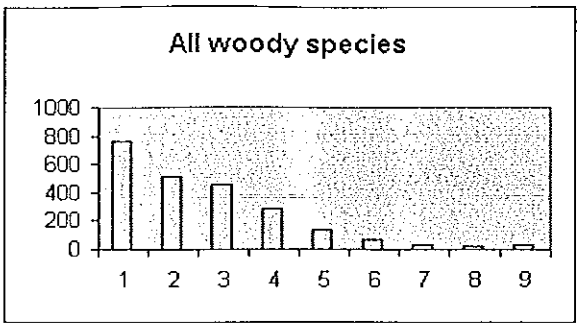


Fig. 9. DBH class distributions of some selected trees and shrubs and all woody species in each and all island(s) (DBH classes: 1 = < 2.5 cm; 2 = 2.5-10 cm; 3 = 10-20 cm; 4 = 20-30 cm; 5 = 30-40 cm; 6 = 40-50 cm; 7 = 50-60 cm; 8 = 60-70 cm; 9 = > 70 cm).

4.2. Socio-economic Survey

4.2.1. Characteristics of the Households

4.2.1.1. Age and Sex Structure

The total family members of the 60 households were 418 individuals, of which 49.3% were males and 50.7% females (Appendix 8). About 75% of the households were male-headed while 25% were female-headed. About seven persons inhabit a household on average. From the total households, about 28.3% received health and family planning education. About 76.7% of the respondents expressed that they do not want to have more children because of low income among many other reasons.

About 67% of the total household members were in the age of ≤ 20 years, 31% from 21-60 years and only 1.9% > 60 years. This suggests that in the islands there is high young generation, which is a dependent group. The high population growth has resulted in increased pressure on the environment, particularly on the plant resources. On the other hand, the community had understood that the existing economy could no longer support the needs of the growing population in the islands and realized the importance of limiting the number of children. This is a promising attitudinal change for conservation and sustainable utilization of the remnant vegetation in the islands.

4.2.1.2. Education

The results indicated that 34.0% of the total household members couldn't read and write, 3.3% could read and write and 62.7% were literate varying from primary to higher education (Appendix 9). The results indicated that the importance of education is understood by the Zay. The high literacy level will have positive impact on any development and conservation activities that could be carried out in the islands.

4.2.1.3. Occupations, Income and Expenditure

The occupations of the households were diverse (Table 7). The major activities were fishing (85.0%), crop production (80.0%), selling local drinks (41.7%), fruit production (31.7%), weaving traditional clothes (30.0%) and labour work (30.0%). The households generated their income from different activities. The average annual income and expenditure of the households were 1804.27 and 1742.02 Birr, respectively. The contribution to the income from

fish sale alone was 1365.60 Birr. The other sources of income included sale of animals and their products, fruits, handcrafts, local drinks and honey and labour work. The major items on which the households expend money were food, clothing, health, education and ceremonies.

The average annual income was slightly higher than the expenditure. This showed that the people save money to buy grain, which is usually in deficit, and to cover extra expenses that might be encountered due to various reasons. About 75.7 % of the annual income was derived from fish sale, indicating that the islanders are highly dependent on fishing. However, discussion with the local people has shown that they are economically poor and lead miserable lives.

Table 7. Major livelihood means of the households in the islands of Lake Ziway.

Occupation	Frequency	%
Fishery	51	85.0
Crop production	48	80.0
Selling local drinks	25	41.7
Fruit production	19	31.7
Weaving traditional clothes	18	30.0
Labour work	18	30.0
Handcraft (Artisian)	16	26.7
Apiculture	13	21.7
Vegetable production	12	20.0
Chat production	7	11.7

Trading	3	5.0
Total	**230**	**383.5**

4.2.1.4. Land Ownership and Size

The average land holding of the households was about 0.79 ha. Out of the total households, 88.3% had their own land, 23.3% rented-land, 6.7% share cropland and 3.3% were landless. Out of the total households, 33.3% had access to ≤ 0.5 ha, 53.3 % from 0.5-1.0 ha, 11.7% from 1.0-1.5 ha and 1.7% > 1.5 ha. This variation in land holding is due to the traditional land tenure system, which is from parent to children. The results suggested that land distribution has to be carried out in order to ensure resource use rights. Most of the land was used for crop cultivation. Only a very small portion was used for fruit and vegetable production, and no land was allocated for woodlot. The respondents indicated that the major problems associated with land use were shortage of land (98.3%), lack of moisture (96.7%), poor soil fertility (91.7%), insecurity of land holding (25.0%) and other factors like steep and rocky land (3.3%).

4.2.2. Agricultural Activities

4.2.2.1. Crop Cultivation

Crop production was one of the major activities of the Zay People next to fishery (Table 7). Crops were largely produced for consumption. The major crops cultivated in the islands were teff (*Eragrostis tef*), finger millet (*Eleusine coracana*) and maize (*Zea mays*). Other crops produced in small quantities included sorghum (*Sorghum bicolor*), barley (*Hordeum vulgare*), wheat (*Triticum* spp.), haricot bean (*Phaseolus vulgaris*), linseed (*Linum usitatissimum*),

pepper (*Capsicum frutescens*) and sugarcane (*Saccharum officinarum*). The Zay People also cultivated cash crops like cotton (*Gossypium* spp.), chat (*Catha edulis*) and gesho (*Rhamnus prinoides*) and fruit crops such as lemon (*Citrus aurantifolia*), papaya (*Carica papaya*) and zeytun (*Psidium guajava*). Lemon was widely cultivated in the islands, usually at the edges of the lake (Plate 1). According to local informants, chat was produced only for sale and not for consumption. Generally, homegardening was very limited. Animal dung was mostly used as the source of fertilizer.

The plots of land on the islands of Lake Ziway were rich in volcanic fertile soil, but the fertility of the soil had deteriorated as a result of continuous cultivation and soil erosion. Terracing and horizontal ploughing have been widely practiced to minimize soil erosion. Crop rotation and manure and fertilizer application are methods employed to improve soil fertility. Fallowing was not practiced due to shortage of land. The people in the islands didn't practice irrigation because of the slopy land, which makes drawing water from the lake difficult. The major reasons for low crop production in the islands were lack of moisture (93.3%), shortage of land (90.0%), poor soil fertility (90.0%), damage by wild animals (88.3%), diseases and pests (86.7%), lack of improved seeds (81.7%) and other factors (3.3%). The solutions forwarded by the respondents for improving the production were fertilizer application (81.7%), manure application (60.0%), introducing irrigation system (26.7%), supply of improved seeds (23.3%), crop protection (10.0%), supply of land (10.0%), crop rotation (8.3%), early sowing (5.0%), contour ploughing (3.3%), terracing (3.3%), training (3.3%), extension program (1.7%) and tree planting (1.7%).

From the survey it was found that crop damage by hippopotamus, warthog, porcupine, monkeys and birds is high and the local people need assistance to solve the problem. In order to improve production, provision of fast growing, high yielding and moisture stress tolerant crop varieties is of paramount importance. Promoting lemon production can increase the income level of the islanders. Prevention of soil erosion through maintenance of the terraces requires due attention. It is also important to arrange and deliver training and extension programs.

4.2.2.2. Livestock Production

The households rear cattle (81.7%), goats (80.0%), sheep (33.3%), donkeys (16.7%) and poultry (86.7%). The average number of livestock per household was 13, and for cattle, goats, sheep, donkeys and poultry were 3, 5, 2, 1 and 5, respectively. The main reasons for rearing animals were for draught power, transport, production of milk and meat for consumption, income from sale of animals and their products as well as hide and skin for bedding and mattress. Some of the animals in the inhabited islands and those left in the uninhabited islands have become feral and act like wild animals. The Zay People rear both indigenous and improved varieties of poultry. About 18.3% of the respondents had improved varieties. The respondents indicated that the major reasons that prevented them from breeding improved varieties were their high cost and lack of awareness. But poultry is a potential economic alternative since it needs low input.

4.2.2.3. Apiculture

The Zay People practice traditional beekeeping, which is carried out entirely in the natural vegetation (Plate 2). Honey was collected from beehives hung on trees and pits on stems. It was mainly used for consumption but it also served as source of income. The honey has good quality and preferred by the islanders and people from the mainland, indicating its high potential for income generation. The respondents indicated that the major constraints in beekeeping were lack of input (20.0%), lack of bee feed (18.3%), lack of awareness (20.0%), diseases and pests (21.7%). The major solutions forwarded by the respondents to improve beekeeping and increase honey production were input and protection (16.7%), use of modern beehives (13.3%), supply of beehives (6.7%) and training on beekeeping (8.3%).

Beekeeping is a potential alternative for income generation for the islanders and sustainable use of the vegetation. Despite the suitability of the area for beekeeping, the practice is totally traditional and even this is very limited. Thus, it is important to promote beekeeping by providing training and technical assistance so as to enhance the contribution of the sector for diversification of income and thereby sustainability of the vegetation.

4.2.2.4. Fishery

Lake Ziway has played a great role in the economy of the Zay People as it is used for drinking, washing clothes, bathing, fishing and transport. Fishing was the main pillar of the economy and it was entirely the activity of men. Fish were used for both consumption and market. As it is mentioned previously, fish sale was the major source of income for the islanders. The major problems in fishing, as identified by the respondents, were lack of market (88.3%), transport

(85.0%), equipment (83.3%), awareness (28.3%) and proper fisheries management (10.0%), strong lake waves (6.7%) and attack of fishermen by hippopotamus (5.0%).

Without the fishing industry, the survival of the Zay People would not have been possible on the islands of Lake Ziway for such a long period of time (Tesfaye Edetto, 1988). Fishing played a vital role not only in the subsistence economy but also in the development of the unique culture which flourished on the islands. However, at present, there is reduction in the fish resources of the lake as a result of overfishing (key informants, personal communication), as witnessed by Yared Tigabu (2003). This would threaten the survival of the island communities unless proper fisheries management is implemented.

4.2.3. Values of the Vegetation Resources to the Island Communities

Source of wood products

There was no plantation in the islands of Lake Ziway. Thus, the natural vegetation was the only source of wood for various purposes: fuelwood (93.3%), construction material (81.7%) and farm implements (63.3%). The major woody species that provide fuelwood, construction material and farm implements were *Celtis africana*, *Ehretia cymosa*, *Acacia tortilis*, *A. etbaica*, *Euphorbia abyssinica*, *E. tirucalli*, *Aeschynomene elaphroxylon*, *Maytenus senegalensis*, *Ziziphus mucronata* and *Calpurnia aurea*. *Aeschynomene elaphroxylon* was economically important in making local boats. According to the informants, *Olea europaea* subsp. *cuspidata* and *Juniperus procera* were common on the slopes of Tullu Guddo until very recently. However, selective cutting for their valuable wood has now left the trees with only very few individuals. The fuelwood consumption varied among the households. All

households used fuelwood for cooking. The other sources of energy for cooking were crop residue (38.3%), charcoal (36.7%), kerosene (21.7%) and animal dung (15.0%). The sources of light for the households were oil lamps (98.3%) and 'fanos' (30.0%). The percentage of using charcoal for cooking was high but the consumption was very low, and its use was only occasional.

Source of medicines

The Zay People use wild medicinal plants to treat human and livestock diseases. According to the informants, *Solanum incanum* was used against snake bite; *Withania somnifera* against livestock and human ailments; *Cordia monoica* and *Heliotropium steudneri* against human 'Mich' (a febrile disease in which the main symptoms are fever, headache and sweating); *Asparagus africanus* against anthrax; *Heliotropium aegyptiacum* against goat infections. Out of the species identified from the islands, *Achyranthes aspera*, *Acokanthera schimperi*, *Asparagus africanus*, *Capparis tomentosa*, *Commicarpus plumbagineus*, *Cordia monoica*, *Croton macrostachyus*, *Heliotropium aegyptiacum*, *Pavetta gardeniifolia*, *Senna occidentalis*, *Solanum incanum* and *Withania somnifera* were medicinal plants used by the Zay People (Mirutse Giday, 1999).

Source of bee forage

The vegetation has a high potential for beekeeping as it possesses flora favourable for honey production. It provides bee feed and nesting habitat for bees. According to the informants, the woody species that are of great importance in providing bee feed were *Acacia tortilis, Euphorbia abyssinica, E. tirucalli*, *Grewia velutina*, *Capparis fascicularis* and *Aeschynomene elaphroxylon*. Among herbs, *Hypoestes forskaolii* was an important source of bee feed. Fifty-

nine (41.8%) of the plant species encountered in the islands had already been identified by Fichtl and Admasu Adi (1994) for their great potential values as bee forage (Appendix 11).

Source of animal fodder

The dependency of the local people on the vegetation for livestock grazing and browsing was so great. The animals freely graze and browse in the natural vegetation both in the wet and dry seasons.

Source of human food

The local people were found to be familiar with different wild fruits. The woody species that provide edible fruits were *Cordia africana*, *C. monoica*, *Pappea capensis*, *Lannea schimperi*, *Grewia bicolor*, *G. velutina*, *Rhus natalensis*, *Ximenia americana*, *Opuntia ficus-indica*, *Ficus sycomorus*, *F. ingens* and *F. vasta*.

4.2.4. Tree Planting

About 50% of the respondents indicated that they have planted trees during the last five years and the rest 50% have not planted trees in the last five years. The trees planted were the exotic species *Eucalyptus camaldulensis*, *Jacaranda mimosifolia*, *Melia azedarach*, *Schinus molle* and *Spathodea campanulata* subsp. *nilotica*. The respondents indicated that the reasons that prevented them from planting trees were shortage of land (10%), lack of seedling supply (11.7%), have enough in the natural vegetation (6.7%), lack of awareness (5.0%) and others (6.7%). From the total respondents, 78.3% were willing to plant trees in the future if seedlings are supplied to them.

The percentages of the reasons for not planting trees were relatively small. This showed that the people have understood the importance of tree planting and affirmed their willingness to plant trees in the future. Generally, homestead tree planting was very limited in the islands. Thus, education should be given to the islanders on the importance of homestead tree planting since it provides various products and, thereby, reduces the pressure on the natural vegetation. Measures have to be taken to promote planting of indigenous trees as well as appropriate exotic tree species.

4.2.5. Traditional Agroforestry and Management Systems

The Zay People have a very good practice of traditional agroforestry system (Plate 3). They retain indigenous trees like *Acacia tortilis*, *A. albida*, *Cordia africana*, *Ehretia cymosa*, *Celtis africana*, *Euphorbia tirucalli*, *Ficus sycomorus* and *F. vasta* in the farmlands and on farm boundary. According to the informants, *A. tortilis* and *A. albida* are retained in and around the farmlands because of their desirable characteristics such as fast growth, less competition with crops and improving soil fertility. They also retain *Euphorbia tirucalli* on farm boundary as a live fence and its importance in prevention of soil erosion. Resistance to livestock, rapid growth and the ease to propagate it from branch cuttings are important characteristics of the tree for planting around the farmlands. Besides improvement of soil fertility and prevention of soil erosion, trees retained in and around the farmlands provide various products such as construction material, fuelwood, fodder and also serve for fence and shade. Though it was very limited, the Zay People practiced pollarding and coppicing as necessary to improve the tree-crop interactions and increase crop productivity.

4.2.6. Indigenous Soil and Vegetation Management Systems

The Zay People have peculiar resource management systems especially in soil and vegetation conservation. Environmentally friendly resource management systems and practices used by the Zay have played a great role in the maintenance of the soil and vegetation resources in the islands for several years. Terracing is widely practiced in the islands, especially in Tullu Guddo (Fig. 10). Terracing and contour ploughing are the major methods used to conserve soil and moisture. Terracing not only prevented soil erosion but also maintained the vegetation. The Zay People construct the terraces from stone and they plant trees particularly *Euphprbia tirucalli* to give strength to the terraces. Most edges of the lake were also terraced with stone primarily to promote the growth of pasture for livestock as well as to prevent erosion by the strong lake waves and crop damage by hippopotamus.

Fig. 10. Terracing in the islands of Lake Ziway.

The Zay People also have important traditional vegetation management systems and practices, which have contributed a lot for the maintenance of the vegetation resources in the absence or very little involvement of government bodies. It is an area where unique human-vegetation interaction is manifested. The important practices and indigenous knowledge systems that helped for the maintenance of the vegetation in the islands are summarized below.

- The Zay People construct their house wall with stone and earth. This makes the house durable and reduces the turnover of cutting trees for house construction.
- They use dried and fallen logs for fuelwood. They do not cut trees for fuelwood but for construction material, farm implements and other purposes.

- They use fuelwood mostly for cooking and only rarely for lighting.
- They do not sell wood products; they use them only for consumption.
- Charcoal production is insignificant in the islands.
- The traditional agroforestry system provides wood products and thus reduces the pressure on the natural vegetation.
- The people have positive attitude toward the vegetation.

The indigenous soil and vegetation conservation practices of the Zay People are unique and environmentally friendly. These indigenous resource management systems are of great importance and deserve special attention for extrapolation to other rural areas since they have the potential to promote the conservation of biodiversity. According to Demel Teketay (1999), the indigenous/traditional resource management and conservation practices of rural communities in Ethiopia have promoted the conservation of genetic resources for centuries in this country. The traditional agroforestry practices of the south and southwest, soil and water management practices in Konso and resource management in Borena are just a few examples. Demel Teketay (1999) commented that the indigenous rural resource management and conservation practices have to be studied, documented and applied. The present finding supplements our knowledge on environmentally friendly resource management systems that exist in the country and suggests their potential role in conserving biodiversity.

4.2.7. Threats to Vegetation Resources

The vegetation in the islands was intact until very recently (key informants, personal communication). However, at present, the need for more farmland and wood products, spurred by the human population growth and associated factors, have led to the destruction of the vegetation. Galilla and Debre Sina have dense vegetation owing to the low human pressure (Plate 4). Tullu Guddo also has dense vegetation on the slopy areas, hills and rocky lake edges though flat and lower areas are under cultivation (Plates 5, 6, 8). The vegetation in Tsedacha and Funduro is disturbed due to suitability of the land for cultivation (Plate 7).

According to the respondents, the major factors for degradation of the vegetation resources in the islands are free grazing livestock, particularly goats (93.3%), farmland expansion (80.0%), soil erosion (66.7%) and tree cutting for construction material and other purposes (58.3%) (Plates 9, 10, 11 12). They also indicated that the problems that hinder forest development are shortage of land (55.0%), unsuitability of the land (41.7%), free grazing livestock (23.3%) and lack of seedling supply (10.7%). The solutions forwarded to conserve the vegetation were formation of control and management systems (91.7%), tree planting (85.0%), supply of seedlings or establishment of a nursery (70.0%), solving the problem of land (10.0%), maintenance of the terraces (6.7%), allocation of budget and trained manpower (3.3%), promoting beekeeping (3.3%), extension program (1.7%) and development of ecotourism (5.0%).

From the survey it was found that livestock particularly goats have caused considerable damage to the vegetation and terraces. Goats have damaged seedlings of trees through

herbivory (defoliation, removal of meristematic tips) and trampling, and consequently, affected regeneration. They have also damaged the terraces thereby aggravating soil erosion and uprooting of trees. According to the informants, erosion was insignificant in the islands until very recently because of the presence of well-established terraces. But at present, erosion has become a major problem due to damage to the terraces by livestock, particularly goats, and lack of maintenance. Rills have started to form in some places particularly on the slopes of Tullu Guddo. As a result of erosion, trees have become dry or uprooted and rolling stones have caused considerable damage to the vegetation. Thus, the terraces require maintenance in order to prevent soil erosion and conserve the vegetation.

There were livestock left to graze on their own in Galilla and Debre Sina, and also there was entry of goats by native inhabitants of the islands currently living on shore areas. Thus, removal of goats from the uninhabited islands and preventing further entry are the priority actions. It is also important to limit the number of goats on the inhabited islands by providing compensation incentives to the local people. Their impact should be taken into consideration since island biotas are sensitive to disturbance. Unless appropriate and immediate measures are taken to reduce the induced damage on the vegetation, there will be loss of ecologically and economically important and rare species. This, in turn, will lead to overall environmental and socio-economic crises in the islands.

4.2.8. Role of Churches in Conserving the Vegetation

Although the main role of the churches is to give religious services to the local people, they have also played a major role in the conservation of the vegetation. The churches are involved in protection of the sacred groves, tree planting in churchyards and giving advice to the local community on the importance of conserving the sacred groves and the vegetation in the islands as a whole. Trees such as *Acacia tortilis*, *Euphorbia abyssinica*, *E. tirucalli*, *Opuntia ficus-indica*, *Cordia monoica*, *Pappea capensis* and *Ficus vasta* are retained in the church compounds and also trees like *Melia azedarach* are planted. Sacred groves provide various products and services. Trees and shrubs are retained in churchyards mainly for religious purposes, protection of soil erosion and strong winds, fence and shade. They also provide construction material, medicines and edible fruits. Discussion of religious and social issues is mostly undertaken in churchyards. Pressure of the local people on the sacred groves is very low because of their strong religious belief. The recommendations forwarded by the clergy for conservation, management and sustainable use of the sacred groves in particular and the vegetation in the islands in general were formation of control and management systems, environmental education, seedling supply and support from the government. The survey showed that the church is the most important institution in the islands both in socio-economic and conservation issues.

According to Alemayehu Wassie (2002), protection of sacred forests in South Gondar is achieved through creating religious commitment and respect among the followers and legal protection due to increased human pressure. On the other hand, the maintenance of sacred

groves in the islands is attributed to the strong religious belief and respect of the communities to the church, which is considered the house of God.

4.2.9. Analysis of Stakeholders

Generally, the involvement of stakeholders in the islands was very limited. From the stakeholders surveyed, Rural Land and Natural Resources Administration Office, Fisheries Resources Research Centre, Fish Production and Marketing Enterprise and Woreda Church Office had relatively significant contribution in socio-economic activities in the islands (Appendix 10) though the level of integration was very poor. Low involvement of stakeholders and poor integration would have negative impacts on development and conservation activities that could be carried out in the islands. In order to bring sustainable development and ensure the maintenance of the vegetation resources in the islands, there is a need to facilitate the involvement of different stakeholders and integrate their activities (Table 8).

Table 8. Major activities of stakeholders in the islands and recommendations forwarded for conservation of the vegetation and socio-economic development.

Major activities	Recommendations
Market and transport service [5]	Proper fisheries management [2, 5, 6]
Provision of fishing equipment [2, 5, 6]	Maintenance of the terraces [1]
Control of fishing activity [2]	Promoting beekeeping and fruit production [1]
Pollution control [2]	Seedling supply or establishment of a nursery and promoting tree planting [1, 4]
Fisheries research [6]	Provision of alternative energy sources [1]
Training on fishing [2, 6]	Introducing irrigation system [1, 2]
Protection of vegetation [1, 4]	Training and education [1, 2]
Awareness creation [1, 2, 4, 5, 6]	Technical support [1]
	Designating the islands as nature reserves [1]
	Development of ecotourism [1]
	Allocation of budget and manpower [1, 2]
	Involvement of stakeholders and NGOs [1, 2, 3]
	Support from the government [1, 2]

1 = Woreda Rural Land and Natural Resources Administration Office; 2 = Woreda Agriculture Office; 3 = Woreda Administrative Office; 4 = Woreda Church Office; 5 = Fish Production and Marketing Enterprise; 6 = Fisheries Resources Research Centre.

5. CONCLUSION AND RECOMMENDATIONS

The islands of Lake Ziway possess unique floristic composition, high species diversity and distinctive plant communities due to habitat heterogeneity and various modes of dispersal. The existence of lowland and highland species on the islands is the result of immigration from the surrounding mainland. This implies that the maintenance of source pool species on the surrounding mainland would contribute considerably to the species diversity on the islands. The other implication is that the islands can serve as conservation sites for both lowland and highland species if appropriate conservation measures are applied.

The diversity and evenness indices indicated the need to conserve the vegetation in the islands from both diversity and human disturbance point of view. The number of species on the islands correlated with their sizes, degree of human disturbance and habitat diversity. The similarity in species composition between the islands was largely dependent on their geographical proximity and similarity in environmental conditions and exposure to dispersal agents. However, the similarity in species composition among the islands was generally low, indicating that each island has its own unique flora.

The importance value index revealed the most ecologically important woody species in the islands and those to be prioritized for conservation. The diameter class distribution showed that some species are in poor regeneration due to human disturbance and changes in environmental conditions. As indicated by the results, species having low importance value index and poor regeneration need the highest priority for conservation. *In situ* and *ex situ* conservation methods have to be implemented for the conservation of the priority species.

The vegetation in the islands provides various products such as fuelwood, construction material, farm implements, medicines, bee forage, animal fodder and edible fruits. It also

regulates microclimate and serves as a habitat for wildlife, particularly birds. Lake Ziway is one of the important bird areas of the country. The islands are sites of beautiful environment and cultural heritage, and thus, are ideal places for development of ecotourism though this potential economic alternative has not been given due attention. The ecological, cultural and socio-economic values of the plant resources imply the need for conservation and management. The vegetation in the islands represents one of the relicts of the pristine vegetation in the Rift Valley area, if not in the country, and, thus, requires special attention.

The island communities have maintained the soil and plant resources for centuries through their indigenous resource management and conservation systems. However, at present, human population growth coupled with clearing for cultivation, free grazing, tree cutting for construction material and other factors have led to the destruction of the vegetation resulting in severe soil erosion. This can lead to overall environmental and socio-economic crises in the islands unless appropriate and immediate measures are taken.

The relatively high literacy level, efforts in tree planting and better awareness and positive attitude of the local community toward family planning and conservation are promising options for conservation and sustainable use of the plant resources in the islands. The church is the central institution in the islands, playing vital role in the conservation of the vegetation and socio-economic issues. Since the islanders have high respect and trust for the church, integrating conservation measures to this institution would be more effective.

The islanders are confronted with a number of socio-economic problems such as shortage of land, lack of transport, clean water supply, health service and market system, administrative

problems and lack of concern from the government. Efforts that can be made to mitigate these challenges would help to ensure the existence of the island communities with their unique culture and rich indigenous knowledge and this, in turn, contributes, in one way or another, to the maintenance of the vegetation in particular and the island biotas in general.

Therefore, to maintain the plant resources and utilize sustainably and mitigate the existing socio-economic problems, the following recommendations are forwarded.

Conservation measures

- *In situ* and *ex situ* conservation methods have to be employed for the conservation of species having low importance value index and poor regeneration status.
- In order to mitigate the shortage of land and prevent farmland expansion, there is a need to introduce modern agroforestry systems.
- It is necessary to encourage tree planting in homesteads, farmlands and churchyards through supply of seedlings or establishment of a nursery in order to reduce the pressure on the natural vegetation.
- Efforts should be made to provide and encourage the local community to use energy saving stoves to reduce the dependency on the natural vegetation for fuelwood.
- In order to maintain the vegetation and allow natural regeneration, goats and other livestock left in the uninhabited islands have to be taken away and those in the inhabited ones have to be limited in number through provision of compensation incentives to the islanders.
- To prevent soil erosion and maintain the vegetation, it is important to encourage the maintenance of the terraces through mobilizing the local people.

- Since the islands are of great importance in terms of biodiversity and cultural heritage, it is advisable to designate them as nature reserves by generating income for the islanders from national, regional and international donor agencies.

Socio-economic measures

- In order to solve the food insecurity problem in the islands, there is a need to launch agricultural extension programs to improve production.
- Efforts should be made to promote irrigation development to mitigate the moisture stress for crop production.
- Solutions should be found to control crop damage by hippopotamus, warthog, monkeys and birds.
- Efforts should be made to provide improved varieties of poultry with necessary facilities.
- Since fishery is the key economic activity of the islanders, efforts should be made to provide fishing equipment and training, search for attractive market system and implement proper fisheries management.
- As the islands are endowed with bee forage plants, it is important to promote apiculture by providing traditional and modern beehives, training and technical assistance so as to increase the income level of the island communities.
- Efforts should be made to provide clean water supply and transport and health service.
- Family planning services should be provided to the local communities in order to control human population growth, which is the major driving force for socio-economic problems and environmental degradation.

- In order to solve the various socio-economic problems and ensure the conservation and sustainable utilization of the plant resources, it is important to facilitate the involvement of government and private stakeholders and NGOs with proper integration.
- There is a need to develop ecotourism in the islands for diversifying income for communities in particular and sustainable use of the existing biological resources for the country in general.

Recommendations for further research

- Carry out investigation on reproductive biology, ecology, including dispersal ecology, and management of the major woody species in the islands and environmental factors like soils.
- Carry out research on the bio-physical and socio-economic setting of islands in other lakes in the country.

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APPENDICES

Appendix 1. Botanical data collection form –

Date _____ Altitude _____

Island _____ Slope _____

Relevé No. _____ Aspect _____

Position _____

Species	Habit	Count	% cover	DBH
1				
2				
3				
4				
5				
.....				

Species-specific data

Collection No. _____

Local name(s) _____

Habitat and notes _____

Economic importance _____

Appendix 2. List of plant species identified from the islands of Lake Ziway with corresponding family, local name(s), habit and collection number.

Scientific name	Family	Local name(s)	Habit	Coll. No.
Acacia albida Del.	Fabaceae	kigni (Zay), garbi (Oro.)	T	HZ42
A. etbaica Schweinf.	Fabaceae	deru (Zay), dodoti (Oro.)	T	HZ101
A. tortilis (Forssk.) Hayne	Fabaceae	wanta (Zay), grar (Amh.), adecha (Oro.)	T	HZ6
Achyranthes aspera L.	Amaranthaceae		H	HZ32
Acokanthera schimperi (A. DC.) Schweinf.	Apocynaceae	keraro (Zay), qararu (Oro.)	T/S	HZ52
Aeschynomene elaphroxylon (Guill. & Perr.) Taub.	Fabaceae	tongollu (Zay), bobofe (Amh., Oro.)	T/S	HZ19
Ageratum conyzoides L.	Asteraceae		H	HZ87
Aloe pubescens Reynolds	Aloaceae	eret (Zay, Amh.)	H	HZ133
Argemone mexicana L.	Papaveraceae	sokoro (Zay)	H	HZ11
Aristida kenyensis Henr.	Poaceae	geta (Zay)	H	HZ26
Asparagus africanus Lam.	Asparagaceae		S	HZ65
Balanites aegyptiaca (L.) Del.	Balanitaceae	bedena (Zay)	T	HZ55
Barleria eranthemoides R. Br. ex C. B. Clarke	Acanthaceae	ayne kosu (Zay)	S	HZ56
B. ventricosa Hochst. ex Nees	Acanthaceae		H	HZ142
Bidens biternata (Lour.) Merr. & Sherff	Asteraceae	atabuka (Zay)	H	HZ39
Calpurnia aurea (Ait.) Benth.	Fabaceae	cheketa (Zay, Oro.)	T/S	HZ22
Capparis fascicularis DC.	Capparidaceae	kentefa (Zay)	L	HZ66
C. tomentosa Lam.	Capparidaceae	akuka (Zay), gemero (Amh.)	S	HZ92
Carica papaya L.	Caricaceae	papaya (Zay, Amh., Oro.)	T	*
Catha edulis (Vahl) Forssk. ex	Celastraceae	jima (Zay), chat	T	*

Endl.		(Amh.)		
Caucanthus auriculatus (Radlk.) Niedenzu	Malpighiaceae	arengama (Zay)	L	HZ85
Caylusea abyssinica (Fresen.) Fisch. & Mey.	Resedaceae		H	HZ18
Celtis africana Burm. f.	Ulmaceae	kay (Zay)	T	HZ50
Chenopodium murale L.	Chenopodiaceae		H	HZ84
C. procerum Moq.	Chenopodiaceae		H	HZ61
Chloris pycnothrix Trin.	Poaceae		H	HZ49
Cirsium vulgare (Savi) Ten.	Asteraceae		H	HZ137
Cissus quadrangularis L.	Vitaceae	homba /gale (Zay)	L	HZ10
Cistanche tubulosa (Schenk) Hook. f.	Orobanchaceae		H	HZ131
Citrus aurantifolia (Christm.) Swingle	Rutaceae	lomi (Zay, Amh., Oro.)	T	*
Cleome gynandra L.	Capparidaceae	lima (Zay)	H	HZ13
Coffea arabica L.	Rubiaceae	buna (Zay, Amh., Oro.)	T/S	*
Commelina diffusa Burm. f.	Commelinaceae		H	HZ125*
Commicarpus grandiflorus (A. Rich.) Standl.	Nyctaginaceae		HC	HZ74
C. plumbagineus (Cav.) Standl.	Nyctaginaceae		HC	HZ63
Commiphora africana (A. Rich.) Engl.	Burseraceae		T/S	HZ91
Cordia africana Lam.	Boraginaceae	wodessa (Zay, Oro.)	T	HZ117
C. monoica Roxb.	Boraginaceae	ira (Zay), meinera (Oro.)	T	HZ45
Crotalaria pycnostachya Benth.	Fabaceae		H	HZ126*
Croton dichogamus Pax	Euphorbiaceae		T/S	HZ73
C. macrostachyus Del.	Euphorbiaceae	mekanissa (Zay, Oro.)	T/S	HZ123
Cucumis dipsaceus Ehrenb. ex Spach	Cucurbitaceae	yegigni lomi (Zay), yewsha lomi (Amh.)	HC	HZ16
Cussonia holstii Harms ex Engl.	Araliaceae		T	HZ108

Cynodon dactylon (L.) Pers.	Poaceae	serdu (Zay), serdo (Amh.)	H	HZ81
Cyperus alopecuroides Rottb.	Cyperaceae	aladu (Zay)	H	HZ76
C. esculentus L.	Cyperaceae	gudare (Zay)	H	HZ36
C. papyrus L.	Cyperaceae	imbilla (Zay)	H	HZ139
Cyphostemma cyphopetalum (Fresen.) Descoings ex Wild & Drummond	Vitaceae		HC	HZ43
Datura stramonium L.	Solanaceae	benji (Zay)	H	HZ130
Dodonaea angustifolia L. f.	Sapindaceae		S	HZ106
Echinochloa stagnina (Retz.) P. Beauv.	Poaceae		H	HZ37
Ehretia cymosa Thonn.	Boraginaceae	geberira (Zay), ulaga (Oro.)	T	HZ33
Eragrostis cilianensis (All.) Vign. ex Janchen	Poaceae	yeimar serdu (Zay), yeahiya serdo (Amh.)	H	HZ82
Erucastrum arabicum Fisch. & Mey.	Brassicaceae	anshererit (Zay)	H	HZ8
Erythrococca abyssinica Pax	Euphorbiaceae		S	HZ57
Eucalyptus camaldulensis Dehnh.	Myrtaceae	bahir zaf (Zay, Amh.)	T	HZ115*
Euphorbia abyssinica Gmel	Euphorbiaceae	kaka (Zay), qulqual (Amh.), adami (Oro.)	T	HZ1
E. tirucalli L.	Euphorbiaceae	enjib (Zay), kinchib (Amh.)	T/S	HZ2
Ficus ingens (Miq.) Miq.	Moraceae	zembi (Zay), dambi (Oro.)	T/S	HZ41
F. sycomorus L.	Moraceae	subla (Zay), sholla (Amh.)	T	HZ134
F. thonningii Blume	Moraceae		T/S	HZ86
F. vasta Forssk.	Moraceae	murmegn (Zay), warka (Amh.), kiltu (Oro.)	T	HZ136
Flueggea virosa (Willd.) Voigt.	Euphorbiaceae	wonaki (Zay)	T/S	HZ67
Galinsoga quadriradiata Ruiz &	Asteraceae	aba debo (Zay)	H	HZ15

Pavon				
Girardinia diversifolia (Link) Friis	Urticaceae	dobbi (Zay, Oro.)	H	HZ138
Gomphocarpus semilunatus A. Rich.	Asclepiadaceae		H	HZ99
Gossypium hirsutum L.	Malvaceae	tit (Amh.)	S	HZ129*
Grewia bicolor Juss.	Tiliaceae	aroressa (Zay, Oro.)	T/S	HZ90
G. trichocarpa Hochst. ex A. Rich.	Tiliaceae	enstewey (Zay)	T/S	HZ20
G. velutina (Forssk.) Vahl	Tiliaceae	tewey (Zay), teye (Amh.)	T/S	HZ53
Heliotropium aegyptiacum Lehm.	Boraginaceae	ambachirara (Zay)	H	HZ7
H. steudneri Vatke	Boraginaceae	yeamara yemich kitel (Amh.)	H	HZ105
Hibiscus diversifolius Jacq.	Malvaceae	oronchilla (Zay)	S	HZ98
H. vitifolius L.	Malvaceae		H	HZ116
Hyparrhenia hirta (L.) Stapf	Poaceae	bawa (Zay), senbelet (Amh.)	H	HZ27
Hypoestes forskaolii (Vahl) R. Br.	Acanthaceae	ambulala (Zay), dargu arba (Oro.)	H	HZ4
Ipomoea cairica (L.) Sweet	Convolvulaceae	aleshita (Zay)	H	HZ47
Jacaranda mimosifolia D. Don	Bignoniaceae		T	HZ110*
Jasminum grandiflorum L. subsp. *floribundum* (R. Br. ex Fresen.) P. S. Green	Oleaceae		L	HZ68
Juniperus procera Hochst. Ex Endl.	Cupressaceae	tid (Amh.)	T	HZ104
Justicia schimperiana (Hochst. ex Nees) T. Anders	Acanthaceae	kekeli (Zay)	S	HZ58
Kalanchoe Lanceolata (Forssk.) Pers.	Crassulaceae		H	HZ100
Kanahia laniflora (Forssk.) R. Br.	Asclepiadaceae	uchuma (Zay), astey (Amh.)	S	HZ96
Laggera crispata (Vahl) Hepper & Wood	Asteraceae		H	HZ59
Lannea schimperi (A. Rich.) Engl.	Anacardiaceae	amagu (Zay)	T	HZ54

Lantana camara L.	Verbenaceae	yewof kollo (Amh.)	S	HZ93
Leptochloa fusca (L.) Kunth	Poaceae		H	HZ24
Leucas abyssinica (Benth.) Briq.	Lamiaceae		S	HZ124
L. martinicensis (Jacq.) R. Br.	Lamiaceae		H	HZ3
Maerua angolensis DC.	Capparidaceae		T/S	HZ88
M. triphylla A. Rich.	Capparidaceae		T/S	HZ95
Maytenus senegalensis (Lam.) Exell	Celastraceae	kombolcha (Zay, Oro.)	T/S	HZ51
Melanthera scandens (Schumach. & Thonn.) Roberty subsp. *madagascariensis* (Bak.) Wild	Asteraceae		H	HZ141
Melia azedarach L.	Meliaceae	melia (Zay)	T	HZ109*
Monothecium glandulosum Hochst.	Acanthaceae		H	HZ135
Olea europaea L. subsp. *cuspidata* (Wall ex G. Don) Cif.	Oleaceae	woger (Zay), woira (Amh.)	T/S	HZ103
Opuntia ficus-indica (L.) Miller	Cactaceae	aqolquali (Zay)	T/S	HZ38
Oxygonum sinuatum (Meisn.) Dammer	Polygonaceae	yasobu kite (Zay)	H	HZ21
Panicum hygrocharis Steud.	Poaceae		H	HZ25
Pappea capensis Eckl. & Zeyh.	Sapindaceae	mekelku (Zay)	T	HZ69
Pavetta gardeniifolia A. Rich.	Rubiaceae	sememegnit (Zay)	T/S	HZ60
Pergularia daemia (Forssk.) Chiov.	Asclepiadaceae		HC	HZ128
Persicaria senegalensis (Meisn.) Sojak	Polygonaceae		H	HZ23
Phragmites karka (Retz.) Steud.	Poaceae	kembara (Zay)	H	HZ40
Phyllanthus ovalifolius Forssk.	Euphorbiaceae		T/S	HZ122
P. reticulatus Poir.	Euphorbiaceae		T/S	HZ97
Plectranthus cylindraceus Hochst. ex Benth.	Lamiaceae	shunka shunki (Zay)	H	HZ12
P. lanuginosus (Hochst. ex Benth.) Agnew	Lamiaceae	gendemere/yekumshari kite (Zay), yetota kitel (Amh.)	H	HZ5
P. minutiflorus Ryding	Lamiaceae		H	HZ75
Psidium guajava L.	Myrtaceae	zeyto (Zay)	T	*

Pterolobium stellatum (Forssk.) Brenan	Fabaceae	gumar kentefa (Zay)	S	HZ89
Rhamnus prinoides L'Herit	Rhamnaceae	gesho (Amh.)	T/S	*
Rhoicissus tridentata (L. f.) Wild & Drummond	Vitaceae		L	HZ70
Rhus natalensis Krauss	Anacardiaceae	tatessa (Zay, Oro.)	T/S	HZ46
R. retinorrhoea Oliv.	Anacardiaceae	ambusi (Zay)	T/S	HZ79
Ricinus communis L.	Euphorbiaceae	qobo (Zay)	T	HZ127
Rumex nervosus Vahl	Polygonaceae		S	HZ14
Sansevieria forskaoliana (Schult. f.) Hepper and Wood	Dracaenaceae		H	HZ144
Schinus molle L.	Anacardiaceae	trimantri	T	HZ111*
Schoenoplectus confusus (N. E. Br.) Lye	Cyperaceae	chilla (Zay)	H	HZ77
Senna didymobotrya (Fresen.) Irwin & Barneby	Fabaceae		S	HZ29
S. occidentalis (L.) Link	Fabaceae	birbira (Zay)	H	HZ31
S. singueana (Del.) Lock	Fabaceae		T/S	HZ64
Sesbania sesban (L.) Merr.	Fabaceae	jarsu (Zay), jarso (Oro.)	T/S	HZ102
Solanecio angulatus (Vahl) C. Jeffrey	Asteraceae		H	HZ143
Solanum americanum Miller	Solanaceae	Laki mitintiyo (Zay)	H	HZ107
Solanum incanum L.	Solanaceae	silbo (Zay)	S	HZ62
Solanum schimperianum Hochst. ex A. Rich.	Solanaceae	ejanauru kite (Zay), yeibab kitel (Amh.)	S	HZ34
Sonchus asper (L.) Hill	Asteraceae		H	HZ118
Spathodea campanulata P. Beauv. subsp. *nilotica* (Seem.) Bidgood	Bignoniaceae		T	HZ112*
Steganotaenia araliacea Hochst.	Apiaceae	aloqloqe/kewey lebeni (Zay)	T	HZ44
Tagetes minuta L.	Asteraceae	echikali kite/Aba Erko kite (Zay)	H	HZ9

Tragia brevipes Pax	Euphorbiaceae	albaytu (Zay)	HC	HZ30
Typha latifolia L.	Typhaceae	awarie (Zay), filla (Amh.)	H	HZ35
Urtica simensis Steudel	Urticaceae	dobbi (Zay, Oro.)	H	HZ140
Verbascum sinaiticum Benth.	Scrophulariaceae		H	HZ17
Vernonia myriantha Hook. f.	Asteraceae	reji (Zay)	T/S	HZ119
Withania somnifera (L.) Dun.	Solanaceae	gizawa (Zay)	S	HZ113
Xanthium spinosum L.	Asteraceae	sokoro (Zay), yeset milas (Amh.)	H	HZ28
Ximenia americana L.	Olacaceae	enkoy (Amh.)	T/S	HZ71
Ziziphus mucronata Willd.	Rhamnaceae	kurkura (Zay)	T/S	HZ80

T = Tree, T/S = Tree/Shrub, S = Shrub, L = Liana, HC = Herbaceous climber, H = Herb

* = Species encountered outside relevés

Appendix 3. Spatial distribution of species in the islands of Lake Ziway.

No.	*Scientific name*	Galilla	Debre Sina	Tullu Guddo	Funduro	Tsedacha		No.	*Scientific name*	Galilla	Debre Sina	Tullu Guddo	Funduro	Tsedacha
1	*Acacia albida*	x	x		x	x		72	*Heliotropium steudneri*			x	x	
2	*Acacia etbaica*			x				73	*Hibiscus diversifolius*		x			
3	*Acacia tortilis*	x	x	x	x	x		74	*Hibiscus vitifolius*		x			
4	*Achyranthes aspera*		x	x		x		75	*Hyparrhenia hirta*					x
5	*Acokanthera schimperi*	x	x	x	x			76	*Hypoestes forskaolii*	x	x	x	x	x
6	*Aeschynomene elaphroxylon*	x	x	x	x	x		77	*Ipomoea cairica*		x	x	x	
7	*Ageratum conyzoides*	x	x					78	*Jacaranda mimosifolia*			x		x
8	*Aloe pubescens*			x				79	*Jasminum grandiflorum*	x		x		
9	*Argemone mexicana*	x	x			x		80	*Juniperus procera*			x		
10	*Aristida kenyensis*			x	x	x		81	*Justicia schimperiana*		x	x		
11	*Asparagus africanus*	x	x	x				82	*Kalanchoe lanceolata*	x	x	x	x	x
12	*Balanites aegyptiaca*			x				83	*Kanahia laniflora*		x	x		
13	*Barleria eranthmoides*			x				84	*Laggera crispata*	x	x	x		
14	*Barleria ventricosa*		x					85	*Lannea schimperi*			x		
15	*Bidens biternata*			x	x	x		86	*Lantana camara*		x			
16	*Calpurnia aurea*		x	x		x		87	*Leptochloa fusca*			x		x
17	*Capparis fascicularis*	x	x	x	x	x		88	*Leucas abyssinica*		x			
18	*Capparis tomentosa*		x			x		89	*Leucas martinicensis*	x	x	x	x	x
19	*Carica papaya*			x	x	x		90	*Maerua angolensis*	x	x			
20	*Catha edulis*			x		x		91	*Maerua triphylla*	x	x			
21	*Caucanthus auriculatus*	x	x	x				92	*Maytenus senegalensis*	x	x		x	

22	*Caylusea abyssinica*					x		93	*Melanthera scandens*		x			
23	*Celtis africana*	x	x	x	x	x		94	*Melia azedarach*			x		x
24	*Chenopodium murale*	x	x					95	*Monothecium glandulosum*		x			
25	*Chenopodium procerum*	x	x	x				96	*Olea europaea* subsp. *cuspidata*			x		
26	*Chloris pycnothrix*	x	x	x	x			97	*Opuntia ficus-indica*	x	x	x	x	x
27	*Cirsium vulgare*		x					98	*Oxygonum sinuatum*					x
28	*Cissus quadrangularis*	x	x	x		x		99	*Panicum hygrocharis*					x
29	*Cistanche tubulosa*		x					100	*Pappea capensis*	x	x	x		
30	*Citrus aurantifolia*	x		x	x	x		101	*Pavetta gardeniifolia*	x	x	x		
31	*Cleome gynandra*					x		102	*Pergularia daemia*	x	x	x		
32	*Commelina diffusa*					x		103	*Persicaria senegalensis*		x			x
33	*Coffea arabica*					x		104	*Phragmites karka*					x
34	*Commicarpus grandiflorus*			x				105	*Phyllanthus ovalifolius*				x	
35	*Commicarpus plumbagineus*	x	x	x				106	*Phyllanthus reticulatus*		x			
36	*Commiphora africana*		x					107	*Plectranthus minutiflorus*	x		x		
37	*Cordia africana*				x	x		108	*Plectranthus cylindraceus*	x	x	x		x
38	*Cordia monoica*	x	x	x	x	x		109	*Plectranthus lanuginosus*	x		x		x
39	*Crotalaria pycnostachya*					x		110	*Psidium guajava*					x
40	*Croton dichogamus*			x				111	*Pterolobium stellatum*	x	x			
41	*Croton macrostachyus*				x	x		112	*Rhamnus prinoides*	x		x	x	x
42	*Cucumis dipsaceus*					x		113	*Rhoicissus tridentata*			x		
43	*Cussonia holstii*	x	x	x		x		114	*Rhus natalensis*	x	x	x	x	
44	*Cynodon dactylon*		x	x		x		115	*Rhus retinorrhoea*			x		
45	*Cyperus alopecuroides*			x				116	*Ricinus communis*	x	x		x	
46	*Cyperus esculentus*		x			x		117	*Rumex nervosus*	x				x
47	*Cyperus papyrus*	x						118	*Sansevieria forskaoliana*		x			
48	*Cyphostemma cyphopetalum*	x	x	x	x	x		119	*Schinus molle*			x		x
49	*Datura stramonium*		x	x		x		120	*Schoenoplectus confusus*			x		
50	*Dodonaea angustifolia*			x				121	*Senna didymobotrya*				x	x
51	*Echinochloa stagnina*					x		122	*Senna occidentalis*			x		x
52	*Ehretia cymosa*	x	x	x	x	x		123	*Senna singueana*			x		
53	*Eragrostis cilianensis*			x				124	*Sesbania sesban*		x	x		
54	*Erucastrum arabicum*		x	x	x	x		125	*Solanecio angulatus*		x			
55	*Erythrococca abyssinica*	x	x	x				126	*Solanum americanum*		x	x		
56	*Eucalyptus camaldulensis*	x		x	x	x		127	*Solanum incanum*			x	x	
57	*Euphorbia abyssinica*	x	x	x	x	x		128	*Solanum schimperianum*	x	x	x	x	x
58	*Euphorbia tirucalli*	x	x	x	x	x		129	*Sonchus asper*		x			
59	*Ficus ingens*	x	x	x	x	x		130	*Spathodea campanulata* subsp. *cuspidata*			x		
60	*Ficus sycomorus*	x	x	x	x	x		131	*Steganotaenia araliacea*	x				x
61	*Ficus thonningii*	x	x					132	*Tagetes minuta*		x	x	x	x

62	*Ficus vasta*	x	x	x	x	x		133	*Tragia brevipes*	x	x	x	x	x
63	*Flueggea virosa*		x	x				134	*Typha latifolia*			x		x
64	*Galinsoga quadriradiata*	x	x	x	x	x		135	*Urtica simensis*	x				
65	*Girardinia diversifolia*	x	x	x	x			136	*Verbascum sinaiticum*					x
66	*Gomphocarpus semilunatus*		x					137	*Vernonia myriantha*		x		x	
67	*Gossypium hirsutum*			x		x		138	*Withania somnifera*			x		
68	*Grewia bicolor*	x						139	*Xanthium spinosum*	x			x	x
69	*Grewia trichocarpa*	x		x				140	*Ximenia americana*	x	x	x		
70	*Grewia velutina*			x				141	*Ziziphus mucronata*			x		
71	*Heliotropium aegyptiacum*			x		x								

Appendix 4. Abundance, density and frequency of woody species in each island.

Scientific name	Galilla			Debre Sina			Tullu Guddo			Funduro			Tsedacha		
	Abundance	Density	Frequency (%)	Abundance	Density	Frequency (%)	Abundance	Density	Frequency (%)	Abundance	Density	Frequency (%)	Abundance	Density	Frequency (%)
Acacia albida	3	1.0	1.4	3	1.0	1.4				4	1.4	2.7	2	0.7	1.
Acacia etbaica							2	0.7	1.4						
Acacia tortilis	207	71.4	15.1	109	37.6	13.7	453	156.2	35.6	95	32.8	12.3	69	23.8	13.
Acokanthera schimperi	2	0.7	1.4	42	14.5	2.7	11	3.8	6.8						
Aeschynomene elaphroxylon	15	5.2	4.1	12	4.1	4.1	100	34.5	1.4	110	37.9	2.7	61	21.0	2.
Asparagus africanus	12	4.1	6.8	6	2.1	2.7	4	1.4	2.7						
Balanites aegyptiaca							1	0.3	1.4						
Calpurnia aurea				2	0.7	1.4	26	9.0	6.8				30	10.3	2.
Capparis fascicularis	62	21.4	15.1	50	17.2	13.7	161	55.5	37.0	95	32.8	8.2	2	0.7	1.
Capparis tomentosa				41	14.1	8.2							5	1.7	1.
Caucanthus auriculatus	33	11.4	8.2	32	11.0	8.2	3	1.0	1.4						
Celtis africana	13	4.5	6.8	12	4.1	5.5	14	4.8	5.5	4	1.4	2.7	2	0.7	1.
Cissus quadrangularis	25	8.6	6.8	82	28.3	12.3	53	18.3	6.8				105	36.2	12.
Commiphora africana				15	5.2	2.7									
Cordia africana										6	2.1	2.7	2	0.7	1.
Cordia monoica	7	2.4	2.7	3	1.0	2.7	2	0.7	1.4	1	0.3	1.4	2	0.7	1.
Croton dichogamus							60	20.7	1.4						
Croton macrostachyus										6	2.1	2.7	2	0.7	1.

Cussonia holstii				4	1.4	2.7							2	0.7	1
Dodonaea angustifolia							6	2.1	1.4						
Ehretia cymosa	7	2.4	2.7	3	1.0	1.4	4	1.4	4.1	2	0.7	1.4	2	0.7	1
Erythrococca abyssinica	2	0.7	1.4	12	4.1	2.7	2	0.7	1.4						
Euphorbia abyssinica	18	6.2	5.5	61	21.0	9.6	917	316.2	32.9	10	3.4	2.7	65	22.4	6
Euphorbia tirucalli	585	201.7	16.4	350	120.7	13.7	1148	395.9	32.9	432	149.0	11.0	463	159.7	15
Ficus ingens	19	6.6	9.6	14	4.8	6.8	4	1.4	4.1	19	6.6	2.7	7	2.4	2
Ficus sycomorus	3	1.0	2.7	7	2.4	5.5	11	3.8	4.1	5	1.7	4.1	6	2.1	4
Ficus thonningii	4	1.4	2.7	15	5.2	4.1									
Ficus vasta	21	7.2	11.0	19	6.6	8.2	14	4.8	9.6	5	1.7	2.7	14	4.8	5
Flueggea virosa				3	1.0	1.4	25	8.6	8.2						
Grewia bicolor	2	0.7	1.4												
Grewia trichocarpa	4	1.4	2.7				37	12.8	6.8						
Grewia velutina							89	30.7	24.7						
Hibiscus diversifolius				5	1.7	2.7									
Jasminum grandiflorum	8	2.8	1.4				11	3.8	2.7						
Juniperus procera							6	2.1	2.7						
Justicia schimperiana				48	16.6	5.5	4	1.4	1.4						
Kanahia laniflora				7	2.4	1.4									
Lannea schimperi							8	2.8	2.7						
Lantana camara				30	10.3	8.2									
Leucas abyssinica				3	1.0	1.4									
Maerua angolensis	4	1.4	2.7	5	1.7	4.1									
Maerua triphylla	0	0.0	0.0	4	1.4	2.7									
Maytenus senegalensis	17	5.9	6.8	4	1.4	2.7				8	2.8	2.7			
Olea europaea subsp. *cuspidata*							8	2.8	2.7						
Opuntia ficus-indica	114	39.3	9.6	29	10.0	5.5	254	87.6	30.1	2	0.7	1.4	58	20.0	2
Pappea capensis	23	7.9	6.8	9	3.1	4.1	18	6.2	4.1						
Pavetta gardeniifolia	24	8.3	6.8	27	9.3	8.2	312	107.6	27.4						
Phyllanthus ovalifolius										3	1.0	1.4			
Phyllanthus reticulatus				54	18.6	5.5									
Pterolobium stellatum	13	4.5	2.7	31	10.7	6.8									
Rhoicissus tridentata							3	1.0	1.4						
Rhus natalensis	14	4.8	5.5	3	1.0	1.4	51	17.6	15.1	6	2.1	4.1			
Rhus retinorrhoea							3	1.0	1.4						
Ricinus communis	2	0.7	1.4	7	2.4	4.1				2	0.7	1.4			
Rumex nervosus	4	1.4	1.4												

Senna didymobotrya										6	2.1	1.4			
Senna singueana							130	44.8	9.6						
Sesbania sesban				2	0.7	1.4	50	17.2	1.4						
Solanum incanum							24	8.3	6.8						
Solanum schimperianum	56	19.3	6.8	118	40.7	11.0	116	40.0	16.4	24	8.3	2.7	10	3.4	1
Steganotaenia araliacea	2	0.7	1.4										2	0.7	1
Vernonia myriantha				93	32.1	5.5				18	6.2	2.7			
Withania somnifera							3	1.0	1.4	3	1.0	1.4			
Ximenia americana	7	2.4	2.7	2	0.7	1.4	2	0.7	1.4						
Ziziphus mucronata							3	1.0	1.4						
Total	1332	459.3		1378	475.2		4153	1432.1		866	298.6		911	314.1	

Appendix 5. Environmental data recorded from the relevés.

Relevé No.	Altitude (m)	Slope (%)	Aspect	Position	Locality
1	1823	10	NW	07° 58' 77" N, 38° 53' 47" E	Tsedacha
2	1710	5	NW	07° 58' 65" N, 38° 53' 45" E	Tsedacha
3	1840	8	NW	07° 58' 52" N, 38° 53' 36" E	Tsedacha
4	1665	20	W	07° 58' 64" N, 38° 53' 25" E	Tsedacha
5	1708	12	E	07° 58' 78" N, 38° 53' 52" E	Tsedacha
6	1720	5	NE	07° 58' 89" N, 38° 53' 52" E	Tsedacha
7	1656	5	N	07° 59' 08" N, 38° 53' 52" E	Tsedacha
8	1723	80	N	07° 59' 22" N, 38° 53' 67" E	Tsedacha
9	1714	20	NE	07° 59' 18" N, 38° 53' 99" E	Tsedacha
10	1650	35	E	07° 80' 20" N, 38° 53' 98" E	Tsedacha
11	1620	20	SW	07° 58' 39" N, 38° 53' 13" E	Tsedacha
12	1681	0	S	07° 58' 12" N, 38° 53' 29" E	Tsedacha
13	1692	45	S	07° 58' 27" N, 38° 53' 43" E	Tsedacha
14	1790	55	SE	07° 58' 30" N, 38° 53' 47" E	Tsedacha
15	1724	15	S	07° 57' 49" N, 38° 53' 19" E	Funduro

16	1684	10	S	07° 57' 39" N, 38° 53' 28" E	Funduro
17	1623	5	SW	07° 57' 42" N, 38° 53' 11" E	Funduro
18	1626	20	W	07° 57' 48" N, 38° 53' 08" E	Funduro
19	1706	15	SE	07° 57' 50" N, 38° 53' 29" E	Funduro
20	1690	20	E	07° 57' 59" N, 38° 53' 25" E	Funduro
21	1678	3	NE	07° 57' 65" N, 38° 53' 25" E	Funduro
22	1694	20	NW	07° 57' 54" N, 38° 53' 15" E	Funduro
23	1665	10	N	07° 57' 70" N, 38° 53' 19" E	Funduro
24	2033	50	W	07° 56' 42" N, 38° 51' 74" E	Tullu Guddo
25	1913	45	E	07° 56' 40" N, 38° 51' 77" E	Tullu Guddo
26	1922	10	NE	07° 56' 57" N, 38° 51' 72" E	Tullu Guddo
27	1910	35	N	07° 56' 50" N, 38° 51' 79" E	Tullu Guddo
28	1882	32	N	07° 56' 55" N, 38° 51' 83" E	Tullu Guddo
29	1778	25	N	07° 56' 70" N, 38° 51' 90" E	Tullu Guddo
30	1770	15	N	07° 56' 96" N, 38° 51' 92" E	Tullu Guddo
31	1729	10	E	07° 56' 25" N, 38° 52' 00" E	Tullu Guddo
32	1829	30	E	07° 56' 29" N, 38° 51' 90" E	Tullu Guddo
33	1889	33	NE	07° 56' 44" N, 38° 51' 91" E	Tullu Guddo
34	1853	28	NE	07° 56' 51" N, 38° 51' 98" E	Tullu Guddo
35	1690	20	NE	07° 56' 60" N, 38° 52' 13" E	Tullu Guddo
36	1990	65	NW	07° 56' 48" N, 38° 51' 76" E	Tullu Guddo
37	1792	35	NW	07° 56' 57" N, 38° 51' 69" E	Tullu Guddo
38	1737	18	NW	07° 56' 76" N, 38° 51' 33" E	Tullu Guddo
39	1855	35	NW	07° 57' 23" N, 38° 51' 30" E	Tullu Guddo
40	1707	40	NW	07° 57' 21" N, 38° 51' 38" E	Tullu Guddo
41	1855	50	W	07° 56' 42" N, 38° 51' 67" E	Tullu Guddo
42	1759	30	W	07° 56' 43" N, 38° 51' 55" E	Tullu Guddo
43	1802	35	W	07° 56' 46" N, 38° 51' 36" E	Tullu Guddo
44	1993	30	W	07° 56' 34" N, 38° 51' 19" E	Tullu Guddo
45	1740	30	SW	07° 56' 15" N, 38° 51' 55" E	Tullu Guddo

46	1673	5	SW	07° 55' 93" N, 38° 51' 40" E	Tullu Guddo
47	1830	20	S	07° 56' 20" N, 38° 51' 72" E	Tullu Guddo
48	1782	25	S	07° 56' 02" N, 38° 51' 68" E	Tullu Guddo
49	1638	16	S	07° 55' 85" N, 38° 51' 65" E	Tullu Guddo
50	1758	20	SE	07° 56' 21" N, 38° 51' 76" E	Tullu Guddo
51	1730	18	SE	07° 56' 09" N, 38° 51' 78" E	Tullu Guddo
52	1685	10	E	07° 55' 46" N, 38° 45' 28" E	Galilla
53	1674	20	E	07° 55' 51" N, 38° 45' 34"E	Galilla
54	1711	25	SE	07° 55' 41" N, 38° 45' 39" E	Galilla
55	1857	40	SE	07° 55' 35" N, 38° 45' 39" E	Galilla
56	1756	25	S	07° 55' 39" N, 38° 45' 33" E	Galilla
57	1567	20	SW	07° 55' 46" N, 38° 45' 26" E	Galilla
58	1679	15	W	07° 55' 49" N, 38° 45' 20" E	Galilla
59	1639	20	NE	07° 55' 53" N, 38° 45' 28" E	Galilla
60	1557	16	N	07° 55' 59" N, 38° 45' 27" E	Galilla
61	1699	30	N	07° 55' 76" N, 38° 45' 33" E	Galilla
62	1625	4	NW	07° 55' 68" N, 38° 45' 19" E	Galilla
63	1596	3	NW	07° 55' 76" N, 38° 45' 17" E	Galilla
64	1740	10	E	07° 54' 34" N, 38° 46' 37" E	Debre Sina
65	1665	25	E	07° 54' 32" N, 38° 46' 43" E	Debre Sina
66	1777	20	SE	07° 54' 33" N, 38° 46' 38" E	Debre Sina
67	1737	12	NE	07° 54' 45" N, 38° 46' 40" E	Debre Sina
68	1684	13	N	07° 54' 45" N, 38° 46' 34" E	Debre Sina
69	1635	8	NW	07° 54' 38" N, 38° 46' 28" E	Debre Sina
70	1680	25	S	07° 54' 27" N, 38° 46' 31" E	Debre Sina
71	1549	5	SW	07° 54' 30" N, 38° 46' 22" E	Debre Sina
72	1665	5	W	07° 54' 35" N, 38° 46' 32" E	Debre Sina
73	1647	2	W	07° 54' 34" N, 38° 46' 17" E	Debre Sina

Appendix 6. Socio-economic Survey Questionnaire

Questionnaire for Households

Island _____ Village _____ Ser. No. _____

Characteristics of the respondent

1. For how long have you lived in the area?

   1) Since birth 2) The last 20 years 3) The last 5 years 4) Others (specify)

2. Educational status of the respondent

   1) Cannot read and write
   2) Can read and write
   3) Primary school (1^{st}-6^{th} grade)
   4) Junior secondary school (7-8^{th} grade)
   5) High school (9-12^{th} grade)
   6) Completed 12^{th} grade
   7) Higher education

3. Which of the following is (are) the occupation(s) of the respondent?

   1) Weaving traditional clothes
   2) Hand craft
   3) Selling beverage
   4) Trading
   5) Selling wood
   6) Crop production
   7) Fruit production
   8) Vegetable production
   9) Chat production
   10) Fishery
   11) Apiculture
   12) Casual worker
   13) Salaried worker
   14) Others (specify)

4. Gender of the respondent 1) Male 2) Female

5. Age of the respondent 1) < 18 2) 18-40 3) 41-60 4) > 60

6. Religion of the respondent

   1) Orthodox 2) Catholic 3) Protestant 4) Muslim 5) Others (specify)

7. Marital status of the respondent 1) Single 2) Married 3) Divorced 4) Widowed

Characteristics of the households

8. Have you enough children? 1) Yes 2) No

9. Do you want to have more children? 1) Yes 2) No

   If yes, how many? _____ If no, why? _____

10. Have you received health and family planning education? 1) Yes 2) No

11. Age and sex structure of the household members

Sex	≤ 5	6-10	11-15	16-20	21-60	> 60
Male						
Female						

12. Educational status of the family members

Educational status	Unit	Male	Female	Total	Remark
1) Cannot read and write					
2) Can read and write					
3) Primary school (1^{st}-6^{th} grade)					
4) Junior secondary school (7-8^{th} grade)					
5) High school (9-12^{th} grade)					
6) Completed 12^{th} grade					
7) Higher education					

13. How much is the total annual income of the household?

Source of income	Income per year in Birr
1) Income from relatives/Family elsewhere	
2) Income from fuelwood and charcoal selling	
3) Income from fish selling	
4) Income from selling honey	
5) Income from daily labour work	
6) Income from selling hand crafts	
7) Income from selling fruits	
8) Others (specify)	

14. How much is the total annual expenditure of the household?

Type of expenditure	Expense per year in Birr

1) Food	
2) Clothing	
3) Health	
4) Education	
5) Ceremonies	
6) Others (specify)	

15. Where do you get your food? 1) Own production 2) Purchasing 3) Others (specify)
16. If it is purchased, how do you pay for it?
    1) Wood and charcoal selling 2) Fruit selling 3) Others (specify)

Land

17. What is the land tenure type? 1) Own land 2) Rent land 3) Share crop
18. How is the land used?

Type of land use	**Unit**	**Size**	**Remark**
1) Cultivated perennial crops	Timad		
2) Vegetables			
3) Woodlot			
4) Fallow land			
5) Others (specify)			

19. What are the major problems associated with your land use?
    1) Shortage of land 4) Insecurity
    2) Low productivity 5) Others (specify)
    3) Lack of moisture
20. If insecurity is the problem, why?
21. What is the colour of your soil? 1) Red 2) Brown 3) Grey 4) Black
22. How deep is the soil for crop production?
    1) Shallow 2) Medium 3) Deep 4) Very deep
23. How fertile is the soil for crop production? 1) Poor 2) Medium 3) High

24. What is the texture of the soil?

1) Stony 2) Sandy 3) Sandy loam 4) Loam 5) Silt

25. What practice do you undertake to improve soil fertility?

1) Manure/compost application 3) Crop rotation

2) Fertilizer application 4) Others (specify)

26. What do you practice to conserve soil and moisture?

1) Soil bund 4) Mulching

2) Stone bund 5) Others (specify)

3) Contour ploughing

27. Do you grow fruit crops? 1) Yes 2) No

Productivity and total area coverage of fruits

Type of fruits	Total area in ha	Total annual production in quintals/ha	Total amount of money earned per year in Birr
1) Coffee			
2) Lemon			
3) Orange			
4) Others (specify)			

28. Do you grow spice crops? 1) Yes 2) No If yes, list down them

29. Why do you produce spice crops? 1) Consumption 2) Market 3) Both

If it is for market, how much do you get per year?

30. What are the major reasons for low productivity of crops?

1) Poor soil fertility 5) Disease and pest

2) Shortage of land 6) Lack of improved seeds

3) Lack of moisture 7) Wild animals

4) Shade problem 8) Others (specify)

31. What measures do you suggest to alleviate the problems?

Irrigation

32. Do you practice irrigation? 1) Yes 2) No

33. If yes, what is your source of water?

1) Lake 2) Spring 3) Well water 4) Others (specify)

34. Productivity and area coverage of irrigated crops

Crop type	Total area in ha	Productivity in quintals/ha	Purpose of production	Amount of Birr gained per year
1)				
2)				
3)				
4)				

Key: For purpose of production, use MA = for market, CO = for consumption

Livestock

35. Do you have animals? 1) Yes 2) No If no, why?

Type of animals	Number	Order of importance
1) Cattle		
2) Sheep		
3) Goats		
4) Donkeys		
5) Horses		
6) Mules		
7) Poultry		
8) Others (specify)		

36. Do you get income from animals' sale? 1) Yes 2) No

37. Income generated from animals' sale

Type of animals	Income per year in Birr	Remark
1) Cattle		

2) Sheep		
3) Goats		
4) Donkeys		
5) Poultry		
6) Others (specify)		

38. Income generated from animals' products

Type of products	**Unit**	**Amount**	**Income per year in Birr**	**Remark**
1) Milk				
2) Eggs				
3) Hides and skin				
4) Others (specify)				
Total				

39. Do you use improved breeds of poultry? 1) Yes 2) No If no, why?

Apiculture

40. Do you practice beekeeping? 1) Yes 2) No

41. What are the types of beekeepings that you practice? 1) Backyard 2) Natural vegetation 3) Both

42. Do you have modern hive? 1) Yes 2) No If yes, what type?

43. Annual income generated from honey sale

Type of bee hive	**Total annual production in kg**	**Average price/kg**	**Amount consumed in kg**	**Amount sold in Birr**	**Total annual income in Birr**
1) Traditional					
2) Modern					
3) Intermediate					
Total					

44. Do you have honey bee feed problem? 1) Yes 2) No

45. What is the source of the feed? 1) Natural vegetation 2) Own plantation 3) Others (specify)

46. Which trees are especially good for bees? Complete the following table

Tree species	Flowering time	Rank	Quality of product	Remark
1)				
2)				
3)				
4)				
5)				

Key: For quality of product

1 = Excellent 2 = Very good 3 = Good 4 = Nice

47. What are the constraints in beekeeping?

1) Lack of feed
2) Lack of input
3) Lack of awareness
4) Lack of appropriate bee colony
5) Pest and disease
6) No market
7) Others (specify)

48. What measures do you suggest to solve the problems?

Fishery

49. What does your household use Lake Ziway for most often?

1) Drinking
2) Washing clothes
3) Fishing
4) Transport
5) Irrigation
6) Others (specify)

50. If you use the lake for fishing, for what purpose do you use the fish? Complete the table

Purpose	Number of fish caught per year	Total fish caught per year in kg	Money generated per year
1) Consumption			
2) Market			

Total			

51. If you sell fish, where do you do it? 1) Ziway 2) Other place (specify)
52. How do you transport the fish? 1) By boat 2) By Tankwa 3) Others (specify)
53. Do you have your own transport? 1) Yes 2) No
54. If yes, what kind do you have? 1) Boat 2) Tankwa 3) Others (specify)
55. How much does it cost to transport fish by boat to Ziway? By Tankwa to Ziway?
56. What are the problems in relation to fishery?
    1) Lack of market
    2) Lack of equipment
    3) Lack of awareness
    4) Lack of transport
    5) Lack of proper management
    6) Others (specify)

The vegetation resource

57. What do you benefit from the nearby vegetation?
    1) Fuelwood
    2) Charcoal
    3) Construction wood
    4) Timber
    5) Others (specify)
58. Do you have free access to the vegetation? 1) Yes 2) No
59. From where do you get wood for various purposes?

Type of uses	**Private plantation**	**Community plantation**	**Natural vegetation**	**Purchase**
1) Fuelwood				
2) Construction				
3) Timber				
4) Farm implements				
5) Medicine				
6) Fence				
7) Others (specify)				

60. Do you buy wood products for your self-consumption? 1) Yes 2) No

If you are buying, how much Birr do you spend per year for the following uses?

Uses	Amount of money spent in Birr	Remark
1) Fuelwood		
2) Construction		
3) Timber		
4) Farm implements		
5) Others (specify)		

61. How far do you travel to collect wood products?

1) < 1 km 2) 1-2 km 3) 3-5 km 4) > 5 km

62. Who is more responsible in collecting fuelwood? 1) Women 2) Men 3) Children

63. Which five tree species (in order of priority) are most preferable for the following uses?

Products	Rank				
	1	2	3	4	5
1) Fuelwood					
2) Charcoal					
3) Construction material					
4) Timber					

64. Do you get money from selling wood? 1) Yes 2) No

If yes, complete the table below

Wood products	Unit	Total amount	Amount of money earned per year in Birr
1) Fuelwood	Load (Donkey)		
2) Charcoal			
3) Construction wood			
4) Others (specify)			

65. Where do you sale the wood? 1) Ziway 2) Other place (specify)

66. How do you transport the wood? 1) By boat 2) By Tankwa 3) Others (specify)

67. How much does it cost to transport wood by boat to Ziway? By Tankwa to Ziway?

68. How many loads (donkey) of fuelwood do you consume per year?

1) 1-50 2) 51-100 101-150 4) > 150

69. What is your source of light?

1) Fuelwood 2) Mashow 3) Fanos 4) Others (specify)

70. Please indicate the major source of energy for cooking

Source of energy	Rank
1) Fuelwood	
2) Charcoal	
3) Crop residue	
4) Animal dung	
5) Kerosene	
6) Others (specify)	

71. Species of trees grown on the farmland and their management activity

Species	Number	Where found	Management	Desirable traits	Use
1)					
2)					
3)					
4)					
5)					

Key:

Code for where found

FB = Farm boundary

OF = On-farm

WL = Woodlot

HS = Homestead

OT = Others

Code for management

Code for desirable traits

FG = Fast growth

NC = Not compete with crop

RL = Resistance to livestock

SF = Soil fertility

Code for use

FW = Fuelwood

PL = Pollarding

CP = Coppicing

NM = No management

PL = Pole

TM = Timber

MD = Medicinal value

FD = Fodder

72. Do you practice modern agroforestry such as multistory mixing trees/shrubs with crops?

1) Yes 2) No

73. Do you plant trees? 1) Yes 2) No If no, why?

74. Which trees have you planted in the last 5 years?

Species	Rank	Where planted	Products	Home consumption	Sale	Money gained per year in Birr (if sold)
1)						
2)						
3)						
4)						
5)						

Key:

Code for where planted

FB = Farm boundary

OF = On-farm

WL = Woodlot

HS = Homestead

RS = Roadside

Code for products

FW = Fuelwood

PL = Pole

TM = Timber

FR = Fruit

SH = Shade

Code for home consumption

M = Most

S = Some

N = None

Code for sale

M = Most

S = Some

N = None

OM = Ornamental

75. Do you want to plant more trees in the future?

1) Yes 2) No If no, what is the reason? _____

Reason	Yes	No
1) Shortage of land	1	2
2) Shortage of seeds and seedlings	1	2
3) Have enough in the vegetation	1	2
4) Have enough my own	1	2
5) Lack of awareness	1	2
6) Others (specify)	1	2

76. List five most important plants which are very important in medicinal value and other non-wood products

Species	Type of uses
1)	
2)	
3)	
4)	
5)	

Key: 1) Medicine 2) Fruit 3) Spice 4) Others

77. What are the basic reasons for destruction of the vegetation?

Reasons	Rank
1) Farmland expansion	
2) Livestock grazing	
3) Fuelwood extraction	
4) Charcoal production	
5) Cutting for construction wood	
6) Fire incidence	
7) Others (specify)	

78. What are the basic problems hindering forest development?

79. Do churches contribute for the conservation of the vegetation?

1) Yes 2) No If yes, how?

80. What recommendations do you suggest for future conservation, management and sustainable utilization of the vegetation resource?

1) On your side

2) On the side of the community

3) On the side of the government

Institutional support

81. What type of assistance do you get from the following institutions?

Institutions	**Type of assistance**
1) Woreda Agriculture Office	
2) Woreda and Local Administration	
3) Culture and Tourism Bureau	
4) Fish Production and Marketing Enterprise	
5) Woreda Health Office	
6) NGO (if any)	
7) Others (specify)	

Key: 1) Training 2) Credit 3) seed and Seedling provision 4) Technical advice 5) Others

Questionnaire for Clergy

1. What plants do you know form the sacred groves?

2. For what purposes they are used?

1) Fuelwood 4) Medicine

2) Charcoal production 5) Religious purposes

3) Construction 6) Others (specify)

3. What is your role in conserving the sacred groves?

1) Preventing tree cutting by the local people

2) Preventing from grazing

3) Others (specify)

4. Do you carry out management practices? 1) Yes 2) No

5. If yes, what are the practices?

1) Tree planting 3) Coppicing

2) Pollarding 4) Others (specify)

6. How do you rate the pressure of the local communities on the sacred groves?

1) High 2) Medium 3) Low

7. What measures do you take to stop tree cutting by the local people?

1) Guard 2) Punishment 3) Others (specify)

8. What type of support do you get from the following institutions?

Institutions	**Type of support**
1) Woreda Agriculture Office	
2) Woreda and Local Administration	
3) Culture and Tourism Bureau	
4) Fish Production and Marketing Enterprise	
5) Woreda Health Office	
6) Woreda Church Office	
7) NGO (if any)	
8) Others (specify)	

Key: 1) Food 2) Money 3) Medicine 4) Supply of seeds and seedlings 5) Training 6) Others

9. What do you recommend for conservation, management and sustainable utilization of the sacred groves and the surrounding vegetation?

Questionnaire for Stakeholders

1. Who is the owner of the vegetation? 1) State 2) Community 3) Undefined

2. What is your observation on the current status of the vegetation in comparing with the past history? 1) Still intact 2) Slightly disturbed 3) Heavily disturbed

3. What are the basic reasons for destruction of the vegetation?

Reasons	Rank
1) Farmland expansion	
2) Livestock grazing	
3) Fuelwood extraction	
4) Charcoal production	
5) Cutting for construction wood	
6) Fire incidence	
7) Others (specify)	

4. What benefits (economically, socially, ecologically) does the vegetation provide?
5. Do people in the islands transport fuelwood to Ziway town every day?
6. What are the major trees that are cut every day?
7. Do you know some tree species that disappeared from the islands?
8. What is your main role and responsibility in conserving, protecting and utilizing the vegetation?
9. To conserve and manage the vegetation, what major contributions have been made by your institution and what was the outcome obtained so far?
10. What are the major constraints and solutions as far as sustainable vegetation management and utilization is concerned?
11. What are the major opportunities that contribute for conserving and managing the vegetation?
12. What do you intend practically to contribute more for the future development of the vegetation in question?
13. Do you assign development facilitator in the area? 1) Yes 2) No If no, why?
14. Did you train farmers in agroforestry and soil and water conservation activities in the last 5 years?
15. How is the fishing activity of the inhabitants of the islands and your technical support?
16. How are fruit and vegetable productions going on? How are you supporting the poultry and beekeeping activities of the people in the islands?

17. Who is responsible for conserving and managing the vegetation? Why?
18. Who has the right to utilize the vegetation? Why? And how?
19. What recommendations do you suggest for future conservation, management and sustainable utilization of the vegetation resource?
20. As far as sustainability is concerned, what must be the role and responsibility of stakeholders?

Appendix 7. List of key informants contacted in the study area.

No.	Name	Age	Sex	Locality
1	Tesfaye Edetto*	38	M	Ziway
2	Memrie Asfaw Tufa	41	M	Tsedacha
3	Negewo Edao	43	M	Tsedacha
4	Memrie Melaku G/Mariam	65	M	Tullu Guddo
5	Bekure Tussa	50	M	Tullo Guddo
6	Endale Kefeni	37	M	Tullu Guddo

* He is a native of Tullu Guddo island and an historian

Appendix 8. Age and sex structure of the household members in the islands of Lake Ziway (values in brackets are percentages).

Age group	Male	Female	Total
≤ 5	43 (10.3)	45 (10.8)	88 (21.1)
6-10	46 (11.0)	41 (9.8)	87 (20.8)
11-15	30 (7.2)	32 (7.7)	62 (14.8)
16-20	16 (3.8)	27 (6.5)	43 (10.3)
21-60	66 (15.8)	64 (15.3)	130 (31.1)
> 60	5 (1.2)	3 (0.7)	8 (1.9)
Total	**206 (49.3)**	**212 (50.7)**	**418 (100)**

Appendix 9. Educational status of the household members in the islands of Lake Ziway.

Literacy level	Frequency	%
Cannot read and write	142	34.0
Can read and write	14	3.3

Primary School (1st-6th grades)	153	36.6
Junior Secondary School (7-8th grades)	61	14.6
High School (9-12th grades)	35	8.4
12th grade complete	11	2.6
Higher education	2	0.5
Total	**418**	**100**

Appendix 10. Activities of Stakeholders in the islands of Lake Ziway.

1. Rural Land and Natural Resources Administration Office

The office has made efforts to control tree cutting from the uninhabited islands by people on shore areas (previous native inhabitants). In collaboration with the local representatives, the office is involved in giving advice and creating awareness in the community. In the past, it worked in collaboration with an international NGO named Self Help in the protection of the vegetation. However, at present, the activities of the office are very limited due to termination of the NGO, lack of budget and other problems.

2. Woreda Agriculture Office

When compared to areas in the mainland, the activity of the office in the islands is very limited. Its activities are restricted to control of fishermen and fishing gears, control of waste disposal into the lake and awareness creation. No extension package has been implemented so far and no development agent is assigned to the islands.

3. Woreda Administrative Office

The office has made very limited efforts in relation to vegetation conservation and management in the area. In particular, the activities of the office in the islands are insignificant. At the moment, it is facilitating the involvement of stakeholders and NGOs in soil and forest conservation. According to the administrator, Ato Raya Alemu, about 2.5-3

million seedlings will be distributed this year, and he realized the need to distribute seedlings to the islands.

4. Woreda Church Office

In addition to providing religious service, the office is involved in creating awareness among the Christians on the importance of protecting of the vegetation in the islands and planting trees. The office has addressed the damage caused by cattle and goats both on the vegetation and the churches and suggested their removal from the uninhabited islands. It is also involved in planting trees. For instance, *Olea*, *Acacia*, *Eucalyptus* and other trees have been planted around Gebriel Monastery, located in the southwestern shore of Lake Ziway.

5. Fisheries Resources Research Centre

The centre is involved in conducting research on the fish resources of Lake Ziway. The main research areas are reproductive biology and feeding habit, production and fish handling and processing. It provides fishing equipment and training to fishermen.

6. Fish Production and Marketing Enterprise

The contribution of the Enterprise to the island communities is significant since fishing is the major economic activity and the main source of income. Primarily it provides market access to the fishermen as transport is a bottleneck to their marketing. The fishermen are organized in groups and they have smooth relationship with the Enterprise as it provides continuous market service. It is involved in provision of fishing equipment in low cost and on credit basis and awareness creation on fishing. In addition, the Enterprise provides transport service for the islanders as well as researchers and people who travel during religious ceremonies.

The data on fish production from Lake Ziway obtained from the manager, Ato Bantewesen Wetango, showed that the Enterprise generates a lot of money from fish sale while providing source of income for the island communities. The islanders claim that the price per kg of fish is low and needs accountability from the two sides. Both the Enterprise and the islanders have recognized the excessive exploitation of the fish resources of the lake and reduction in

productivity, and they recommended the implementation of proper fisheries management for recovery and sustainable utilization.

Appendix 11. The most important bee forage plant species in the islands of Lake Ziway.

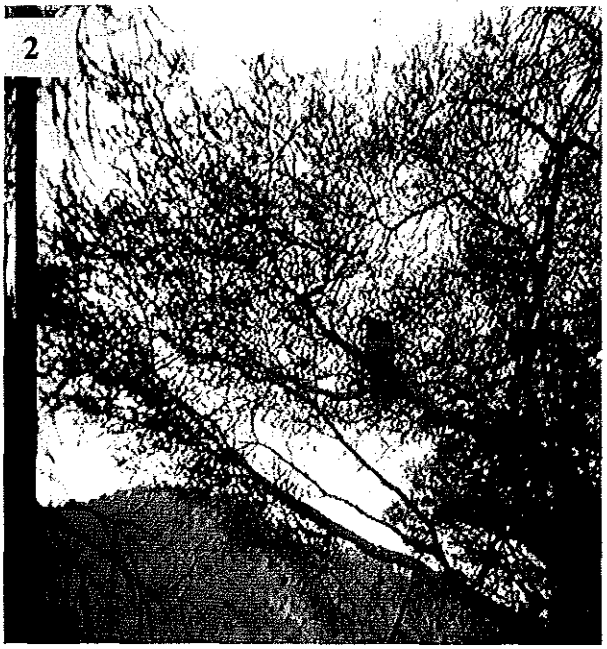
No.	Scientific name	Recorded in the Honeybee Flora *	Identified by the respondents
1	*Acacia albida*	x	
2	*A. tortilis*	x	x
3	*Achyranthes aspera*	x	
4	*Aeschynomene elaphroxylon*		x
5	*Ageratum conyzoides*	x	
6	*Argemone mexicana*	x	
7	*Asparagus africanus*	x	
8	*Balanites aegyptiaca*	x	
9	*Barleria ventricosa*	x	
10	*Calpurnia aurea*	x	
11	*Capparis fascicularis*		x
12	*Carica papaya*	x	
13	*Catha edulis*	x	
14	*Caucanthus auriculatus*	x	
15	*Caylusea abyssinica*	x	
16	*Citrus aurantifolia*	x	
17	*Coffea arabica*	x	
18	*Commicarpus plumbagineus*	x	
19	*Cordia africana*	x	
20	*C. monoica*	x	
21	*Croton macrostachyus*	x	
22	*Cussonia holstii*	x	
23	*Datura stramonium*	x	

24	*Dodonaea angustifolia*	x	
25	*Ehretia cymosa*	x	
26	*Eucalyptus camaldulensis*	x	
27	*Euphorbia abyssinica*	x	x
28	*E. tirucalli*	x	x
29	*Ficus sycomorus*	x	
30	*F. vasta*	x	
31	*Gossypium hirsutum*	x	
32	*Grewia velutina*	x	x
33	*Hypoestes forskaolii*	x	x
34	*Jacaranda mimosifolia*	x	
35	*Justicia schimperiana*	x	
36	*Kalanchoe Lanceolata*	x	
37	*Laggera crispata*	x	
38	*Lantana camara*	x	
39	*Leucas abyssinica*	x	
40	*L. martinicensis*	x	
41	*Maerua angolensis*	x	
42	*Maytenus senegalensis*	x	
43	*Melia azedarach*	x	
44	*Olea europaea* subsp. *cuspidata*	x	
45	*Opuntia ficus-indica*	x	
46	*Oxygonum sinuatum*	x	
47	*Plectranthus lanuginosus*	x	
48	*Psidium guajava*	x	
49	*Rhamnus prinoides*	x	
50	*Ricinus communis*	x	
51	*Rumex nervosus*	x	
52	*Schinus molle*	x	
53	*Solanecio angulatus*	x	

54	*Solanum incanum*	x	
55	*Sonchus asper*	x	
56	*Steganotaenia araliacea*	x	
57	*Tagetes minuta*	x	
58	*Urtica simensis*	x	
59	*Verbascum sinaiticum*	x	
60	*Xanthium spinosum*	x	
61	*Ximenia americana*	x	

* Source: Fichtl and Admasu Adi (1994)

PLATES



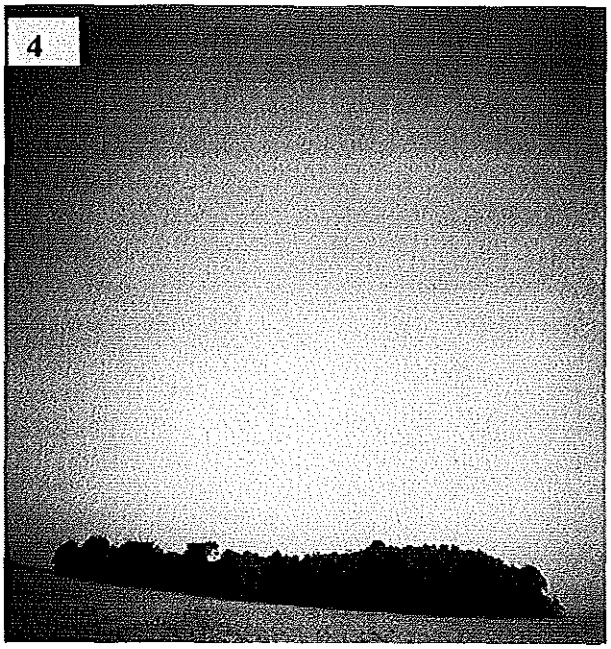


Plate 1. Lemon production at lake edges.

Plate 2. Traditional beekeeping in the islands.

Plate 3. Traditional agroforestry at Tsedacha.

Plate 4. Dense vegetation forming a canopy at Debre Sina.

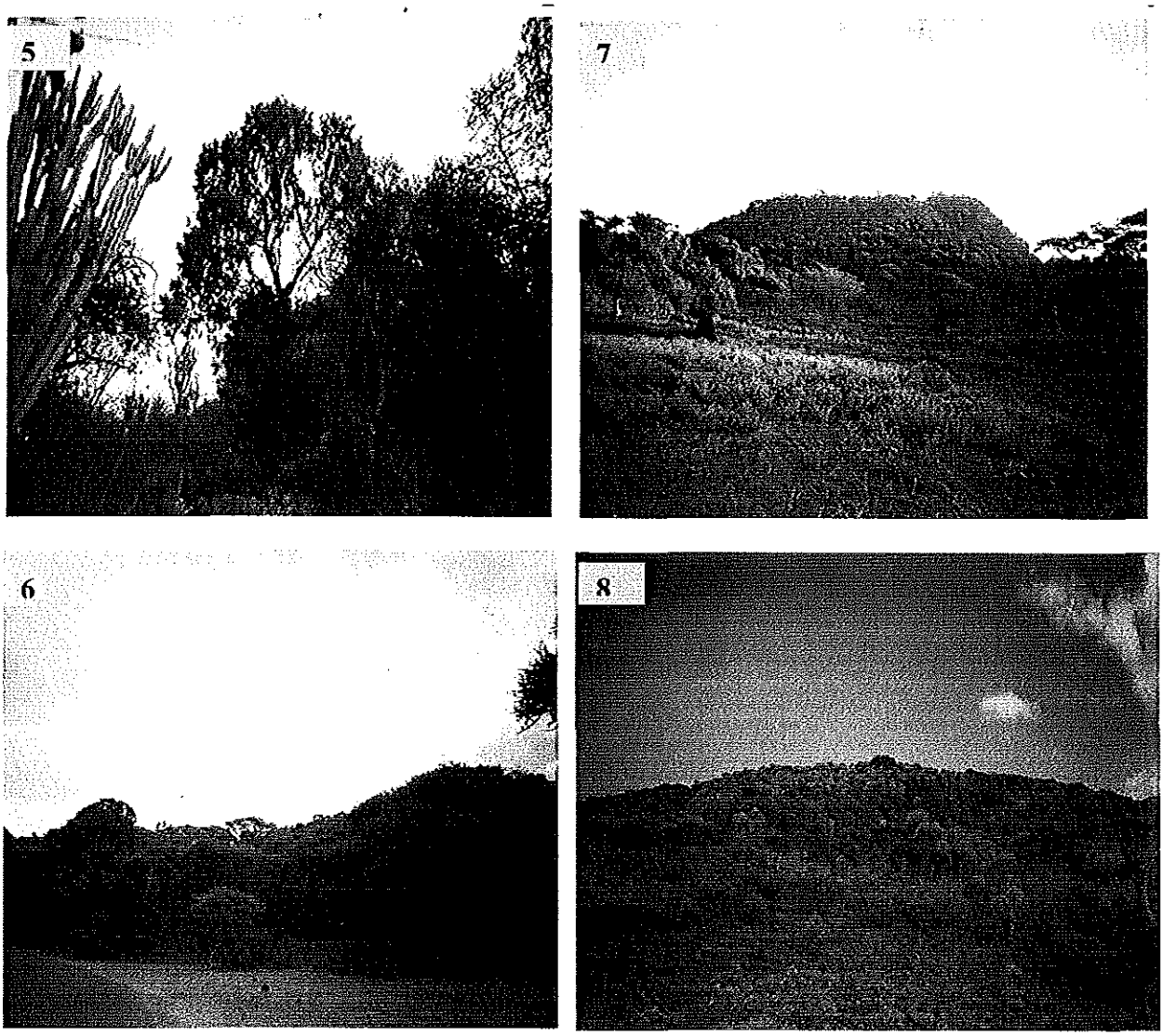
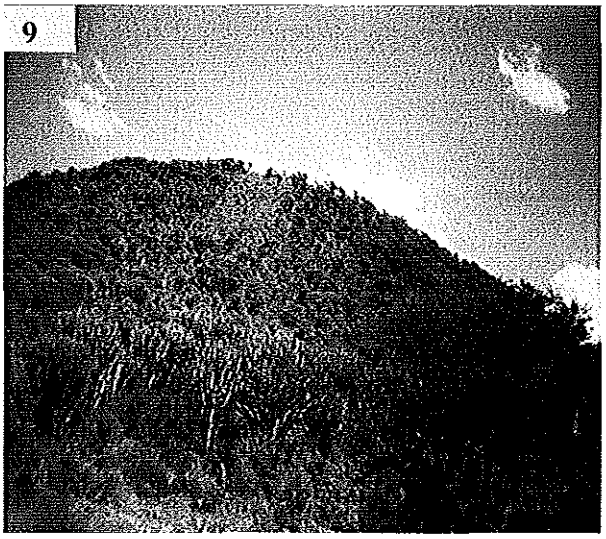


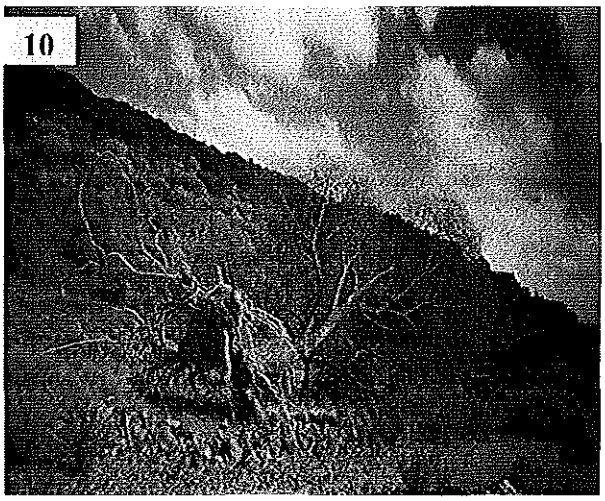
Plate 5. *Juniperus procera, Euphorbia abyssinica* and *E. tirucalli* dominated stand at Gumarghe Summit of Tullu Guddo.

Plate 6. *Acacia tortilis* dominated vegetation at southeastern part of Tullu Guddo, near Kidist-Mariam Church.

Plate 7. *Euphorbia tirucalli, E. abyssinica* and *Acacia tortilis* dominated stand at the northern part of Tsedacha.

Plate 8. Vegetation at western slope of Tullu Guddo maintained by well-established terraces.





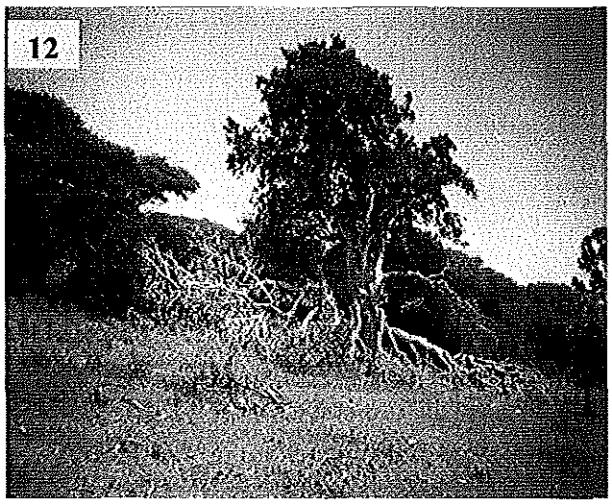


Plate 9. Damage caused to the vegetation by rolling stones (look at the gap formed) at the slope of Woizero Summit of Tullu Guddo.

Plate 10. Damage to the vegetation as a result of erosion at the western slope of Tullu Guddo (look at the uprooted *Acacia tortilis*).

Plate 11. Farmland expansion on the northern hills of Tsedacha (look at the debarked *Acacia tortilis*).

Plate 12. Tree cutting (look at *Ficus sycomorus*) for construction material and other purposes at Funduro.