STUDY OF WOODY SPECIES DIVERSITY AND SOCIO-ECONOMIC IMPORTANCE OF BOKE SALT HOUSE, A VOLCANIC CRATER LAKE, IN SEMI-ARID DRYLANDS OF BORANA, SOUTHERN ETHIOPIA

BY

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ABSTRACT

The diversity of woody plant species and socio-economic importance of salt house of the Borana dryland were conducted in Boke. This area is a volcanic crater lake and assumes a circular shape when viewed from the top. To study woody plant species diversity, evenness, richness and community type, line transects were laid along the four aspects for sampling purposes. A total of 22 quadrats (20 m x 20 m) were sampled. For comparative purposes, 39 quadrats of the same size were sampled from outside the salt house. Participatory Rural Appraisal (PRA) and semi-structured interviews were conducted for a socio-economic data collection. Vegetation, environmental variables and socio-economic data were analyzed using PC-ORD, CANOCO and SPSS software, and descriptive statistics accordingly. A total of 45 woody plant species representing 26 genera in 16 families were recorded in this study. The density of woody plant species recorded in Boke salt house was 2622 individuals ha^{-1}. The diversity and evenness indices of woody plant species of the study area were 2.100 and 0.661, respectively. Six plant community types were identified in the current study, of which the first two (community 1, and 3) were found in Boke salt house and the other four (Community 2, 4, 5 and 6) were restricted to surrounding environment. Soil parameters like moisture content, organic matter, total N and available P had significant positive correlation with altitude, whereas exchangeable Na, pH-H_2O, and electrical conductivity had negative correlation. The salt house is the sole source of both table salt and black salty mud which are used as a livelihood safety net during drought. The indigenous people of the area extract table salt by using leaves of a thorn-less shrub, *Suaeda monoica.* It was found out that the on site retail price of 50-60 kgs of table salt ranges from 80 to 100 ETB while the same amount of a black salty mud was 25-30 ETB. It has been found out that about 50,000 ETB was said to be collected by elected local community leaders per year from eco-tourists visiting the salt house. This income was/is being used for development activities under the leadership of the community. Given the level of poverty and recurrent drought, Boke salt house is under intensive and extensive human exploitations and participatory resource management and sustainable uses should be sought for both by local communities and the Oromia Regional State to bring about long-lasting solutions.

1 INTRODUCTION

Drylands are chracterized by high temperature, low rainfall (less than 800 mm per annum) and high evapotranspiration. In Africa, the drylands cover about 65% of the total land of South of Sahara and were susceptible to various land degradation (Dejene ***et al***., 1997). Ethiopia is one of the tropical countries with varied ecological and climatic conditions. This make Ethiopia home to the most diverse flora and fauna in the world. Among the different types of agro-ecological zones in the country, dry land, which is under the arid and semi-arid environmental condition represents about 620,000 km^2 (Mulgeta Limenih and Demel Teketay, 2004). This huge land mass is known to be dominated by dry decidious wood land and bushland which is estimated to be 25 millions hectares (Abeje Eshete, 2002). The representative genera inhabting such dry decidious woodland and wooded grassland ecosystems of the country are *Boswellia, Commiphora, Acacia, Balanites*, different types of shrubs, grasses and other plant forms (Oba *et al.*, 2000; Abeje Eshete, 2002).

Borana rangeland is one of the known lowland areas in Ethiopia with the largest nomads owing high population of cattle and other domestic animals (Coppock, 1993; Oromia Regional Planning and Economic Development Bureau, 2000; Alemayehu Mengistu, 2003). They traditionally based on cattle husbandry for survival and income generation, and have been effective over generations in producing animal products while maintaining rangeland resources (Pratt and Gwynne, 1977; Helland, 1997). However, review of decade's research indicated that the region of southern Ethiopia mainly Borana was grazed by pastoralists' livestock for many centuries and experiencing ecological and economic stress (Coppock, 1994).

Ecological stress is manifested by progressive growth of bush cover, which is a common cause of herbaceous vegetation loss in dry savannahs, and is responsible for a decline in range condition (Smith, 1988; Oba ***et al***., 2000). In particular, recent increases in human and livestock populations coupled with the invasion of trees and shrub/bushes species in to prime rangelands, decreases the availability of grazing lands, and lead to decline in adherence to social mores and have eroded the effectiveness of traditional means of range resources management, which are symptomatic of rangelands where the pastoral production systems are under environmental stress (Scholes and Walker, 1993). The extent of tree/shrub/bush invasion in Borana was estimated to be 40% in 1980 and within a decade the cover was doubled (Oba, 1998), and currently it is becoming a great challenge to livestock production and livelihood of pastoralists and/or agro-pastoralists.

This problem calls scientists to undertake research in order to minimize the problem to certain extent and improve the livelihood of the pastoral and/or agro-pastoral society in the area. Based on this different studies have been conducted in Borena zone on different project topics mainly focusing on the plant diversity and Ethnobotany (Gemedo Dalle *et al*., 2005), vegetation change (Zerihun Woldu and Sileshi Nemomissa, 1998), invasive woody plant species (Coppock, 1993: Ayana Angassa, 2002: Mohammed Adilo *et al*., 2005), woody vegetation (Haugen, 1992) and Rangeland diversity and forage (Coppock, 1994; Alemayehu Mengistu, 1998, 2003 and 2004; ; Ayana Angassa and Fekadu Beyene, 2003). These research outcomes can have their own contribution to alleviate development problems if properly implemented and have also provided baseline information to undertake further studies by identifying potential research areas and gaps, which directly or indirectly contributes to the improvement of the livelihood of the community.

Some of the potential research areas in the zone include historical and cultural places, and natural features, which are favorable for the development of tourist industry. Boke salt house, which is also commonly known by the name El-soda, is a volcanic crater lake, located in Dire District of Borana zone, Oromia Regiona State. It is one of the three known potential tourist area (Boke salt house, Gumigayo cultural place and Boke Dilo natural well) in the District (Oromia Regional planning and Economic Development Bureau, 2000). It is large volcano, usually circular depression formed by collapse of the summit or flanks of a volcano into underlying chambers evacuated by very large explosive eruptions or the effusion of large volumes of lava flows (VHP WWW Team, 2000).

In areas disturbed by volcano, vegetations are formed through succession (Burke, 1964; Clarkson, 1990). The area is covered by vegetations of most lowland species with water body at the lower base of the salt house. The direct economic and social importance of the salt house, and an indirect ecological benefit through eco-tourism, made the area an interesting site and means of survival for thousands of people. Even though, the studies undertaken on vegetation, forage and invasive species further have got paramount significance, information on woody plant species diversity and socio-economic importance of Boke salt house is still lacking. Therefore, this study was mainly undertaken to document woody plant species diversity in the volcanic Crater Lake and give baseline data on socio-economic importance of the area.

2 OBJECTIVES OF THE STUDY

2.1 General objective

The general objective of the study was to assess the diversity of woody plant species, the chemical and physical properties of soil and the socio-economic importance of Boke salt house.

2.2 specific objectives

1. To record the diversity of woody plant species and their regeneration status based on counting of seedlings and saplings in Boke salt house.
2. To evaluate the variation of woody plant species diversity along the four geographical aspects of the salt house
3. To investigate plant communities of the study area.
4. To study some soil parameters and evaluate their variation trends along altitudinal gradient vis-a-vis woody plant species diversity
5. To provide baseline information on the socio-economic importance of the salt house for the livelihoods of the local people and recommend proper management and conservation measures for sustainable resource uses.

2.3 Research Questions

1. What are the woody plant species diversity in the study area?
2. What are the plant communities occurring in the salt house ?
3. Is there a clear pattern in woody plant species distribution along altitudinal gradient in the study area in relation to soil physical and chemical properties?
4. What is the socio-economic and cultural importance of the salt house for the local people?

3 LITERATURE REVIEW

3.1 Drylands

Dryland ecosystems cover more than one third of the earth's land surface and are home to about one-forth of the earth's population (IUCN, 1999). Above 50% of the land surface of the developing countries is situated in the arid and semi-arid zones and nearly 30-40% of the global land surface is arid and semi arid (Kigomo and Chikamai, 2003). Drylands occur in all continents and are estimated to cover approximately 61 million square kilometers or more than 47% of the earth's land surface, excluding cold climate regions (UNEP, 1992; IUCN, 1999).

Drylands are defined as areas with the ratio of annual precipitation to potential evapotranspiration falling between 0.05 - 0.65. Drylands cover hyper arid, semi-arid, and dry sub humid ecosystems having low ratio of annual precipitation to potential evapotranspiration (IUCN, 1999). These ecosystems cover areas with unpredictable precipitation in time and space with low total amounts. On top of these, the more arid areas have high diurnal temperature variability. Drylands have highly seasonal rainfall regimes with significant inter-annual variability and mean annual precipitation value, which vary from about 800mm in summer rainfall areas to 250mm in winter regimes (IUCN, 1999).

Arid areas are characterized by mean annual rainfall of between 100-800mm, mean annual temperature of 21-27.5° C and mean annual potential evapotranspiration of between 1700 -2600mm. The semi-arid zones of Ethiopia have mean annual rainfall of between 300– 800mm, mean annual evapotranspiration of 1600-2100mm and mean annual temperature of between 16-27°C. The dry sub-humid zones of the country are characterized by mean annual temperature of between 16-28° C and mean annual rainfall ranging between 700-1000mm. Areas of the Oromia Region falling in this dry sub-humid zone include some parts of Bale, Arsi and Wollega (EPA, 1997).

Due to varied topography, the Rift Valley and the surrounding lowlands have given Ethiopia a wide spectrum of habitats and a large number of endemic plant and animal species (EFAP, 1994; Zerihun Woldu, 1999). According to FAO (1996) classification, Ethiopia is one of the thirty-six dryland developing countries in the world. The drylands, which includes the arid, semi-arid and dry sub-humid areas account for about 75 % of the total landmass of the country, and 46% of the total arable land (Tamrie Hawando, 2000).

The biggest challenge in the drylands of Ethiopia is environmental degradation aggravated by poverty, which in turn accelerates the environmental degradation process itself. Earlier estimates indicated that 1.5- 2.0 billion tons of soils is lost annually because of erosion. The annual rate of deforestation in Ethiopia ranges from 100,000 to 200,000 hectares (FAO, 1988). It has been accelerating in recent years for different subsistence and local economic activities, like agriculture, fuel wood and incidence of uncontrolled forest fires.

Borana zone is one of arid and semi-arid dryland area in Ethiopia (Oba *et al*., 2000). The Borana plateau extends approximately 95,000 km^2, is slightly undulating and ranges in altitude from 1000 to 1500 m, with peaks up to 2000m; the area has a bimodal rainfall regime, with annual rainfall ranging on average from 400mm in the south to 600mm in the north and droughts are common once every 5-10 years. Moreover, the soils of the region is mainly composed of 53% sand, 30% clay and 17% silt (Coppock, 1994).

3.2 Woody plant species diversity

Plant diversity is heterogeneously distributed across the earth (Gaston, 2000; Tuomisto *et al*., 2003). Ultimately, understanding the variation in plant diversity patterns at different scales is an important topic of concern both for ecological explanations and for effective conservation design. Patterns of plant species diversity have often been noted for prioritizing conservation activities because they reflect the underlying ecological processes that are important for management (Smitinand, 1995; Lovett *et al*., 2000).

Various scientists have described the vegetation type of Ethiopia. For instance, White (1983) classified the vegetation of Africa and Madagascar in to 20 phytochoria. Of these, four occur in Ethiopia. These are: Sudanian regional center of endemism, Somalia-Massai Regional Center of Endemism, Afromontane Regional Center of Endemism and Afroalpine Regional Center of Endemism. The vegetation of the study area falls in the Somalia-Massai Regional Center of Endemism, which is characterized by having a flora dominated by Acacia (usually called *Acacia-Commiphora*) woodland. According to Ensermu Kelbessa ***et al***. (1992), *Acacia-Commiphora* woodland is found mainly between the altitudes of 500 m and 1900 m, with average annual temperatures of 18^0 C to 27^o C and an annual rainfall between 410mm and 820mm, which directly fits with the environmental characteristic of the Borana lowland, where this study is conducted.

The nine broad vegetation types recognized for Ethiopia are (1) Afroalpine and sub-afroalpine vegetation, (2) Dry Evergreen Montane Vegetation, (3) Moist Evergreen Montane Forest, (4) Wetlands, (5) Evergreen Scrub, (6) *Combretum-Terminalia* (Broad-leaved deciduous) woodland, (7) *Acacia-Commiphora* woodland, (8) Lowland Dry Forest, and (9) Lowland Semi-Desert and Desert areas (Pichi-Sermolli, 1957; Zerihun Woldu, 1999). Of which, *Combretum-Terminalia* and *Acacia-Commiphora* woodlands characterize the lowlands of Borana (Gemedo Dalle *et al.*, 2005).

3.3 Species diversity, evenness and similarity

The description of plant community involves the analyses of species diversity, evenness and similarity (Whittaker, 1975). Diversity and equitability of species in a given plant community is used to interpret the relative variations between and within the community and help to explain the underlying reasons for such a difference. The diversity and evenness are often calculated using Shannon diversity index. The Shannon diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5 **(**Magurran, 1988; Kent and Coker, 1992).

Since heterogeneity/diversity contains two separate ideas-such as species richness and evenness, then they tried to measure the evenness component separately. Whittaker

(1975), on the other hand expressed this concept as equitability. Its base is on the fact that most communities of plant and animals contain a few dominant species and many species that are relatively uncommon. Evenness measure attempts to quantify this unique representation against a hypothetical community in which all species are equally common such that all species have equal abundances in the community, and hence, evenness is maximal.

One of the simplest means of analyzing floristic vegetation data is to look at the degree of association between species and the level of similarity between quadrats or samples. Similarity indices measure the degree to which the species composition of quadrats or sample matches is alike. Its coefficient values ranges from 0 (complete dissimilarity to 1 (total similarity) (Kent and Coker, 1992).

3.4 Plant population structure

Population structure is defined as the distribution of individuals of each species in arbitrarily diameter-height size classes to provide the over all regeneration profile of the study species (Peters, 1996; Simon Shibru and Girma Balacha, 2004). Information on population structure of a tree species indicates the history of the past disturbance to that species and the environment and hence, used to forcast the future trend of the population of that particular species (Peters, 1996).

Population structure is extremely useful tool for orienting management activities and, perhaps most important for assessing both the potential of a given resources and the impact of resource extraction (Peters, 1996). Analyses of population structure has then some thing to do with the future management of the key and untapped resources of the dryland of Ethiopia. Information on populaton structure help to respect the healthy regeneration of the species under utilization (Kindeya G/Hiwot, 2003).

The population structure of a given species can be roughly grouped in to three types. Type I, II and III. Type I, shows the case in which diameter/height size class distribution of the species displays a greater number of smaller trees than big trees and almost constant reduction in number from one size class to the next (Peters, 1996; Simon Shibru and Girma Balcha, 2004; Abeje Eshete *et al.*, 2005). Such a pattern skewed to a reversed J-shape distribution in a forest are considered to have a favorable status of regeneration and recruitment and hence, stable and healthy population (Kindeya G/Hiwot, 2003). Type II, is characteristic of species that show discontinuous, irregular and/or periodic recruitment. In this type, the frequency exhibited, for instance, in diameter/height size class causes discontinuities in the structure of the population as the established seedlings and saplings grow in to larger size classes. Type III, reflects a species whose regeneration is severely limited for some reasons (Peters, 19996). Hence, knowledge about the category in which our study species fall is important issue before planning to utilize the resources.

3.5 Frequency and important value index

Frequency is defined as the proportion of sample quadrates in which individuals of a species are recorded. Frequency measures reveal the uniformity of the distribution of the species in the study area, which again tell about the habitat preference of the species (Silvertown and Doust, 1993 cited in Abeje Eshete *et al.*, 2005). In other words, it gives an approximate indication of the homogeneity of the stand under consideration (Kent and Coker, 1992).

The important value index (IVI) permits a comparison of species in a given forest type and depict the sociological structure of a population in its totality in the community. It often reflects the extent of the dominance, occurrence and abundance of a given species in relation to other associated species in an area (Kent and Coker, 1992; Kindeya G/Hiwot, 2003; Simon Shibru and Girma Balcha, 2004). It is also important to compare the ecological significance of a given species. Therefore, it is a good index for summarizing vegetation characteristics and ranking species for management and conservation practices.

3.6 Environmental factors and vegetation

The complex interaction of environmental variables along spatial gradients will form a complex environmental gradient that characterizes the nature and distribution of communities along landscapes (Begon *et al*., 1996). Ethiopia has very diverse climatic conditions varying from hot and dry desert in the lowland areas, part of which are as deep as 116 m below sea level, to cold and humid alpine habitats in highlands, which rises to over 4000 m a.s.l. Such diverse climatic conditions and habitats partly contributed to the presence of high species diversity in plants and animals, making Ethiopia one of the top 20 richest countries of the world in biodiversity (WCMC, 1992). Forest is one of the diverse ecosystems in Ethiopia, varying from broad-leaved deciduous woodland in the lowlands to montane rainforest in the high lands (Tadesse Woldemariam, 2003).

As described in Zerihun Woldu (1999), the vegetation of Ethiopia is extremely complex. The complexity arises from the great variations in altitude implying equally great spatial differences in moisture regimes as well as temperatures within very short horizontal distances. The potential distribution of a community can be predicted based on annual rainfall and elevation data. At relatively low temperature and high rainfall distribution, evergreen shrubs, herbs and grasses are dominant, while deciduous and spiny shrubs are dominant and grasses are less abundant at low temperature and rainfall distribution (Getachew Tadesse, 2005).

Altitude affects temperature, moisture, radiation and atmospheric pressure and thereby influences the growth and development of plants and the distribution of vegetation. Altitude is one of the most important environmental factors that determine the type of plant community (Whittaker, 1967; Smith and Huston, 1989). Moreover, altitudinal factors determining the nature of soil and the prevailing moisture and temperature conditions have a very significant effect on vegetation. According to Zerihun Woldu *et al*., (1989), the most important factor that orders the tree-shrub layer in to respective vegetation type is altitude for it is positively correlated with other environmental factors like organic matter and negatively correlated with pH, clay and calcium.

The change of temperature gives rise to altitudinal zonation of vegetation. In addition mountain regions usually have more rainfall, higher relative humidity and greater wind speeds. Mountain region have mainly steep slopes and rocky soils. Therefore, altitude is an important factor, which affects temperature, radiation, moisture and atmospheric pressure, and influences the growth and development of plants and vegetation distribution and composition (Toomey, 1947; Oasting, 1956). In general from the above discussion it is possible to conclude that altitude affects climate and its effect on temperature varies considerably according to the prevailing conditions specially the aspect and steepness of the slope. Altitude, exposure to wind and to a lesser extent disturbance was found to be the major determinant of vegetation variation where as parent rock and inclination were less important (Fernandez- Palacious and de Nicolas, 1995).

Topographic features act on local vegetation largely through climate or edaphic features. Polunin (1960), Riley and Young (1966) and Avila (1992) agree on the fact that strong topographical relief tend to produce more marked local climate. Maintaining optimal biomass at a given level may be problematic because plant productivity is sustained by the climate, which causes high inter annual variability in forage production in arid rangelands. This might mean that herbaceous species richness for any site fluctuates from season to season and from year to year, with years of exceptional rainfall producing greater herbaceous species richness than in dry years. Altogether climatic variation become more and more extreme and rapid with increasing altitude, such local climate would not take place if it were not for the topography (Hedberg, 1964; Daniel Gemechu, 1986).

In general, in Borana lowlands, at higher altitudes from 700 to 1100m a.s.l., dense woodland and bushland thickets of predominantly Acacia species occurred. At lower altitudes from 200 to 700m a.s.l., savanna and xerophilic vegetation types predominated (Lemenih *et al*., 2003). Moreover, the soil physical and chemical properties are greatly influenced by the topography, the rate of decomposition of the litter fall, the inherent quality of the litter, environmental conditions, and the available decomposer community (Swift *et al*., 1979; cited in Alicia and Roberto, 2003).

Different studies have revealed that although competition influences the growth and distribution of the plants, soil characteristics are of high importance in distribution of salt lands plants. In areas of saline soils, there is low plant diversity. Because, of that plants can absorb their necessary ions only when there is a constant ionic ratio among existing ions in the soil, otherwise roots will not be able to absorb soil ions and this causes a disturbance in plants growth and distribution. Low diversity of plants in such saline soils is an evidence for this material. In addition, high soil salinity and unsuitable structure are other reasons that make difficulty in the establishment and regeneration of saline land plants. Only high adaptability plants to salinity can grow in the mentioned conditions (Jafari, *et al,* 2003).

3.7 Community classification, indicator species and Ordination Analysis

Cluster analysis is the general term applied to many techniques used to build classification. The concept of classification in ecological works aims at grouping individual stands or species in to homogenous categories based on their similarity with one another. The stands those are similar with one another form one class, which is separated from other such classes that also consists of similar stands (Digdy and Kempton, 1996). The properties common to a group of similar stands are then abstracted to serve as a description of that class. Therefore, the abstracted class properties may be compared to the average or mean of a set of various values when combined with a measure of range. For practical and scientific validity, the abstracted class features should adequately describe the individual members of each class (Mueller-Dombosis and Ellenberg, 1974; Digdy and Kempton 1996). This technique is primarily qualitative. However, since this makes it too broad or too narrow for practical purpose, it is necessary to consider the quantity of more prominent species. This means that it provides a useful summary when complemented by an ordination (Digby and Kempton, 1996).

Dufrene and Legendre (1997) define indicator species as the most characteristic species of each group, found mostly in a single group of the typology, and present in the majority of the sites belonging to that group. The indicator value ranges from 0 (no indication) to

100 (Perfect indication) (Tadesse Woldemariam, 2003). The novelty of this approach is that the indicator value of species is based only on within species abundance and frequency comparisons, without any comparison among species. The analysis procedure provided in PC-ORD software (McCune & Mefford, 1999) was used to perform the indicator species analysis. The statistical significance of the indicator values was tested using the Monte Carlo permutation techniques.

Ordination is a technique used to order a group of objects along a given gradients (Kent and Coker, 1992). The usual objective of ordination in ecological work is to generate hypothesis about the relationship between the species composition at a site and the underlying environmental factors (Digby and Kempton, 1996). Ordination summarizes the patterns of species and samples along environmental variables by collapsing the data in to a single graph so that similar species or samples are close together. Digby and Kempton (1996) provided a detail of Direct Gradient Analysis, Detrended correspondence analysis (DCA), Principal components analysis (PCA), Canonical correspondence Analysis (CCA), principal co ordinate's analysis and many other different ordination approaches.

3.8 Formation and ecology of volcanic Crater Lake

To examine a volcano, one must first examine the makeup of the earth itself. The earth is made up of several layers. The thin, outermost layer is called the crust. This is the area that we walk on. The innermost piece of the earth is called the core, and it contains boiling gases, magma and iron. The middle of the earth, in between the outer and inner parts, is called the mantle. This part of the earth contains mostly rock. When rock melts in the mantle of the earth, it rises toward the surface for release. When this rock reaches the surface and erupts from the earth, along with pent-up gases, this is an eruption. The surface and slope of the volcano will swell with gas and lava before this event. The fountain of liquid rock that comes from an eruption will form a "spatter cone" around the areas that the earth is releasing lava from, which is known as volcano (Kathie, 1997; VHP WWW Team, 2000; Genevieve, (2002)).

The chemistry of volcanic lakes can vary between pure, oxygen rich water and water that may be highly saline, acidic or alkaline, and gas rich. The latter can consist of oxygen and sulfur dioxide, or conversely, carbon dioxide (McDonough, 2001).

Most of the studies in volcanic Crater Lake mainly focused on the chemistry of the lake, living things in the lake and mineral contents of the lake, where as the study on vegetation description around the lake after volcanic disturbance are very rare in most countries (Burke, 1964). Vegetations, which exist in volcanic area, are the result of succession. The resource-ratio hypothesis of succession can be used to explain the general pattern of the volcanic successions (Bates and Jackson, 1987).

Moreover, heterogeneity of substrate enables many taxonomic plant groups to establish more or less concurrently. Partial disturbance successions are not easily categorized and may contain elements of several successional models. Records of the vegetation before, shortly afterwards and at intervals following the eruption offer the unique chance to study plant establishment and successions on a new volcanic surface (Clarkson, 1990). With the fact that the study area is formed by volcano before centuries, the vegetation found in the area comes up through succession.

3.9 Socio-economic importance

The economic importance of rangelands worldwide is extremely variable according to the socio-economic system in which they are embedded. The importance ranges from being suitable for low-intensity stock rearing and hunting in Australia and America, low-fertility savanna of interest only to wealthy ranchers in Brazil and areas which are essential to the subsistence of pastoralists, foragers and farmers dependent on rain fed crops, who usually constitute the most vulnerable groups in the ecozone, in Africa and Asia (Oba, 1998; Mulgeta Lemenih ***et al***, 2003; Alemayehu Mengistu, 2004). It is estimated that these ecosystems cover one third of the earth total land surface and about half of this area is in economically productive use as range or agricultural land (CCD Secretariat, 1997).

For instance, Ethiopian Rift Valley, which is part of the famous East African Rift Valley, comprises numerous hot springs, beautiful lakes and a variety of wildlife. The Great Rift Valley's passage through Ethiopia is marked by a chain of seven lakes. Each of the seven lakes has its own special life and character and provides ideal habitats for the exuberant variety of flora and fauna that make the region a beautiful and exotic destination for tourists (Hurni *et al.*, 1987; Abdurahman Kubssa, 1995; Michael and Catherine, 2001). Most of the lakes are suitable and safe for swimming and other water sports. Besides, Lake Abiata and Shalla are ideal places for bird watchers. Most of the Rift valley lakes are not fully exploited for tourist purposes except Lake Langano where tourist class hotels are built. This indicated that even though areas are suitable for the development of tourist industry, facilities play key role to attract tourists and improve the income generation from the sector.

Although the major socio-economic activities in Borana rangeland is livestock husbandry (Coppock, 1994; Alemayehu Mengistu, 2003; Ayana Angassa and Fekadu Beyene, 2003), there are different natural features as well as cultural places in the semi-arid drylands of Borana, which directly or indirectly contributes to improve the livelihood of the community and add the value of drylands. Boke salt house is one of such natural features which is used as means of survival for thousands of people in the zone. However, the information on this important natural feature is lacking to utilize the resources on sustainable base. It was pointed out by Gemedo Dalle *et al.,* (2005) that ecological and socio-economic information of a given area is highly important and needed to support the concerned body for sustainable use of resources and management decisions. It is also true that exploration of natural ecosystems will help to utilize its biological resources and socio-economic importance sustainably.

4 DESCRIPTION OF THE STUDY AREA

4.1 Location

Dire District is located in the southern part of Borana zone, Oromia Regional State (Fig. 1). It is bordered by Kenya to the south, Somali Regional state to the East, Teltele District to the West, and Yabello and Arero District to the North. Boke salt house is a volcanic crater Lake in the District and found at a distance of about 665 km south of Addis Ababa, 42 km north of Mega (the capital town of the District) and 17 km north-eastern of the main road Addis - Moyale,

The salt house has an inverted frustum of cone shape (Fig. 2) with Lake at the bottom base. Geographically, it is located at 4.08^0 N latitude and 37.42^0 E longitudes. Its altitude ranges from 1124 m (at the bottom, Crater Lake area) to 1512 m at the top. According to the Soda village administration office, a 2004/05 population census has recorded 2021 people (1122 male and 899 female) living in the village which is located at the southern top plain of the salt house.

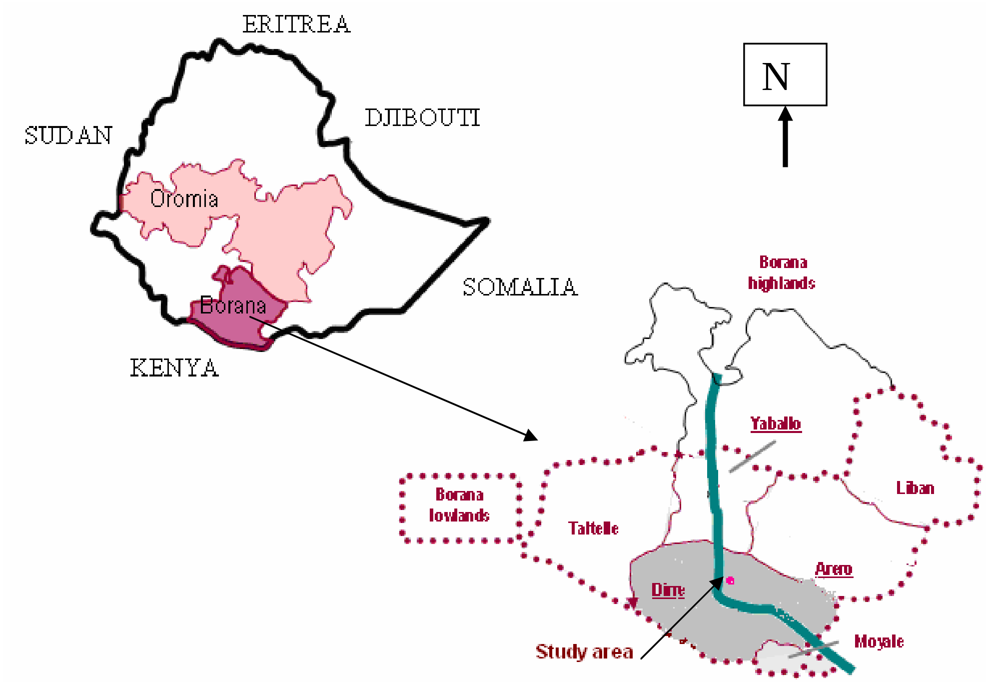

Figure 1: Map of the study area

Given its shape (Fig. 3), the total area of the Boke salt house was calculated by using the formula for area for frustum of cone (Fig. 2) – see below.

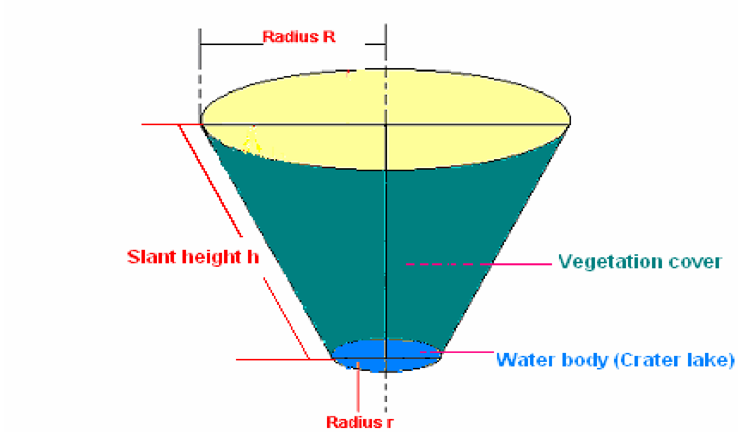

Figure 2: The map of inverted frustum of cone for estimating the total surface area of the study area

Figure 3: Boke salt house from the top to the bottom view

4.2 Topography and soil

In southern Ethiopia, diverse geology creates dissimilar landscapes. The Borana plateau occupies approximately 95, 000 km^2, is slightly undulating and ranges in elevation from 1000–1500 m with peaks of up to 2000 m above sea level (Coppock, 1994). Dire is one of the Districts in Borana zone. Physiographically, it is mainly characterized by lowlands and plateaus. Altitudinally, the district stretches between 750 and 1670m a.s.l with 70% kolla and 30% Woinadega agro-climatic zones. The major soil types found in the district are Chromic and Orthic Luvisols (45%), Calcaric and Eutric Regosols (15.25%), and Lithosols together with Humic, Mollic and Vertic Andosols (39.75%) (Oromia Regional Planning and Economic Development Bureau, 2000).

4.3 Climate

The climate of southern Ethiopia in general and that of Borana in particular is arid and semi-arid. Rainfall is variable and bimodal, with the long rainy season occurring during March– May and the short during October and November (Coppock, 1994). Based on 20 (1984-2004) years meteorological data with the exception of 1992, in which there was no data record both for temperature and rainfall, the mean monthly rainfall was 47.1mm with minimum in August (4.72mm) and maximum in April (148.1mm). The mean annual rainfall in the study area was 532.2mm with mean minimum in 1984 (127mm) and maximum in 1997 (894mm). There is slight variation in mean temperature throughout the year, with the hottest months in January to March (maximum 26.9^{0}C) and the coldest during June to August (minimum 12^{0}C). The mean monthly minimum and maximum temperature of the area was 16.2^{0}C in July and 20.8^{0}C in January respectively. The mean annual temperature was 18.9^{0}C with mean minimum in 1984 (17.8^{0}C) and maximum in 1993 (20.9^{0}C).

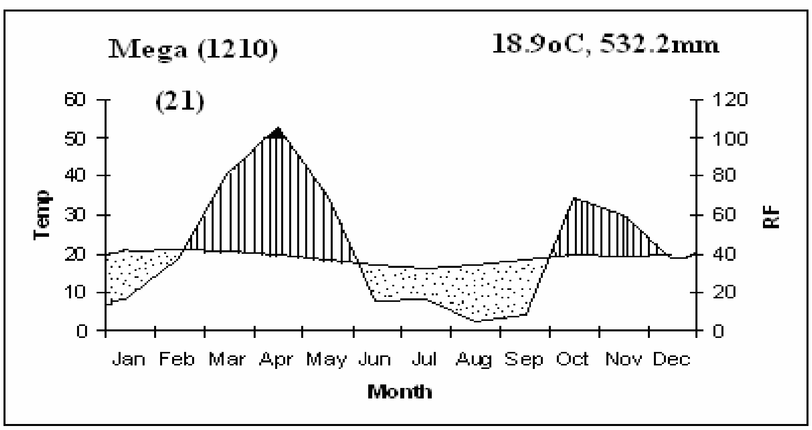

Figure 4: Climatic diagram of Dire District (Mega station) of 21 years (1984-2004)

4.4 Materials and methods

4.4.1 Reconnaissance survey of the area

Reconnaissance survey was conducted in August 2005 to collect visual information on the study area in relation to its vegetation and topography. Furthermore, during this period, (1) some baseline information was collected, (2) a preliminary notes on the distribution of woody plant species was collected and (3) the direction and number of transects lines were determined.

4.4.2 Geometric or physical features of Boke salt house

In order to estimate the total surface area of the salt house, the top and bottom circular plain circumference were measured using a 25 m long measuring tape. The radius was computed from the circumference. The horizontal distance from the top to the bottom of the salt house, i.e., its slant height was measured by using GPS (Garmin-72).
The total surface area (TSA) of Boke salt house was computed by using the formula for the area for frustum of cone as follows.

$$\mathbf{TSA = \Pi\ (R + r)\ \sqrt{(R\text{-}r)^2 + h^2} + \Pi R^2 + \Pi r^2}$$

Where: **r-**radius of the lower circular base

R-radius of the upper circular plain

h-slant height (from the top to the bottom of the lake).

4.4.3 Vegetation data

Vegetation data were collected in October and December along the four transects lines (East, West, South and North) starting from the bottom of Boke salt house. Along each transect line; a 20 m x 20 m (400m^2) quadrat at a distance of 100m from each other was laid. Moreover, samplings of thirty nine plots of the same dimension around Boke salt house were considered to make comparison of woody plant species composition with that of the salt house and to identify plant community types of the study area.

Within each quadrat, woody plant species were counted at individual level and taxonomically identified, and their diameter at breast height (DBH), and height were recorded. Sunto clinometer and calibrated bamboo stick, and calliper were used to measure tree height and DBH, respectively. Moreover, visual estimates of percent cover for each woody plant were recorded within the $400m^2$ quadrat (Muller-Dombois and Ellenberg, 1974). That is, percentage cover was estimated as a vertical projection onto the ground of all above ground parts of the individual plant species expressed as percentage of the plot area. Regeneration status of the woody plant species within the sampling quadrat was investigated based on the counts of seedlings. Furthermore, their height and root collar diameter were measured using meter marked stick and calliper, respectively (Abeje Eshete, 2002). Voucher specimens of woody plant species of the Boke salt house were identified by comparing with already identified specimens in the National Herbarium and referring to various flora books on the plants of Ethiopia and Eritrea. Plant names followed the published flora of Ethiopia (Edwards *et al*., 1995; Hedberg and Edwards, 1989; Edwards *et al*., 2000 and Hedberg *et al*., 2003) and specimens are deposited at The National Herbarium of Ethiopia, Department of Biology, Addis Ababa University.

The following parameters were derived from the vegetation data.

A large number of indices of diversity have been devised, each of which seeks to express the diversity of a sample or quadrate by a single number. Of the various indices, the most frequently used is the simple totaling of species numbers to give species richness (Magurran, 1988). However, of the indices that combine species richness with relative abundance, probably the most widely used is the Shannon Index (H'), which makes the assumption that individuals are randomly sampled from an infinitely large population and also assumes that all the species from a community are included in the sample and calculated according to Kent and Coker (1992). The value of Shannon diversity index usually found to fall between 1.5 and 3.5 and only rarely surpasses 4.5 (Magurran, 1988).

The Shannon diversity index is calculated using the formula:

$$\mathbf{H' = -\sum_{i=1}^{n} pi \ln (pi)}$$

Where: H = Shannon Diversity Index; Σ = Summation symbol; pi = the proportion of individuals or the abundance of i^{th} species expressed as a proportional of total cover in the sample and Ln = natural logarithms

Equitability or evenness index was calculated from the ratio of observed diversity to maximum diversity using the equation.

$$\mathbf{E = H'/ln\ (S) = H'/H_{max}}$$

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Where: E = Evenness; H' = Shannon-Wiener Diversity Index; Hmax = InS; S = total number of species in the sample. The value of evenness index falls between 0 and 1. The higher the value of evenness index, the more even the species is in their distribution within the given area.

Species richness is a count of the number of species in a quadrate, area or community. Species turnover analysis was complemented by calculating the floristic similarities between all pairs of aspects using Sorensen's similarity index (magurran 1988), i.e.,

$$\mathbf{Ss = 2C/\ (A+B)}$$

Where: C= the number of species common to both directions,

A= the number of species present in one of the direction to be compared, and B= the number of species present in the other direction.

Basal area is the cross-sectional area of tree stems at diameter at breast height. Generally it is a measure of dominance where the term "dominance" refers to the degree of coverage of a species as an expression of the space it occupies, and calculated by using the following formula.

$$\mathbf{BA = \Pi d^2/4}$$

Where BA = Basal area in m^2 per hectare, d= diameter at breast height; Π= 3.14

Important Value Index (IVI) of a species was calculated from the sum of relative dominance, relative density and relative frequency as recommended by Kent and Coker (1992). Relative dominance (RD) is the total basal area of a species/ total basal area of all species x 100, relative density (Rd) is the total number of individuals of a species / total number of individuals' x 100, and the relative frequency (RF) is the frequency of species/

sum frequencies of all species x 100. Each of the components of IVI was computed as described below.

$$\text{Relative density} = \frac{Total\ No.\ of\ individual\ species\ A}{Total\ No.\ of\ individuals\ of\ all\ species}\ \text{X } 100$$

$$\text{Relative frequency} = \frac{\text{Re}\,lative\ frequency\ of\ Species\ A}{Frequency\ of\ all\ species}\ \text{X } 100$$

$$\text{Relative dominance} = \frac{Domiance\ of\ species\ A}{Doinance\ of\ all\ Species}\ \text{X } 100$$

4.4.4 Socio-economic data collection methods

The socio-economic data was collected in October and December 2005, and May 2006. Key informants and other household respondents were selected purposively and at random, respectively from the local people. Group discussion was held with key informants by using Participatory Rural Appraisal (PRA) tools. Interviews were conducted with household respondents from different age groups and both sexes following Martin (1995) by using semi-structured questionnaires. The interviews have included individuals who have got direct or indirect benefit from the salt house. Respondents' ages range from 20 – 80 years old. Fifteen individuals (3 females and 12 males) participated on a group discussion for PRA and fifty participants (8 females and 42 males) were interviewed using a semi-structured questionnaire.

4.4.5 Soil sampling

Soil samples from the four corners and the centre of the quadrat at a depth of 0-15cm were collected and mixed up to form a composite soil sample for a quadrat. Soil analyses were carried out at the soil laboratory of the International Livestock Research Institute (ILRI). Seven soil parameters such as Organic matter (OM), total nitrogen ($N_{2)}$, Available phosphorous (P), exchangeable sodium (Na), pH water, electronic conductivity E.C) and moisture contents were considered in the current study. The determination of soil organic matter follows Walkey and Black (1934). Total N was determined following Kjeltec system. Available P was determined by Olsen method (Bray and Kurtz, 1945). Exchangeable Na was determined by Ammonium acetate extraction at pH-7. The pH-H_2O water was determined following Gravimetric method. The E.C was determined in 1:2.5 soils to water ratio and shaking for two hours and then reading taken using conductivity meter. Moisture content was determined through drying the soil samples in an oven at 105^0 cover night (Jackson, 1958).

4.5 Data analysis

A Cluster analysis helps to group together a set of observations (here plots or vegetation samples) based on their attributes or floristic similarities (Kent and Coker, 1992). To this effect, a hierarchical cluster analysis was performed by using PC-ORD for windows version 4.20 (McCune and Mefford, 1999). The identified groups were tested for the hypothesis of no difference between groups using the multi-response permutation procedure (MRPP). Deterended Correspondence Analysis (DCA) were used to analyze the patterns of distribution of woody plant species in relation to environmental gradients like altitude and measured soil properties using CANOCO software. This also helps to analyze the ordination of soil parameters and woody plant species diversity of the study area. Moreover, correlation analyses were implemented by SPSS version 11 (SPSS Statistical Package for Social Sciences, 1996) were used for depicting characteristics of soil parameters in relation to altitudinal gradient. Descriptive statistics was used to analyze socio-economic data.

5 RESULTS AND DISCUSSION

5.1 Physical features of the Boke salt house

The radius of the top circular plain of the salt house was 0.994 km and the bottom base radius was 0.241km. The horizontal distance from the top to the bottom (slant height) was 1.04 km. The total surface area of the salt house was estimated to be 8.264 km^2 (826.4 ha).

5.2 Woody plant species diversity and density

A total of forty five woody plant species belonging to 26 genera in 16 families were recorded (Table 1; Appendix 5) of which twenty four woody plant species belonging to 18 genera in 14 families (Table 1; Appendix 5) were identified from Boke salt house. The most woody plant species rich families of Boke salt house are Fabaceae (2 genera, 5 species), Tiliaceae (1 genus, 4 species) and, Euphorbiaceae and Burseraceae having 2 genera and 3 species each. The two species rich families (Fabaceae and Tiliaceae) have accounted for 37.5% of the total woody plant species diversity in Boke salt house. Shannon diversity index of woody pant species in the salt house was found to be 2.100 while the species evenness value was 0.661. Moreover, Sorensen's similarity index of the forty five woody species between salt house and outside woody plant species was 0.5. This indicates that there is more or less good woody plant species similarity between the Boke salt house and the species found outside the salt house.

Table 1: Number of woody plant families, genera and species found within and around the salt house.

	Inside	Outside	In both
No. of families	14	12	10
No. of genera	18	18	10
No. of species	24	36	15

In general, the total number of woody plant species recorded in Boke salt house was 24 whereas 36 woody plant species were recorded from the surrounding areas of Boke salt house. Out of the total of 16 families recorded in both areas, 62.5% of them are common to them while 25% were exclusive to the salt house and 12.5% to the surrounding outside area (Table 1). In terms of woody plant species richness, 33% (15 species) were common to both areas, whereas 20% (9 species) and 47% (13 species) were specific to the salt house and outside area, respectively. The most probable reason for species richness difference between the two areas is the micro climatic factors like temperature which have direct influence on soil physical and chemical properties.

Table 2: Number of woody plant families, genera and species found within the salt house along different aspects.

	East	**West**	**North**	**South**
No. of families	12	11	11	11
No. of genera	13	13	11	11
No. of species	18	18	18	15

The three aspects (East, West and North) have similar number of species (18) although different in quality whereas the South direction had only 15 species. The East and West facing slopes of the salt house have slightly more genera than the North and South facing ones. This difference in genera composition might be due to the length, intensity and time of sun light received by the geographical aspects.

The total density of woody plant species in the salt house was 2622 ha^{-1}. This value is greater than the mean density of trees and shrubs in the Dida Hara and Web sites of Borana lowland (1274 ha^{-1}) obtained by Dalle *et al*. (2005).

Table 3: Density and basal area of woody plant species along the four aspects of Boke salt house

Characteristics	**East**	**West**	**North**	**South**
Total plots	6	5	6	5
Total density	733	520	553	587
Min density/plot	30	60	41	43
Max density/plot	160	163	169	173
Mean density/plot	122	104	92	117
Density/ha	3054	2600	2304	2935
Basal area (m^2/ha)	2.165	2.357	0.7118	1.4837

The density of woody plant species across the four aspects was variable. The highest density of woody plant species was recorded in the west facing direction (3054 ha^{-1}) followed by the north aspect (southern) (2935 ha^{-1}). On the other hand, the lowest density was observed in the northern slope (2304 ha^{-1}) of the salt house.

The total basal area of woody plant species in the salt house was about 6.72m^2ha^{-1}. The highest value was recorded in the western slope (east aspect) (2.357m^2ha^{-1}) and the lowest in the south aspect (0.7118 m^2ha^{-1}). A possible explanation for this apparent discrepancy may be attributed to human exploitations of woody plant species with a high value of DBH. These are used mainly for firewood, house construction and fencing.

Table 4: Abundance of woody plant species along altitudinal gradient of Boke salt house

Species	Abundance per hectare of woody plant species along altitude in the salt house (pooled quadrat)					
	1134 (1)	**1142 (2)**	**1167 (3)**	**1190 (4)**	**1222 (5)**	**1237 (6)**
Acacia bussei	0	6	0	0	13	6
Acacia oerfota	13	19	13	38	44	13
Acacia Senegal	0	19	81	88	6	6
Acalypha fruticosa	88	344	1619	1663	1281	769
Boscia mossambicensis	0	0	0	0	0	6
Commiphora erythraea	0	0	13	44	69	25
Commiphora terebinthina	19	94	263	50	138	206
Cordia gharaf	63	13	19	19	19	0
Delonix baccal	31	25	81	144	131	144
Euphorbia abyssinica	0	0	0	0	44	0
Ozoroa insignis	0	0	0	6	0	0
Grewia bicolor	313	381	688	525	188	94
Grewia pennicillata	13	6	6	25	19	6
Grewia tembensis	94	81	63	88	56	19
Harmsia sidoides	0	119	38	0	0	0
Hibiscus aponeurus	50	63	31	450	513	200
Lannea rivae	6	13	0	0	0	0
Maerua triphylla	0	0	50	44	31	13
Salvadora persica	0	38	44	106	69	38
Sericocomopsis hilderbrandtii	31	25	0	63	13	0
Solanum somalensis	19	6	25	231	519	456
Steganotaenia araliacea	0	0	0	0	0	6
Sterculia stenocarpa	0	0	0	0	0	13
Suaeda monoica	456	94	0	0	0	0

Table 5: Mean soil analytical result along altitudinal gradient of Boke salt house

Quadrat No.	Mean Altitude	Mean soil parameters analytical result						
		Moisture	Ph-H2O	OM	Total N	Avail P	Exch.Na	E.C
1	1134	1.69	7.78	2.25	0.12	23.14	0.53	0.44
2	1142	1.71	7.56	2.10	0.12	25.10	0.40	0.24
3	1167	1.97	7.47	3.15	0.18	38.82	0.21	0.25
4	1190	2.28	7.44	3.36	0.19	42.24	0.18	0.23
5	1222	2.43	7.41	3.77	0.20	50.50	0.20	0.24
6	1237	2.09	7.32	3.13	0.18	43.61	0.20	0.24

As altitude increases, the density of woody plant species such as *Suaeda monoica, lannea rivae* and *Grewia tembensis* decreases whereas that of *Solanum somalensis* and *Hibiscus aponeurus* increases. Noteworthy is a tendency of soil to become more saline at lower altitudes than higher ones (Table 5). For example, the higher mean value of exchangeable sodium and electrical conductivity at the lower altitude. The latter also has less value of organic matter, moisture content, total nitrogen and available phosphorus (Table 5) than higher altitude. It is to be noted that woody plant species were found to have high density at altitude between 1167 m and 1222 m may attributed to the high values of OM at the same altitude range (Table 4) in Boke salt house.

Table 6: Sorensen's similarity coefficient in woody plant species diversity between the four aspects in Boke salt house

Geographic direction	East	West	North	South
East	-	0.83	0.83	0.79
West		-	0.83	0.84
North			-	0.79
South				-

Sorensen's similarity coefficient has revealed that the similarities of woody plant species diversity between aspects were not significantly different ($p > 0.05$) although there are numerical differences (Table 6).

5.3 Abundance of woody plant species and pooled quadrat of Boke salt house

Sampling quadrats occurring at the same altitudinal range regardless of the aspect were pooled together to depict patterns of species abundance along altitudinal gradient (Fig. 5; Table 4).

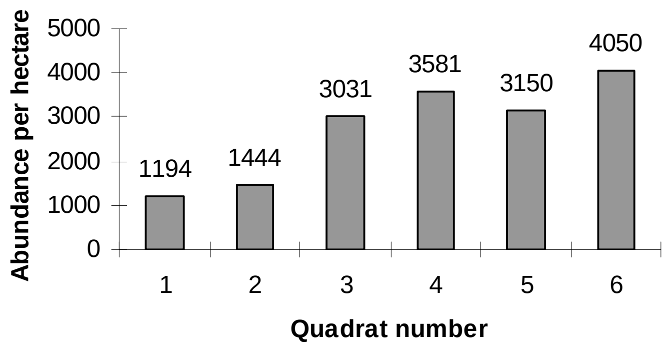

Figure 5: Density of woody plant species per hectare when pooled quadrats are considered

The altitudinal ranges for the pooled quadrats are 1132-1135m, 1138-1148m, 1161-1177m, 1181-1213m, 1281-1246m and >1246m a.s.l for the pooled quadrats 1, 2, 3, 4, 5 and 6, respectively. Generally, the abundance of woody plant species increases with an increasing altitude, i.e., from quadrat 1 to 6 although are notable interspecific variations (Fig 5). This general trend may be due to changing environmental parameters, for example, decreased salinity and increased OM (Table 5).

The woody plant species density per hectare was highest in quadrat 6 (at an altitude of >1246m a.s.l). In quadrat 4 the numerical value of density of woody plant species was high due to the highest number of *Acalypha fruticosa* recorded in the quadrat than in quadrat 5. From this result one can deduce that as altitude increases on the slope of the Crater Lake, density (abundance) of woody plant species also increases. This is also related with soil properties in which the value of organic matter, moisture content, total nitrogen and available phosphorus significantly increases ($p<0.01$) with altitude.

5.5 Importance Value Index for woody plant species of Boke salt house

The values of Importance Value Index (IVI) for the woody plant species of Boke salt house was given in Appendix 2. It was found out that *Acalypha fruticosa* (IVI = 48.5), *Delonix baccal* (IVI = 37.3), *Commiphora erythraea* (IVI = 28.7) and *Grewia bicolor* (IVI = 26) were the woody plant species of the study area with the highest IVI. Furthermore, *Delonix baccal*, *Commiphora erythraea*, and *Commiphora terebinthina* have the highest relative basal area (Appendix 2). On the other hand, *Acalypha fruticosa* and *Grewia bicolor* were found to have the highest relative density and *Grewia bicolor*, *Acacia mellifera* and *Delonix baccal* have the highest relative frequency in Boke salt house. The current findings agree with what has been reported about these species from Web site of Borana lowland (Dalle *et al.*, 2005). However, the same author has recognized *Commiphora africana* and *Lannea rivae* as the most frequent woody plant species when he considered both Dida Hara and Web of his study sites.

5.3 Population structure of woody plant species at the Boke salt house

Six woody plant species were selected for this study based on preference selection of the local people. These are *Acacia mellifera, Suaeda monoica, Salvadora persica, Delonix baccal, Commiphora erythraea* and *C. terebinthina*. Except for *A. mellifera*, which has exhibited an inverted J-shape, the population structure of the remaining species has revealed noticeable deviations from the theoretical expectation (Fig. 6). For example, *Suaeda monoica*, *Salvadora persica* and *Delonix baccal* lack mature individuals while *Commiphora erythraea* and *C.terebinthina* have displayed a discontinuity in recruitments of saplings to mature individuals. The absence of mature individuals of *Suaeda monoica* could be due to its extensive uses for the extraction of table salt from the Crater Lake. A large amount of the braches and sometimes whole plants are used for this purpose. With regard to the remaining species with irregular population structure, selective logging may account for the observed findings. It has been asserted that diameter class distribution of plant species could indicated the general trends of a population dynamics and recruitment process of a given species (Feyera Senbeta, 2006). If the current exploitation of *Suaeda monoica* continues unchecked, it will certainly critically endanger its population biology

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sooner or later. Therefore, a sustainable use of this limited resource is essential not only for the normal functioning of biodiversity but also for the basic livelihoods of the local inhabitants and the long standing cultural values attached to the Boke salt house.

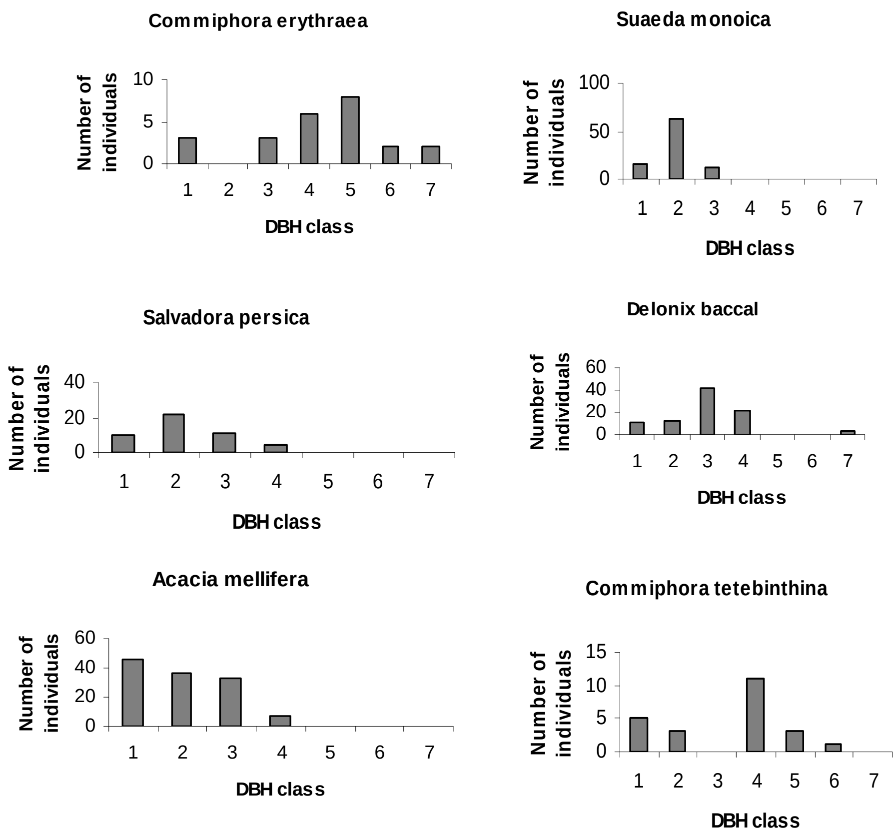

Figure 6*:* Diameter class frequency distribution of selected woody plant species in the Boke salt house**.**

DBH class (cm) 1= 0-4.9; 2= 5-9.9; 3= 10-14.9; 4= 15-19.9; 5=20-24.9; 6= 25-29.9; 7= >30

5.4 Plant Communities at and areas around Boke salt house

Six types of plant communities were identified following a hierarchical cluster analysis (Fig. 7; Table 7). The number of the groups were decided based on MRPP technique which allows no differences in hypothesis (***T*** = **-**26.686, $p<0.001$ and the agreement statistic, **A** = 0.318). Generally, the test statistic, ***T*,** describes the separation of groups and the more negative ***T*** value shows the stronger the separation. On the other hand, the agreement statistic, **A,** describes the within group homogeneity compared to the random expectation and falls between 0 and 1. If the within groups are identical, ***A*** = 1 and if the within groups are heterogeneous, A = 0. In the current study, the three cluster solution (plant community) was considered optimal and the null hypothesis was rejected. That is, the three groups have occupied different regions of species space as revealed by the strong chance correction within the group (***A***) and test statistic (***T***). In a community ecology, ***A*** value are commonly below 0.1 and value greater 0.3 is quite high (McCune and Grace, 2002). Of the six communities identified, three of them (community 1and 3) were found in Boke salt house, whereas the other three (community 2, 4, 5 and 6) were restricted to the area around the salt house. The plants communities are described below.

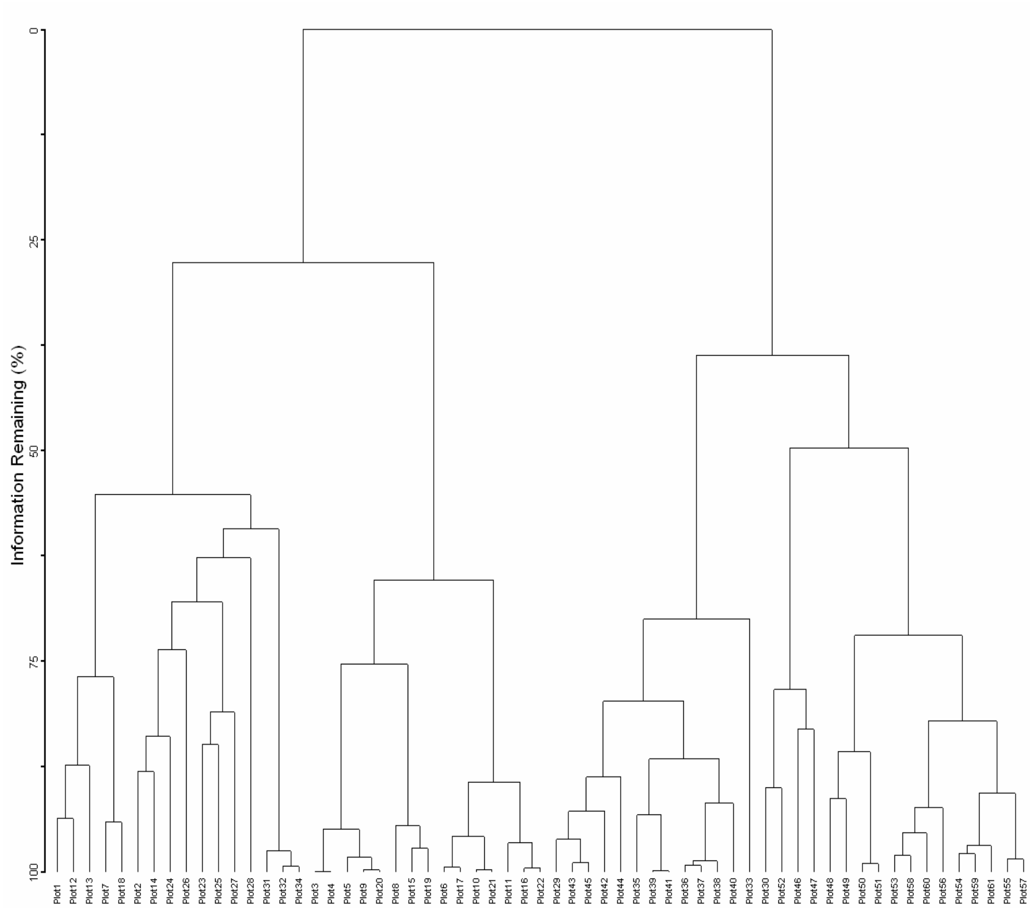

Figure 7: Dendrogram of the cluster analysis result of 45 woody plant species abundance found in 61 plots in the study area**.**

Key: **C1** = quadrat 1, 12, 13, 7, 18; **C2 =** 2**,** 14, 24, 26, 23, 25, 27, 28, 31, 32, 34; **C3** = 3, 4, 5, 9, 20, 8, 15, 19, 6, 17, 16, 22, 10, 21, 11; **C4 =** 29, 43, 45, 42, 44, 35, 39, 41, 36, 37, 38, 40, 33**; C5 =** 30, 52, 46, 47**; C6 =** 48, 49, 50, 51, 53, 58, 60, 56, 54, 59, 61, 55, 57.

The level of grouping was based on 50% information remaining.

Communities are named after two or three indicator species. Indicator species are species with statistical significance values when tested using the Monte Carlo permutation techniques-Table 7.

Table 7: Quantified indicator species of the six plant communities of the study site: Species are listed by group affinity in the ascending order of the probability value. Bold values indicate significant indicator value ($p<0.05$) in each group**.**

Species	**Max group**	**Observed Indicator Value (IV)**	**IV from randomized groups**		**P-value**
			Mean	S. Dev	
Suaeda monoica	**1**	**96.3**	**12.9**	**7.50**	**0.001**
Grewia tembensis	**1**	**47.0**	**17.2**	**7.01**	**0.006**
Cordia gharaf	**1**	**38.3**	**15.5**	**7.70**	**0.017**
Rhus natalensis	**2**	**30.0**	**10.9**	**6.83**	**0.023**
Grewia bicolor	2	30.5	21.3	4.74	0.053
Acacia nioitica	2	23.3	11.3	7.26	0.065
Acacia deroplobium	2	20.0	10.9	6.10	0.082
Maytenus gracilipes	2	20.0	10.1	6.54	0.092
Rhus ruspolii	2	10.0	9.5	5.04	0.299
Pavonia gallaensis	2	10.0	10.3	5.73	0.359
Grewia tenax	2	10.0	10.3	5.73	0.359
Sterculia stenocarpa	2	4.9	11.4	6.47	0.936
Salvadora persica	**3**	**66.7**	**14.6**	**7.19**	**0.001**
Hibiscus aponeurus	**3**	**64.2**	**15.4**	**7.30**	**0.001**
Acalypha fruticosa	**3**	**92.1**	**16.8**	**6.85**	**0.001**
Delonix baccal	**3**	**72.6**	**17.3**	**7.49**	**0.002**
Solanum somalenses	**3**	**58.1**	**16.8**	**7.73**	**0.003**
Maerua triphylla	**3**	**37.8**	**13.7**	**7.67**	**0.018**
Commiphora terebinthina	**3**	**38.8**	**14.6**	**7.94**	**0.017**
Commiphora erythraea	3	22.9	15.8	6.68	0.122
Sericocomopsis hilderbrandtii	3	13.8	11.2	6.65	0.191
Acacia mellifera	3	30.1	24.2	6.77	0.165
Euphorbia abyssinica	3	6.7	9.8	5.38	1.000
Ozoroa insignis	3	6.7	9.6	5.11	1.000
Steganotaenia araliacea	3	6.7	9.9	5.47	1.000
Commiphora habessinica	**4**	**29.1**	**14.3**	**6.96**	**0.046**
Acacia bussi	4	34.8	18.1	8.40	0.051
Commiphora confusa	4	28.7	17.3	6.79	0.069

Acacia Senegal	4	28.5	19.3	7.08	0.090
Commiphora kua	4	17.5	11.2	6.51	0.145
Acacia tortilis	4	14.9	15.4	6.71	0.425
Acacia oerfota	4	12.8	14.0	7.20	0.459
Commiphora schimperi	4	7.4	10.5	6.49	0.713
Euphorbia cuneata	4	7.1	10.1	5.57	0.767
Grewia villosa	**5**	**91.7**	**15.8**	**8.29**	**0.001**
Bosswellia neglecta	**5**	**40.0**	**12.3**	**7.42**	**0.009**
Commiphora africana	**5**	**31.7**	**14.9**	**7.83**	**0.039**
Harmsia sidoides	5	22.4	12.9	7.38	0.108
Ormocarpum trichocarpum	5	15.9	10.3	7.08	0.204
Lannea rivae	5	18.2	16.0	8.18	0.277
Boscia mossambicensis	5	10.8	10.8	6.33	0.418
Acacia seyal	**6**	**55.6**	**15.8**	**6.76**	**0.001**
Dichrostachys cinerea	6	15.4	10.0	6.59	0.263
Balanite aegyptica	6	12.1	11.6	6.64	0.322
Grewia penicillata	6	11.7	14.8	6.70	0.639

1: *Suaeda monoica* community

This community is formed by 5 quadrats and 3 species. All the quadrats were found in the salt house. This community is dominated by *Suaeda monoica*. The common woody plant species of this community are *Cordia gharaf and Grewia tembensis*. It is located at an altitudinal range of 1132-1161 where the soil has a high level of exchangeable Na (0.83) and electrical conductivity (0.35) and ± alkaline pH-H_2O (7.63). This community is saline tolerant and the woody plant species could be considered as halophytes since they occupy areas very close to the salt Lake. It is also to be noted that the woody plant species of *Suaeda monoica* community become rare as one goes farther from the salty Lake strengthening the assertion that they are halophytes. Noteworthy is a complete absence of *suaeda monoica* after 1140 m a.s.l. from the Lake within the salt house. Therefore, the species of this community are under the direct detrimental influences of the aforementioned soil chemistry.

2: *Rhus natalensis* community

This community is composed of 11 quadrats and nine woody plant species. It is dominated by *Rhus natalensis.* The common woody plant species of this community are

Grewia bicolor, Acacia nilotica, Acacia deroplobium, Maytenus gracilipes, Rhus ruspolii, Pavonia gallaensis, Grewia tenax and *Sterculia stenocarpa.* It is the community with richest woody species (35 species) than the others. This community is found adjacent to the salt house.

3: ***Acalypha fruticosa- Hibiscus aponeurus- Salvadora persica*** **community**

This community is composed of 15 quadrats and 13 woody plant species. All the quadrats of this community are found in Boke salt house. It is the second most woody plant species rich (23 species) as compared to the others – Table 8. *Maerua triphylla, Solanum somalenses, Delonix baccal* and *Commiphora terebinthina* are also species with significance indicator value. The common woody plant species are *Delonix baccal, Solanum somalensis, Maerua triphylla, Commiphora terebinthina, Commiphora erythraea, Sericocomopsis hilderbrandtii, Acacia mellifera, Euphorbia abyssinica, Ozoroa insignis* and *Steganotaenia araliacea.*

4: ***Commiphora habessinica*** **community**

This community is dominated by ***Commiphora habessinica.*** It is formed by 13 quadrats and nine woody plant species. The common woody plant species are *Acacia bussi, Commiphora confusa, Acacia Senegal, Commiphora kua, Acacia tortilis, Acacia oerfota, Commiphora schimperi* and *Euphorbia cuneata.* Most of the woody species of this community belongs to the genera commiphora. Therefore the community can be described as commiphora wood land in the Borana drylands.

5: ***Grewia villosa-Bosswellia neglecta-Commiphora africana*** **community**

This community is formed by 4 quadrats and 7 woody plant species. The common woody plant species are *Harmsia sidoides, Ormocarpum trichocarpum, Lannea rivae* and *Boscia mossambicensis.* This community is found outside Boke salt house.

6: ***Acacia seyal*** **community**

This community is formed by 13 quadrats and 4 woody plant species. It is dominated by Acacia seyal. The common woody plant species are *Dichrostachys cinerea, Balanite*

aegyptica and ***Grewia penicillata.*** The community is found in water flood area with fertile soil in the Borana lowlands.

Woldu and Nemomissa (1998) have identified seven plant communities, i.e., ***Tarconanthus camphorates*** woodland, ***Commiphora*** woodland, ***Acacia drepanolobium-Acacia seyal*** woodland, ***Chrysopogon plumulosus*** grassland, ***Barbeya oleoides-Combretum molle*** woodland, ***Clausena anisata-Panicum arundinacea*** and ***Juniperus procera-Clausena anisata*** forest in the central plateau of Borana. On the other hand, Dalle ***et al.,***(2005) has identified eight plant communities: (*Acacia drepanolobium-Pennisetum meziamum, Bidens hildebrandtii- Chrysopogon aucheri, Chrysopogon aucheri-Commiphora africana, Cenchrus ciliaris- Chrysopogon aucheri, Acacia bussei-Pennisetum meziamum, Commiphora erythraea-Sansevieria ehrenbergi, Acacia mellifera-Setaria verticillata* and *Heteropogon contortus-Hildebrandtia obcordata* in the Dida hara and Web sites of Borana lowland.

Of the seven plant communities identified in the central plateau (above), four of them were not found in lowland of Borana (Dalle ***et al.,*** 2005). Of the six communities identified in this study, out of the four communities identified around Boke salt house two of them (commiphora woodland and Acacia seyal communities) were in agreement with Woldu and Nemomissa (1998)., However, out of the two communities identified in Boke salt house, none of these were identified in Borana lowlands. This may suggest that the salt house is an isolated system of its own because of the intricate interactions of local climate and environmental conditions. Generally, it could be considered as an 'open hot-air hole' packed with unique plant communities in the Borana dry lands.

Table 8: Shannon Diversity Index of woody plant species found in the community types

	C1	C2	C3	C4	C5	C6
Shannon diversity (H')	2.023	2.50	1.89	2.43	2.02	2.37
Evenness (E)	0.731	0.702	0.603	0.812	0.714	0.803
Species richness (N)	16	35	23	20	17	19

Analytical presentation of the degree of abundance of the identified plant community types in the study area may give a clue to the degree of anthropogenic impacts apart from the environmental determining factors. In view of this, it was found out that plant community 2, 4 and 6 is limited in abundance owing to unchecked human exploitation. These community are found around human settlements where both anthropogenic and livestock impact are seriously damaging the matured as well as under growths of woody plant species. On the other hand, plant community 3 is relatively more abundant than the other five because of the community is found in the salt house where tree cutting is relatively culturally forbidden and the observed less diversity of woody plant species of outstanding economical importance at a local scale. However, community type 1 which is found adjacent to salty lake in Boke salt house had less density because of the salty nature of the soil (Fig. 9). In general it is to be noted that plant community around the salt house had relatively highest woody plant species diversity than the salt house (Table 8).

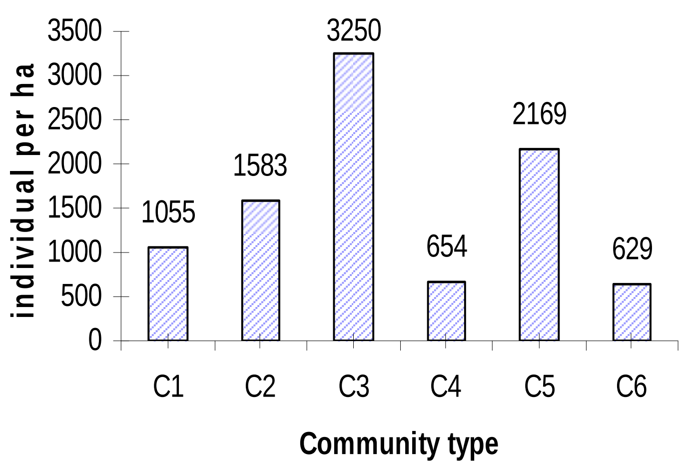

Figure 8: The density of woody plant species for the community types

5.5 Woody plant Species and environmental variables ordination of the salt house using DCA

Ordination is a multi-variate method that expresses the relationships between samples, species and environmental variables in a low-dimensional space using ordination diagrams (McCune and Grace, 2002). Detrended Correspondence analysis (DCA) is an indirect unimodal ordination method. The analysis was done with the computer program CANOCO version 4.5. The distribution of sample plots (quadrats) over complex environmental gradients was explained well by indirect ordination analysis using detrended correspondence analysis (DCA). The DCA is chosen because it met the criteria of (1) ecological interpretability and effective spreading out of the points according to sites (Hill and Gauch, 1980 cited in Feyera Senbeta, 2006). The DCA result tends to strengthen cluster analysis result in figure 7.

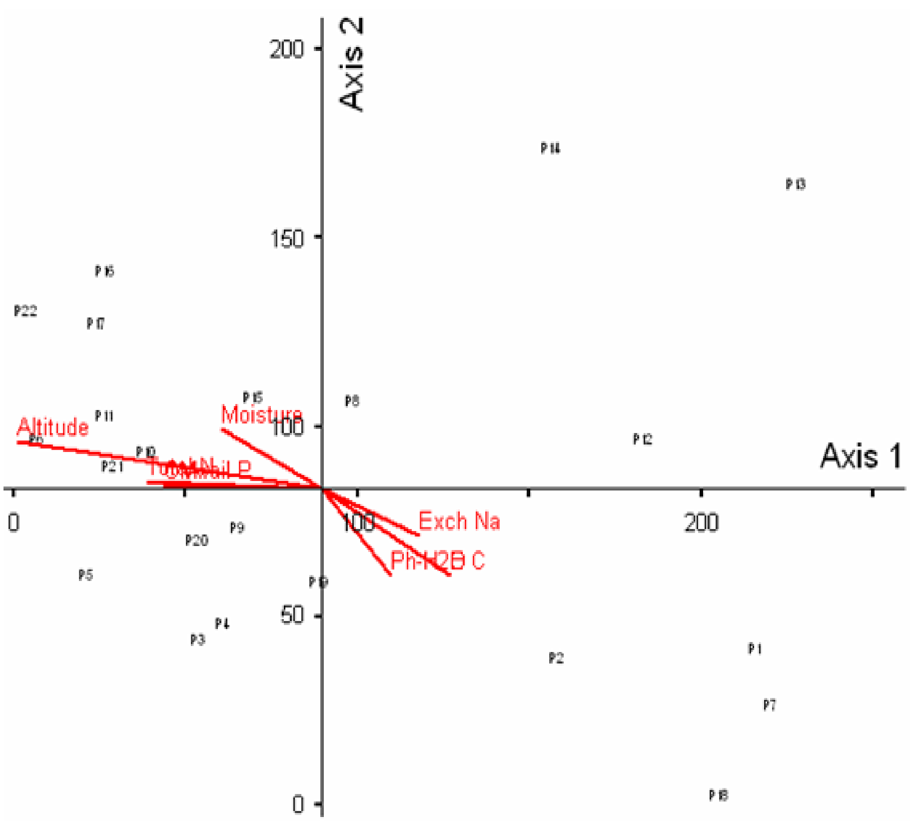

Figure 9: DCA ordination diagram of environmental variables-plots (quadrat)- biplot

From the ordination result it was observed that quadrats, which represents community 1 were positively correlated with exchangeable sodium, electrical conductivity and pH-H_2O whereas negatively correlated with organic matter, available phosphorus, total nitrogen and moisture content, however, quadrats which represent community 3 had positive correlation with organic matter, available phosphorus, total nitrogen and moisture content but negative correlation with exchangeable sodium, electrical conductivity and pH-H_2O (Fig 10). This result is in agreement with the regression analysis result of soil parameters with respect to altitudinal gradients (Fig 12)

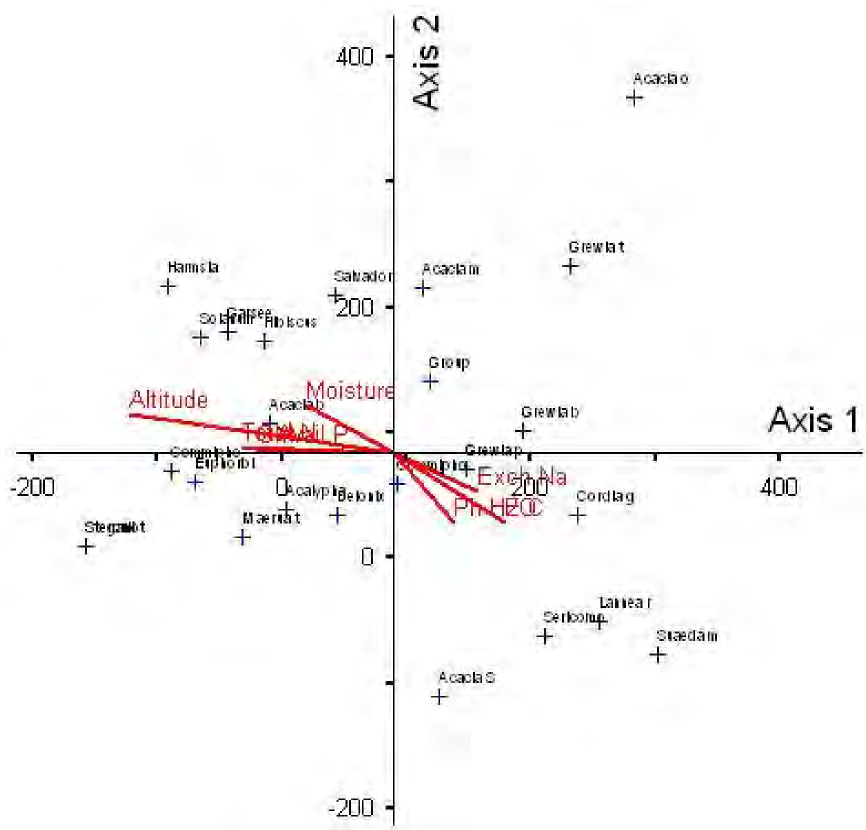

Figure 10: DCA ordination diagram of environmental variables-species- biplot

DCA ordination result of environmental variables-species biplot revealed that woody plant species such as *Suaeda monoica, Acacia senegal, Lannea rivae, Cordia gharaf* and *Sericomopsis hilderbrandtii* were influenced by exchangeable sodium, electrical conductivity and pH-H_2O. These soil parameters especially exchangeable sodium and electrical conductivity are indicators of soil salinity, so that these species are relatively salt tolerant compared to the others. On the other hand woody plant species such as *Harmsia sidoides, Solanum somalenses Hibiscus aponeurus Salvadora persica, Commiphora erythrae* and *Acacia bussei* were influenced by organic matter, available phosphorus, total nitrogen and moisture content than the other soil parameters mentioned above (Fig. 11).

5.6 Some soil characteristics and altitude of the salt house

It has been found that as altitude increases, moisture content, organic matter, total N and available P increase significantly ($p<0.01$) while electrical conductivity, exchangeable sodium and pH-H_2O decrease in the same direction (Table 9; Fig 12). The former depicts a clear linear correlation and the latter relationships of soil variables could be explained through non-linear correlation model (Fig. 12). Moisture content, organic matter, total N and available P have exhibited a significant positive correlation with altitude (R^2 = 375.7, 38.5, 39.5 and 31.9 at $p< 0.01$) respectively – Table 9. On the other hand, exchangeable Na, pH-H_2O, and electrical conductivity (E.C) have shown a negative correlation with altitude. Remarkable is the significant negative correlation between exchangeable Na and altitude (R^2 =30.9; $p<0.01$).

Table 9: Correlation table of seven soil parameters in relation to altitudinal gradient in Boke salt house

Soil parameters Vs Altitude	**Correlation output**					
	DF	SS	MS	F	P*	R^2 (%)
Moisture content	1	11356	11356	11.12	0.003**	35.7
pH-H_2O	1	3034	3034	2.11	0.162ns	-9.5
Organic matter (OM)	1	12241	12241	12.53	0.002**	38.5
Total N	1	12541	12541	13.04	0.002**	39.5
Available P	1	10121	10121	9.35	0.006**	31.9
Exchangeable Na	1	9818	9819	0.95	0.007**	-30.9
Electrical conductivity (E.C)	1	4190	4190	3.04	0.097ns	-13.2

** Strong significance; ns-non significance

5.7 Socio-economic importance of Boke salt house

5.7.1 Cultural value of the Boke salt house

According to the local key informants, the village itself (Boke) was established following the discovery of the salt house. There was no single house around the area before the discovery of the salt house. The nearest temporary settlement was positioned at a distance of more than 40 km from the current Boke salt house. The beginning of salt extraction and subsequent commercialization have attracted few settlements whereby the Borana pastoralists have started the extraction of the salt for mainly a supplementary cattle feed following rituals before entering the Boke Salt house. Therefore, the current settlement is of a recent phenomenon. Further to its economic importance and cultural significance, the salt house has also significantly contributed to environmental conservation and indigenous natural resources management since cutting or uprooting a single plant from this area is a taboo.

According to Wamo Tiye, 78 years old man local key informant who has worked as the community leader of the area for several years~~,~~ the local people living in the village have a strong spiritual bond to the Boke salt house. As a rule, it is completely forbidden to talk about unholy words once in territory of the salt house. Furthermore, it is the norm of this local community to take out shoes before entering into the salt house. Environment 'damaging' materials or hand tools such as sharp cutting metals and fire are strictly forbidden for use in the salt house. Owing to the long standing traditional norms of the Borana, individuals who have entered the salt house for the extraction of the salt do leave their belongings at the gate unattended without fear of losing them.

5.7.2 Economic benefits due to the salt house

The dualistic nature of the economic contributions of the Boke salt house to the local inhabitants is remarkable. Currently, the population of the village is 2021 and all of them drive benefits from this natural resources in one way or another.

5.7.2.1 Eco-tourism

Boke salt house is one of the three known potential tourist attractions in the Dire District of Borana zone (Oromia Regional planning and Economic Development Bureau, 2000) in addition to Gumigayo (established cultural place) and Boke Dilo natural well

Although at its infant stage, eco-tourism is a promising business at the current study area. According to the key informants' group discussion, many foreigners from different corners of the world come to visit the area. Eco-tourism of Boke salt house has in 1992 and since then many tourists have visited the area. At the beginning, i.e., the first 2-3 years, they have visited the area free of charge. But later on, the local communities have hold discussions concerning its potential source of income for community development and decided to charge a foreign tourist 50 ETB Per head for a single entry. Furthermore, a charge amounting to 50 ETB per a vehicle should be paid. Current data have shown that an average of 50,000 ETB per year is usually collected from eco-tourists. Again, owing to their long standing cultural norm, an assigned (by the local community) person is in charge of collecting the fees.

The incomes generated from the eco-tourists are mainly used for various community development activities. As a result, one grade 1-8 school, one clinic and one five rooms building for the Kebele Administrative Office were constructed by the community. Furthermore, one V-Sat Telecommunication is under construction and a number of water wells at different sites for both human and livestock uses were built.

The discovery of the salt: According to the key informants, there was a rich man, named Obbo Boru Sele who has had hundreds of cattle and used to live in the West of the salt house. As is expected two oxen have fought where one was defeated and chased away. It appeared that the loser has accidentally headed down to Boke salt house and found the Lake saturated with salt. This ox has visited this Lake alone on a regular basis and become exceptionally fatty. After this occasion, this ox, a loser, has led the local people to discover their fortune.

The owner, Obbo Boru Sele was perplexed by this exception and resorted to an investigation to solve the puzzle. He has decided to follow this ox without interference, and noted that the ox went to the Lake and have started to drink. Upon tasting the Lake water, Obbo Boru has found out that it is highly salty. Following his brief yet elegant experiment, he has informed his neighbors to use that Lake for cattle fattening purposes. The direction through which the ox went to the lake is known by the name “Bu’a sangaa Boruu Seelee” which means, the route of Boru Sele’s ox.

Since the route through which the ox went down to the Lake was difficult for cattle and even for people at a time, the local community made another route from the eastern direction, through which females locally called “Galtama” meaning females strong as male, went down to collect the salt. The route is still known by the name “Afan Galtama”. According to their response the four aspects have their own locally assigned names (Bu’a sangaa Boruu Seelee in the western, Afaan Gaaltamaa in the eastern, Afaan Boroo in the northern and Afaan Bu’aa in the southern direction). Now Soda village is located at the upper southern direction at about 2 km from the salty lake. The 2 km route is the road used by local people and donkeys for transportation of extracted salt.

There are two types of salt extracted from the lake, i.e., table salt and black salty mud. The salts are used for household consumption and sale. The price of both types of salt is cheap at the site, but it is expensive after it is transported to other places such as Bulee Hora (185 km), Moyalle (about 140 km) and Yabello (about 100 km) from the salt house. The product is also transported to Nairobi through Kenya Moyalle.

5.7.2.2 Extraction of black salty mud

Black salty mud, which is used for livestock feed and believed to serve as a sexual libdo for cattle, is extracted throughout the year, but becomes high in a quantity during rainy season owing to the absence of table salt. According to the respondents this salt is extracted by males of age above 15 years. The man dive in to the lake, cut the salty mud, swim out and fill in plastic bowls (Fig 14). After that, the salt will be put in bags (Fig 15) and loaded on donkeys back for temporary storage in the rooms constructed at Soda village.

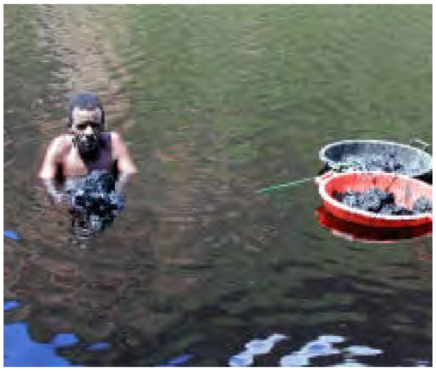

Figure 11*:* A man swim out and fill salty mud in plastic bowls

Figure 12*:* The salt is put in bags and carried up by donkeys

One donkey is usually loaded with 50-60 kg of this muddy salt to transport it from the bottom of the Lake to the Boke Soda village. On site retail price of 50-60 kg of black salty mud ranges from 25-30 ETB. However, the price becomes high during dry season since most people are mainly engaged in the extraction of table salt. During dry period, about 2500-3600 kg of black muddy salt per day will be extracted from the Lake and this number will be doubled during the rainy season.

5.7.2.3 Table salt extraction methods

a) Manual Extraction

During dry season, extraction of table salt is favoured due to the high intensity of solar radiation to enhance evaporation. Therefore, it is easy to extract a crystalline salt.

Figure 13: A hill of table salt manually extracted from the Boke salt Lake

The current study has revealed that the table salt, which is extracted from this lake, is believed to have high iodine content. Noteworthy is that there is no incidence of goiter encountered during this study in the local communities exclusively using this table salt since the latter is rich in iodine. The price of 50-60 kg of table salt ranges from 80-100 Eth. Birr. A total of 5000-7200 kg of table salt per day is usually transported from the Lake to the Boke Soda village. The figure may sometimes rise to 9000 kg per day. The key informants of the area have mentioned that these products were available in some market places and households in Kenya owing to the establsihed kinships of the Borana people.

b) Extraction of table salt by using a thorn less and succulent shrub

Suaeda monoica J.F.Gmel is a shrub in the family Chenopodiaceae and grows on moist saline places in the semi-arid regions with bush land and salt marsh. The leaves are usually alternate, simple and often succulent (Edwards *et al*., 2000).

Figure 14: Habit of *Suaeda monoica* at Boke salt house

The current study has shown that this species was entirely found adjacent to the lake within salt house where the soil is highly saline. As one goes up across the altitudinal gradient in every direction within the salt house, it tends to become totally absent in the plant communities. The local people use this plant to extract the table salt from the Lake. They cut the branches of this plant and keep it imersed in the Lake for 10-15 days. The table salt crystals will be attached to the leaves of this succulent plant in the course of this period and the braches are ready to be removed from the Lake. Further investigation are required to illustrate the physical and chemical mechanisms underlying this process.

Why *suaeda monoica* for table salt extraction?

The local informants have pointed out that *Suaeda monoica* is used for table salt extraction due to the following reasons:

1. A**vailability**: this species is an evergreen plant in the area and can be used during the dry season, the period for table salt extraction. Since it is a halophyte, ***S.***

monoica is very common just few meters from the salt Lake and very little energy is spent to find it.

2. **High surface area**: it has many tiny and succulent leaves, features mostly appreciated by the local community for high efficacy of table salt extraction.
3. **Convenient growth morphology**: it is a thorn less plant. As a result, local people can dive deep into the Lake without fear of being hurt by residual thorns if other kinds of plants are used.
4. **Food safety**: the local informants have unanimously mentioned that the leaves of *S. monoica* do not change the taste of the table salt and is also unknown for toxicity.

5.7.3 Development bottlenecks to maximize benefit of the Boke salt house

Lack of infrastructure such as near-modern but traditional looking lodges for tourists, well maintained road from the village to the salty lake (the current trail very sloppy and not maintained) and transportation facilities such as small-scale public transports from the main road to the Boke village could be cited among the myriads of development hurdles concerning the valuable eco-tourism potential of the salt house. The absence of any mode of supervision by professionals of Government Offices, applicable rules and regulations concerning sustainable utilization and management of the resources and lack of traceable financial accounting system have also accounted for the observed deterioration of the environmental conditions of the Lake. Furthermore, the observed unchecked and unbalanced utilization of *Suaeda monoica* for table salt extraction will certainly depauperate the populations of this species and may eventually drive it to rarity over a course of time. Although the local people are well aware of the fact that this natural resource (the plant) is limited and could be scarce over time, these strongly directional anthropogenic impacts on *S. monoica* have been attributed to increased human population and severe poverty during drought period. Last but not least, the absence of trained tour guide as an alternative livelihood and a fair marketing system for the products of the Lake are additional major problems which are negatively affecting benefit maximization for the local community.

6 CONCLUSION AND RECOMMENDATIONS

The studies of woody plant species diversity and socio-economic importance of Boke salt house were undertaken. The current study has shown that 45 woody plant species belonging to 16 different families were taxonomically identified both from the salt house and surrounding area.

The cluster analysis of the woody plant species data revealed six community types, which are distinct in terms of species composition. The distributions of these plant community types were highly influenced by altitude, which influence the availability of soil moisture content and other soil nutrients. Moreover, of the six communities identified, two communities were found in the salt house whereas, the other four were restricted to the surrounding environment in the drylands of Borana zone.

The mean Shannon diversity index of the six communities considering the 45 woody plant species was 2.206, which varies from an index value of 2.5 for community type 2 to 1.89 for community type 3. The mean evenness index of the communities was 0.728 with the highest value (0.812) for community 4 and lowest (0.603) for community 3. The species richness was high for community type 2 (35 species) and least for community type 1 (16 species).

The comparison of species richness of the salt house with the surrounding vegetation indicated that the surrounding vegetation had more species than the salt house. Moreover, *Acacia drepanolobium,* which is notorious invasive woody plant species, causing acute problem around the study area is not observed in the salt house.

The correlation analysis result of seven soil parameters with respect to altitude showed positive correlation for soil moisture content, organic matter, total N, available P and negative for exchangeable Na, electrical conductivity and pH-H_2Owhich inturn affects the abundance and distribution of woody plant species in the study area.

The socio-economic study of the area also indicated that Boke salt house is the lifesaver of thousands of people living around it. All the respondents, both from group discussion and individuals interview pointed out that “**no Boke-no life**” which implies that their livelihood is totally dependent on the income obtained from this site in the form of salt extraction and eco-tourism.

Despite the fact that the salt house is the lifesaver for thousands of people, it is now under extensive misutilization. Therefore, it is recommended to:

1. Make participatory management by the office of natural resources and the local people for sustainable utilization of the resources.
2. Build basic infrastructures such as recreation center for temporary residence of tourists, road from the top to the bottom and arrange transportation facilities from the main road to the site
3. Train local tour guide who can effectively communicate with and introduce about the salt house for the tourists
4. Awareness creation for the local people on how to use the resource on sustainable base

Future Research directions

1. The biology of *Suaeda monoica* in relation to the biochemical mechanisms underlying its uses for table salt extraction and its regeneration biology of *Suaeda monoica* for a restoration purposes owing to the dwindling number of populations of this species due to over exploitation.
2. The physico-chemical composition of the salt extracted from the Lake.
3. Participatory sustainable uses, management and development of this natural resources.

4. Research and development of the Salt of Boke Lake in connection to its biological basis for sexual libido in Cattle and import the same concept to other domestic animals to boost production.

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8 APPENDICIES

Appendix 1: Soil analytical result of the Boke salt house

Quadrat	Altitude	Moisture	Ph-H2O	OM	Total N	Avail P	Exch.Na	E.C
1	1134	1.32	8.1	1.98	0.11	25.91	3.48	0.54
2	1142.5	1.73	7.52	2.25	0.13	19.4	0.25	0.21
3	1161.5	1.52	7.33	2.44	0.14	47.43	0.22	0.19
4	1181	1.63	7.22	3.23	0.18	47.36	0.23	0.22
5	1218.5	2.98	7.42	4.22	0.2	69.18	0.2	0.24
6	1253	2.35	7.49	3.03	0.17	44.7	0.19	0.23
7	1132	1.83	7.4	2.34	0.12	33.96	0.51	0.63
8	1139	1.94	7.48	3.18	0.16	32.65	0.82	0.28
9	1177	2.15	7.68	4.52	0.25	56.07	0.22	0.31
10	1213	2.25	7.73	2.77	0.16	17.1	0.22	0.22
11	1246	2.35	7.59	4.44	0.23	48.66	0.2	0.26
12	1134	1.88	7.77	2.29	0.13	17.01	0.28	0.25
13	1138	1.94	7.44	2.1	0.12	36.96	0.21	0.29
14	1161	2.25	7.33	2.15	0.12	21.47	0.22	0.17
15	1170	2.15	7.25	2.72	0.15	35.41	0.22	0.22
16	1194	2.15	7.18	2.67	0.15	32.32	0.32	0.18
17	1221	1.83	7.14	3.23	0.18	42.52	0.2	0.25
18	1135	1.73	7.85	2.4	0.13	15.67	0.86	0.35
19	1148	1.21	7.81	0.86	0.06	11.38	0.33	0.17
20	1167	1.94	7.53	3.48	0.2	30.32	0.16	0.31
21	1197	3.09	7.55	4.72	0.27	69.08	0.05	0.27
22	1226.5	2.25	7.46	3.75	0.22	51.85	0.09	0.27
23	1481	3.84	7.67	3.4	0.2	17.4	0.24	0.24
24	1465	5.15	7.5	4.87	0.28	5.59	0.23	0.26
25	1513	6.16	7.52	8.44	0.46	6.23	0.34	0.33
26	1500	5.49	7.55	4.72	0.27	10.57	0.87	0.25
27	1500	5.49	7.44	5.08	0.29	2.27	0.21	0.34
28	1488	11.61	7.7	4.35	0.22	1.43	0.21	0.32

The quadrat from 1-6, 7-11, 12-17, 18-22 and 23-28 represents East, West, North, South within the salt house and outside respectively.

Appendix 2: Relative Frequency (RF), Relative Density (RD), Relative Basal Area (RBA), Important Value Index (IVI) and Density per hectare (D/ha) of woody plant species in Boke salt house

Species	RF	RD	RBA	IVI	D/ha
Acacia bussei	*1.9*	*0.2*	*13.5*	*15.5*	*4.5*
Acacia mellifera	9.3	5.3	8.3	22.9	139.8
Acacia oerfota	0.9	1.1	0.1	2.2	28.4
Acacia Senegal	2.8	2.1	1.3	6.2	54.5
Acalypha fruticosa	8.4	40.0	0.1	48.5	1047.7
Commiphora erythraea	4.2	1.0	23.4	28.7	27.3
Commiphora terebinthina	4.7	1.0	16.0	21.6	25.0
Cordia gharaf	5.6	0.9	0.4	6.9	23.9
Delonix baccal	8.9	3.9	24.6	37.3	101.1
Euphorbia abyssinica	0.5	0.3	3.5	4.3	8.0
Ozoroa insignis	0.5	0.0	1.3	1.8	1.1
Grewia bicolor	10.3	15.2	0.6	26.0	397.7
Grewia pennicillata	3.7	0.5	0.1	4.3	13.6
Grewia tembensis	8.4	2.8	0.6	11.8	72.7
Harmsia sidoides	0.5	0.1	0.0	0.6	2.3
Hibiscus aponeurus	6.1	9.1	0.1	15.2	237.5
Lannea rivae	0.9	0.1	0.1	1.1	3.4
Maerua triphylla	3.3	1.0	0.2	4.4	25.0
Salvadora persica	6.1	2.0	4.1	12.2	53.4
Sericocomopsis hildebrandtii	2.3	0.9	0.0	3.3	23.9
Solanum somalensis	6.5	8.7	0.3	15.6	228.4
Steganotaenia araliacea .	0.5	0.0	0.0	0.5	1.1
Sterculia stencarpa	0.5	0.0	0.7	1.2	1.1
Suaeda monoica	3.3	3.8	0.7	7.8	100.0

Appendix 3: Borana woody plant species Multi-Response Permutation Procedures (MRPP), PC-ORD, Version 4.20

```
  Multi-Response Permutation Procedures (MRPP)
PC-ORD, Version 4.20
21 Jul 2006, 15:56

     Groups were defined by values of: Group
     Input data has:     61 Plot     by     45 species
     Weighting option: C(I) = n(I)/sum(n(I))
     Distance measure: Sorensen (Bray-Curtis)

GROUP:    1
Code:     1
Size:     5      0.53440307    = Average distance
Members: Plot1    Plot7    Plot12   Plot13   Plot18

GROUP:    2
Code:     2
Size:    11      0.70429137    = Average distance
Members: Plot2    Plot14   Plot23   Plot24   Plot25   Plot26   Plot27   Plot28   Plot31
 Plot32   Plot34

GROUP:    3
Code:     3
Size:    15      0.43240071    = Average distance
Members: Plot3    Plot4    Plot5    Plot6    Plot8    Plot9    Plot10   Plot11
 Plot15   Plot16   Plot17   Plot19   Plot20   Plot21   Plot22

GROUP:    4
Code:     4
Size:    13      0.54873834    = Average distance
Members: Plot29   Plot33   Plot35   Plot36   Plot37   Plot38   Plot39
 Plot40   Plot41   Plot42   Plot43   Plot44   Plot45

GROUP:    5
Code:     5
Size:     4      0.63605150    = Average distance
Members: Plot30   Plot46   Plot47   Plot52

GROUP:    6
Code:     6
Size:    13      0.55656356    = Average distance
Members: Plot48   Plot49   Plot50   Plot51   Plot53   Plot54   Plot55   Plot56
 Plot57   Plot58   Plot59   Plot60   Plot61
```

Test statistic: T = -26.686197
Observed delta = 0.55184932
Expected delta = 0.80884407
Variance of delta = 0.92741719E-04
Skewness of delta = -0.63540975

Chance-corrected within-group agreement, A = 0.31773089
A = 1 - (observed delta/expected delta)
Amax = 1 when all items are identical within groups (delta=0)
A = 0 when heterogeneity within groups equals expectation by chance
A < 0 with more heterogeneity within groups than expected by chance

Probability of a smaller or equal delta, p = 0.00000000

Appendix 4: Borana woody plant species Indicator Values analysis result, using PC-ORD, Version 4.20 calculated with method of Dufrene & Legendre, 1997.

RELATIVE ABUNDANCE in group, % of perfect indication (average abundance of a given species in a given group of Plot over the average abundance of that species in all Plot expressed as a %)

				Group					
			Sequence:	1	2	3	4	5	6
			Identifier:	1	2	3	4	5	6
			Number of items:	5	11	15	13	4	13
Column	Avg	Max	MaxGrp						
1 Salvador	17	91	3	6	3	91	0	0	0
2 Euphorbi	17	100	3	0	0	100	0	0	0
3 Commipho	17	38	3	0	10	38	5	18	29
4 Acacia b	17	61	4	0	14	7	61	14	4
5 Lannea r	17	36	5	3	36	2	0	36	22
6 Grewia b	17	34	2	19	34	25	6	15	1
7 Balanite	17	52	6	0	14	0	0	34	52
8 Delonix	17	78	3	15	7	78	0	0	0
9 Hibiscus	17	88	3	10	2	88	0	0	0
10 Acacia n	17	78	2	0	78	0	22	0	0
11 Euphorbi	17	100	4	0	0	0	100	0	0
12 Rhus rus	17	100	2	0	100	0	0	0	0
13 Rhus nat	17	100	2	0	100	0	0	0	0
14 Bosswell	17	80	5	0	8	0	3	80	9
15 Acacia t	17	32	6	0	21	0	30	17	32
16 Grewia t	17	59	1	59	13	28	0	0	0
17 Acalypha	17	92	3	4	4	92	0	0	0
18 Maerua t	17	81	3	0	11	81	8	0	0
19 Suaeda m	17	96	1	96	0	4	0	0	0
20 Ozoroa i	17	100	3	0	0	100	0	0	0
21 Sericomo	17	52	3	48	0	52	0	0	0
22 Pavonia	17	100	2	0	100	0	0	0	0
23 Acacia d	17	100	2	0	100	0	0	0	0
24 Solanum	17	67	3	3	30	67	0	0	0
25 Acacia S	17	33	4	1	18	14	33	25	9
26 Steganot	17	100	3	0	0	100	0	0	0
27 Cordia g	17	64	1	64	19	17	0	0	0
28 Grewia p	17	38	6	17	21	25	0	0	38
29 Boscia m	17	43	5	0	17	0	0	43	40
30 Sterculi	17	49	2	0	49	5	20	0	27
31 Harmsia	17	90	5	0	6	1	0	90	3
32 Acacia o	17	57	1	57	13	0	30	0	0
33 Commipho	17	73	3	22	5	73	0	0	0
34 Acacia m	17	35	2	5	35	30	13	8	8

Column	Avg	Max	MaxGrp	1	2	3	4	5	6
35 Grewia t	17	100	2	0	100	0	0	0	0
36 Maytenus	17	100	2	0	100	0	0	0	0
37 Acacia s	17	56	6	0	0	0	4	40	56
38 Commipho	17	34	2	0	34	0	31	32	3
39 Commipho	17	45	4	0	14	0	45	36	4
40 Commipho	17	61	4	0	39	0	61	0	0
41 Commipho	17	63	5	0	3	0	10	63	23
42 Commipho	17	52	4	0	48	0	52	0	0
43 Grewia v	17	92	5	0	0	0	1	92	8
44 Ormocarp	17	64	5	0	0	0	36	64	0
45 Dichrost	17	100	6	0	0	0	0	0	100
Averages	17	70		10	27	25	13	16	10

RELATIVE FREQUENCY in group, % of perfect indication
(% of Plot in given group where given species is present)

Group

Sequence: 1 2 3 4 5 6
Identifier: 1 2 3 4 5 6
Number of items: 5 11 15 13 4 13

Column	Avg	Max	MaxGrp	1	2	3	4	5	6
1 Salvador	17	73	3	20	10	73	0	0	0
2 Euphorbi	1	7	3	0	0	7	0	0	0
3 Commipho	25	60	3	0	10	60	14	25	38
4 Acacia b	28	57	4	0	50	27	57	25	8
5 Lannea r	27	50	5	20	40	7	0	50	46
6 Grewia b	69	100	1	100	90	100	57	50	15
7 Balanite	10	25	5	0	10	0	0	25	23
8 Delonix	29	93	3	60	20	93	0	0	0
9 Hibiscus	21	73	3	40	10	73	0	0	0
10 Acacia n	6	30	2	0	30	0	7	0	0
11 Euphorbi	1	7	4	0	0	0	7	0	0
12 Rhus rus	2	10	2	0	10	0	0	0	0
13 Rhus nat	5	30	2	0	30	0	0	0	0
14 Bosswell	14	50	5	0	10	0	7	50	15
15 Acacia t	25	50	4	0	30	0	50	25	46
16 Grewia t	35	80	1	80	50	80	0	0	0
17 Acalypha	30	100	3	60	20	100	0	0	0
18 Maerua t	12	47	3	0	20	47	7	0	0
19 Suaeda m	19	100	1	100	0	13	0	0	0
20 Ozoroa i	1	7	3	0	0	7	0	0	0
21 Sericomo	8	27	3	20	0	27	0	0	0
22 Pavonia	2	10	2	0	10	0	0	0	0
23 Acacia d	3	20	2	0	20	0	0	0	0
24 Solanum	23	87	3	20	30	87	0	0	0
25 Acacia S	41	86	4	20	30	27	86	50	31

Formatted: Portuguese (Portugal)

Formatted: Portuguese (Portugal)

26 Steganot	1	7	3	0	0	7	0	0	0
27 Cordia g	26	60	1	60	50	47	0	0	0
28 Grewia p	22	40	1	40	30	33	0	0	31
29 Boscia m	7	25	5	0	10	0	0	25	8
30 Sterculi	7	15	6	0	10	7	7	0	15
31 Harmsia	10	25	5	0	20	7	0	25	8
32 Acacia o	15	43	4	20	30	0	43	0	0
33 Commipho	17	53	3	40	10	53	0	0	0
34 Acacia m	62	100	3	60	60	100	71	25	54
35 Grewia t	2	10	2	0	10	0	0	0	0
36 Maytenus	3	20	2	0	20	0	0	0	0
37 Acacia s	26	100	6	0	0	0	29	25	100
38 Commipho	36	93	4	0	30	0	93	75	15
39 Commipho	19	64	4	0	20	0	64	25	8
40 Commipho	8	29	4	0	20	0	29	0	0
41 Commipho	22	50	5	0	10	0	29	50	46
42 Commipho	4	14	4	0	10	0	14	0	0
43 Grewia v	27	100	5	0	0	0	7	100	54
44 Ormocarp	5	25	5	0	0	0	7	25	0
45 Dichrost	3	15	6	0	0	0	0	0	15
Averages	17	48		17	19	24	15	15	13

INDICATOR VALUES (% of perfect indication, based on combining the above values for relative abundance and relative frequency)

				Sequence:	1	2	3	4	5	
				Identifier:	1	2	3	4	5	
				No of items	5	11	15	13	4	13
	Species	Avg	Max	MaxGrp						
1	*Salvador*	11	67	3	1	0	67	0	0	0
2	*Euphorbi*	1	7	3	0	0	7	0	0	0
3	*Commipho*	7	23	3	0	1	23	1	4	11
4	*Acacia b*	8	35	4	0	7	2	35	3	0
5	*Lannea r*	7	18	5	1	14	0	0	18	10
6	*Grewia b*	14	30	2	19	30	25	3	8	0
7	*Balanite*	4	12	6	0	1	0	0	9	12
8	*Delonix*	14	73	3	9	1	73	0	0	0
9	*Hibiscus*	11	64	3	4	0	64	0	0	0
10	*Acacia*	4	23	2	0	23	0	2	0	0
11	*Euphorbi*	1	7	4	0	0	0	7	0	0
12	*Rhus rus*	2	10	2	0	10	0	0	0	0
13	*Rhus nat*	5	30	2	0	30	0	0	0	0
14	*Bosswell*	7	40	5	0	1	0	0	40	1
15	*Acacia t*	7	15	4	0	6	0	15	4	15

16	*Grewia t*	13	47	1	47	7	22	0	0	0
17	*Acalypha*	16	92	3	3	1	92	0	0	0
18	*Maerua t*	7	38	3	0	2	38	1	0	0
19	*Suaeda m*	16	96	1	96	0	0	0	0	0
20	*Ozoroa i*	1	7	3	0	0	7	0	0	0
21	*Sericomo*	4	14	3	10	0	14	0	0	0
22	*Pavonia*	2	10	2	0	10	0	0	0	0
23	*Acacia d*	3	20	2	0	20	0	0	0	0
24	*Solanum*	11	58	3	1	9	58	0	0	0
25	*Acacia sen*	9	29	4	0	5	4	29	12	3
26	*Steganot*	1	7	3	0	0	7	0	0	0
27	*Cordia g*	9	38	1	38	10	8	0	0	0
28	*Grewia p*	5	12	6	7	6	8	0	0	12
29	*Boscia m*	3	11	5	0	2	0	0	11	3
30	*Sterculi*	2	5	2	0	5	0	1	0	4
31	*Harmsia*	4	22	5	0	1	0	0	22	0
32	*Acacia o*	5	13	4	11	4	0	13	0	0
33	*Commipho*	8	39	3	9	1	39	0	0	0
34	*Acacia m*	12	30	3	3	21	30	9	2	5
35	*Grewia ten*	2	10	2	0	10	0	0	0	0
36	*Maytenus*	3	20	2	0	20	0	0	0	0
37	*Acacia sey*	11	56	6	0	0	0	1	10	56
38	*Commipho*	11	29	4	0	10	0	29	24	0
39	*Commipho*	7	29	4	0	3	0	29	9	0
40	*Commipho*	4	17	4	0	8	0	17	0	0
41	*Commipho*	8	32	5	0	0	0	3	32	11
42	*Commipho*	2	7	4	0	5	0	7	0	0
43	*Grewia v*	16	92	5	0	0	0	0	92	4
44	*Ormocarp*	3	16	5	0	0	0	3	16	0
45	*Dichrost*	3	15	6	0	0	0	0	0	15
	Averages	7	30	6	6	13	5	7	4	4

MONTE CARLO test of significance of observed maximum indicator value for Borana woody plant species

S/Nr.	Species	Group	Observed indicator Value (IV)	Mean	S.Dev	P-value
1	*Salvadorper*	3	66.7	14.6	7.19	0.001
2	*Euphorbi aby*	3	6.7	9.8	5.38	1.000
3	*Commipho ery*	3	22.9	15.8	6.68	0.122
4	*Acacia bus*	4	34.8	18.1	8.4	0.051
5	*Lannea riv*	5	18.2	16	8.18	0.277
6	*Grewia bic*	2	30.5	21.3	4.74	0.053
7	*Balanite aeg*	6	12.1	11.6	6.64	0.322

8	*Delonix bac*	3	72.6	17.3	7.49	0.002
9	*Hibiscus apo*	3	64.2	15.4	7.3	0.001
10	*Acacia nil*	2	23.3	11.3	7.26	0.065
11	*Euphorbi cun*	4	7.1	10.1	5.57	0.767
12	*Rhus rus*	2	10	9.5	5.04	0.299
13	*Rhus nat*	2	30	10.9	6.83	0.023
14	*Bosswell neg*	5	40	12.3	7.42	0.009
15	*Acacia tor*	4	14.9	15.4	6.71	0.425
16	*Grewia tem*	1	47	17.2	7.01	0.006
17	*Acalypha fru*	3	92.1	16.8	6.85	0.001
18	*Maerua try*	3	37.8	13.7	7.67	0.018
19	*Suaeda mon*	1	96.3	12.9	7.5	0.001
20	*Ozoroa ins*	3	6.7	9.6	5.11	1.000
21	*Sericomo hel*	3	13.8	11.2	6.53	0.191
22	*Pavoniagal*	2	10	10.3	5.73	0.359
23	*Acacia dre*	2	20	10.9	6.1	0.082
24	*Solanum som*	3	58.1	16.8	7.73	0.003
25	*Acacia sen*	4	28.5	19.3	7.08	0.090
26	*Steganot ara*	3	6.7	9.9	5.47	1.000
27	*Cordia gha*	1	38.3	15.5	7.7	0.017
28	*Grewia pen*	6	11.7	14.8	6.7	0.639
29	*Boscia mos*	5	10.8	10.8	6.33	0.418
30	*Sterculi ste*	2	4.9	11.4	6.47	0.936
31	*Harmsia sid*	5	22.4	12.9	7.38	0.108
32	*Acacia oerf*	4	12.8	14	7.2	0.459
33	*Commiphoter*	3	38.8	14.6	7.94	0.017
34	*Acacia mel*	3	30.1	24.2	6.77	0.165
35	*Grewia ten*	2	10	10.3	5.73	0.359
36	*Maytenus gra*	2	20	10.1	6.54	0.092
37	*Acacia sey*	6	55.6	15.8	6.76	0.001
38	*Commipho con*	4	28.7	17.3	6.79	0.069
39	*Commipho hab*	4	29.1	14.3	6.96	0.046
40	*Commipho kua*	4	17.5	11.2	6.51	0.145
41	*Commipho afr*	5	31.7	14.9	7.83	0.039
42	*Commipho sch*	4	7.4	10.5	6.49	0.713
43	*Grewia vil*	5	91.7	15.8	8.29	0.001
44	*Ormocarp tri*	5	15.9	10.3	7.08	0.204
45	*Dichrost cin*	6	15.4	10	6.59	0.263

* proportion of randomized trials with indicator value equal to or exceeding the observed indicator value. p = (1 + number of runs >= observed)/(1 + number of randomized runs)
Max grp = Group identifier for group with maximum observed IV

Appendix 5: Woody plant species distribution across the four aspects within and around the salt house**.**

Species	Geographic Direction				
	East	West	North	South	Outside
Salvadora persica	+	+	+	+	
Euphorbia abyssinica		+			
Commiphora erythraea	+	+	+	+	
Acacia bussei	+	+	+		+
Lannea rivae				+	+
Grewia bicolor	+	+	+	+	+
Balanite aegyptica					+
Delonix baccal	+	+	+	+	
Hibiscus aponeurus	+	+	+	+	+
Acacia nilotica					+
Euphorbia cuneata ssp.					+
Spinescens					
Rhus ruspolii					+
Rhus natalensis					+
Boswellia neglecta					+
Acacia tortilis					+
Grewia tembensis	+	+	+	+	+
Acalypha fruticosa .	+	+	+	+	+
Maerua triphylla	+	+	+	+	+
Suaeda monoica	+	+	+	+	
Ozoroa insignis		+			
Sericocomopsis hilderbrandtii.		+		+	
Pavonia gallaensis					+
Acacia drepanolbium					+
Solanum somalensis	+	+	+	+	+
Acacia Senegal	+		+		+
Steganotaenia araliacea.	+				

Cordia gharaf	+	+	+		+
Grewia pennicillata Chiov.	+	+	+	+	+
Boscia mossambicensis					+
Sterculia stenocarpa	+				
Harmsia sidoides			+		+
Acacia oerfota			+		+
Commiphora terebinthina	+	+	+	+	+
Acacia mellifera	+	+	+	+	+
Grewia tenax					+
Mytenus gracilipes					+
Acacia seyal					+
Commiphora Africana					+
Commiphora habessinica					+
Grewia villosa					+
Commiphora kua					+
Commiphora schimperi					+
Dichrostachyus cinerea					+
Commiphora confusa					+
Ormocarpum trichocarpum					+

+ Represents the presence of family, genera and/or species

Appendix 6: Species diversity and evenness calculation for the 24 woody plant species found in Boke salt house

Plot	density	D/ha	Pi	lnPi	PilnPI
Salvadora persica	*47*	*53.40909*	*0.020373*	*-3.89356*	*-0.07932*
Euphorbia abyssinica	7	7.954545	0.003034	-5.79779	-0.01759
Commiphora erythraea	24	27.27273	0.010403	-4.56565	-0.0475
Acacia bussei	4	4.545455	0.001734	-6.35741	-0.01102
Lannea rivae	3	3.409091	0.0013	-6.64509	-0.00864

Grewia bicolor	350	397.7273	0.151712	-1.88577	-0.28609
Delonix baccal	89	101.1364	0.038578	-3.25507	-0.12557
Hibiscus aponeurus	209	237.5	0.090594	-2.40137	-0.21755
Grewia tembensis	64	72.72727	0.027742	-3.58482	-0.09945
Acalypha fruticosa	922	1047.727	0.399653	-0.91716	-0.36655
Maerua triphylla	22	25	0.009536	-4.65266	-0.04437
Suaeda monoica	88	100	0.038145	-3.26637	-0.12459
Ozoroa insignis	1	1.136364	0.000433	-7.7437	-0.00336
Sericocomopsis hilderbrandtii	21	23.86364	0.009103	-4.69918	-0.04278
Solanum somalensis	201	228.4091	0.087126	-2.4404	-0.21262
Acacia Senegal	48	54.54545	0.020806	-3.8725	-0.08057
Steganotaenia araliacea	1	1.136364	0.000433	-7.7437	-0.00336
Cordia gharaf	21	23.86364	0.009103	-4.69918	-0.04278
Grewia pennicillata	12	13.63636	0.005202	-5.2588	-0.02735
Sterculia stencarpa	1	1.136364	0.000433	-7.7437	-0.00336
Harmsia sidoides	2	2.272727	0.000867	-7.05056	-0.00611
Acacia oerfota	25	28.40909	0.010837	-4.52483	-0.04903
Commiphora terebinthina	22	25	0.009536	-4.65266	-0.04437
Acacia mellifera	123	139.7727	0.053316	-2.93152	-0.1563
Total		2621.591	1	-110.583	-2.10023
Species diversity index					2.10023
Evenness index					0.661

Appendix 7: List of woody plant species

Abbreviations for growth form: T = tree, S = shrub and T/S = tree/shrub

Species name	Vernacular name (Afan Oromo)	Family	Habit
Acacia bussei Harms ex Sjostedt	Alloo	Fabaceae	T
Acacia drepanolobium Harms ex Sjostedt	Fulleensa	Fabaceae	T

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Acacia mellifera (Vahl.) Benth.	Saphaansa	Fabaceae	T/S
Acacia nilotica (L.) Willd. Ex Del.	Burquqqee	Fabaceae	T
Acacia oerfota (Forssk.) Schweinf.	Waangaa	Fabaceae	S
Acacia Senegal (L.) Willd.	Hidhaadhoo	Fabaceae	T
Acacia seyal Del.	Waaccuu diima	Fabaceae	T
Acacia tortilis (Forssk.) Hayne	Dhaddacha	Fabaceae	T
Acalypha fruticosa Forssk.	Dhirrii	Euphorbiaceae	S
Balanites aegyptiaca (L.) Del.	Baddana	Balanitaceae	T/S
Boscia mossambicensis Klotzsch	Qanqalcha	Capparidaceae	T
Boswellia neglecta S. Moore	Dakkara	Burseraceae	S
Commiphora Africana (A. Rich.)	Hammesa dhiiroo	Burseraceae	T/S
Commiphora confusa	Siltachoo	Burseraceae	T
Commiphora erythraea (Ehrenb.) Engl.	Agarsuu	Burseraceae	T
Commiphora habessinica (Berg)	Hoomacho	Burseraceae	T/S
Commiphora kua (R.Br.Ex Royle) Vollesen	Callanqaa	Burseraceae	T/S
Commiphora schimperi (Berg.)Egngl	Hammesa qayyoo	Burseraceae	T/S
Commiphora terebinthina Vollesen	Sangagguu	Burseraceae	T
Cordia gharaf (Forssk.) Asch.	Madheera	Boraginaceae	T
Delonix baccal (Chiov.) Bak. F.	Baallanjii	Fabaceae	T
Dichrostachyus cinerea (L.) wight et Arm	. Jirimmee	Fabaceae	T/S
Euphorbia abyssinica Gmel.	Adaammaa	Euphorbiaceae	T
Euphorbia cuneata ssp. *Spinescens* (Pax) S. Carter	Bursa	Euphorbiaceae	S
Grewia bicolor Juss.	Arooreessa	Tiliaceae	S
Grewia pennicillata Chiov.	Ogomdii	Tiliaceae	S
Grewia tembensis Fresen.	Dheekkaa	Tiliaceae	S
Grewia tenax (Forssk.) Fiori	Sarkama	Tiliaceae	S
Grewia villosa	Ogomdi diidaa	Tilaceae	S
Harmsia sidoides K. Schum.	Qaxxee	Sterculiaceae	S

Hibiscus aponeurus Sprague & Hutch.	Bungaala	Malvaceae	S
Lannea rivae (Chiov.) Sacl.	Andaraka	Anacardiaceae	T/S
Maerua triphylla A.Rich	Dhumasoo	Capparidaceae	T/S
Maytenus gracilipes (Welw. ex Oliv.) Exell	Tin'acha	Celastraceae	S
*Ormocarpum trichocarpum(*Tuab*)*	Buutiyyee	Fabaceae	S
Ozoroa insignis Del.	Garrii	Anacardiaceae	S
Pavonia gallaensis Ulbr.	Gurbii daalattii	Malvaceae	S
Rhus natalensis Krauss	Daboobessa diidaa	Anacardiaceae	S
Rhus ruspolii Engl.	Daboobessa	Anacardiaceae	S
Salvadora persica L.	Aadee	Salvadoraceae	S
Sericocomopsis hildebrandtii Schinz	Gurbii	Amarantaceae	S
Solanum somalensis Franch.	Hiddi xirooftuu	Solaniaceae	S
Steganotaenia araliacea Hochst.ex A.Rich.	Luqaanluqqee	Apiaceae	T
Sterculia stenocarpa H. Winkler	Qararrii	Stericulaceae	S
Suaeda monoica J.F.Gmelin	Dhuurtee	Chenopodiaceae	S

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Appendix 8: Semi-structured questionnaires prepared to collect information on socio-economic importance of Boke salt house

General information

Kebele-________________________________Village________________________

Gender: Female_______________ Male__________ Age________________

Level of Education 1_____________ 2_____________ 3___________ 4___________

Key: 1-Elementary 2-Junior secondary, 3-High school, 4-Above high school level

1 For how long you lived in this area? ____

2 Would you tell me the n information you have about this area in general and the salt house in particular?

____

____

3 How was the salt house created?

____

____

Socio-economic data

4 What benefits you get from this salt house?

a)____

b)____

c)____

d)____

Who collects the benefit that you can get from the salt house ________________________

At what season and at what time you collect it _________________________________

5 Who manages the area from unwise utilization?

____

____

6 Do you have local rules and regulations for managing the area?

a) Yes ________________ b) No _________________

6.1 If yes, would you mention some of them?

a)____

b)____

c)____

7 What type of punishment is given for individuals who broke the rules?

____

____

8 Are foreign and local tourists visit the area? Yes __________No ________________

8.1 If yes, how much money does he/she pay per head? Local _____________________

Foreigner ____________________

9 Who decides the amount of the payment? ___________________________________

10 Who collect the charge? ____

11 For what purpose does the charge used?

a)____

b)____

c)____

12 In which month does the number of visitors/tourists becomes high, and why?

____

13 Why you put grasses and pray at the gate of the salt house?

____

14 Do the visitors do the same Yes _____________ No _________________

15 What will happen to them if they refused to do so?

____

Ethnobotanical data

16 Would you mention plants used as medicine from the Crater Lake?

No	Local name of the species	Plant part used	Applied for curing disease
1			
2			
3			
4			

17 Would you mention plants used as food from the Crater Lake?

No	Local name of the species	Plant part used	Remark
1			
2			
3			
4			

Concluding remark

18 What do you want to be done from the Government side to enhance the utilization of the salt house?

____

____

____

19 What do you want to be done from the local people to enhance the utilization of the salt house?

____

____

20 If you have any idea or suggestion concerning the salt house?

____

____

Declaration

I, the undersigned, do hereby honestly declare to the Senate of Addis Ababa University, that the content of this thesis is my original work and it has never been submitted for any Degree in any other academic institution to fulfill a similar purpose. All sources of material used for the Thesis have been duly acknowledged.

Name: Teshome Takele Dime

Signature _______________

Place and date of submission

Addis Ababa University

July 2006