ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

WOODY SPECIES ENCROACHMENT AND RELATED ECOLOGICAL CONDITIONS IN THE GRASS PLAIN OF NECHSAR NATIONAL PARK

By

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE DEGREE OF MASTER OF SCIENCE IN BIOLOGY (BOTANICAL SCIENCES)

June 2008
ADDIS ABABA

ACKNOWLEDGEMENTS

The writing of this thesis is obviously not possible without the personal and practical support of numerous people. First, I would like to thank Allaha/God almighty for the strength that He supplied to me for finalizing this work.

This thesis would not have been possible without the expert guidance of my esteemed Supervisors, Professor Sebsebe Demissew and Professor Zerhun Woldu. I wish to express my deep gratitude to them for their follow up and encouragement throughout my study period.

I would like to thank the cooperation of Wellaga University for handling of all the administrative matters during my study period. I am especially grateful to Professor Fekadu Beyene, the president of Wellaga University for his encouragement and unreserved support. I would also like to thank Addis Ababa University Herbarium workers w/t Shewa, Melaku, and Assefa for their provision of all necessary materials required for the study and assistance during plant species identification work.

The field research was conducted in Nechsar National Park. I am thankful also, for African Parks Foundation-Ethiopia(APF plc) for initiating this demand driven research, and assist me in all research activities, and I would love to thank Dr.Assefa Meberate, Ato Matios Ersado,Mr.Derik Clark, Ato Girema Timer, Ato Aramdie, Ato Olani, Park Scouts Ato Ademasu, Ato Hasan,and Ato Jarso where I received all kind of support.

I am particularly thankful to my friends Juhar Yasin, Juhar Jibril, Kamil Ahmed, Zeinu Ahmed, Tofik Shukur, Deresse Teshome, Fite Getanhe, Ayantu Mekonon, Jibril Mamo, Siraj Mamo, Sintayehu Shuri, Teshome Takale for their assistance and encouragement in various ways during my course of studies.

I would like to thank my parents for their prayers, encouragement, support, sacrifice and advice ever since my youth. Words can not express my feelings, which I have for my family, my dear mother, Makiya Abdurhaman, I am very much thankful for her love, encouragement and support. Special thanks for my dear sisters Keriya Yusuf and her family, Fate Ali and her family and dear brothers Nasir Yusuf, Imam Yusuf, Kasim Yusuf, Amdihun Yusuf, Mohamud Yusuf, Kedir and Anuwar Yusuf for the courage and love they gave me during my study. Miss you Dad.

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ABSTRACT

Encroachment of woody species has been reported as the major threats to the Grassland of Nechsar National Park of Ethiopia. The objectives of the study were to determine the invasive bush species, woody species density and woody species cover; to determine plant diversity and community; to asses the relationships between woody species cover, herbaceous cover, grass cover, forbs cover, and bare land cover in the Grass plain of the Park. Vegetation survey methodology was employed. Floristic composition, species relative frequency and abundancy, plant community, species diversity, species richness, species evenneness, density and cover of woody species, grass cover, forbs cover, total herbaceous cover were determined in 75 relev`es. One hundred and thirty one plant species belonging to 45 different families were recorded. Dicrostachys cinerea, Acacia nilotica, Acacia mellifera, and Acacia Oerfota were the major woody species encroacher in the area. Abutilon anglosomaliae (RF = 0.95), Bothrichloa inssculpata (RF = 0.81), Rhynchosia malacophylla (RF = 0.79), Endostemon tereticaulis (RF = 0.72), Commelina diffusa (RF = 0.70), Digitaria abyssinica (RF = 0.67) were the most frequent species in the area. Abutilon anglosomaliae (6.5%), Dicrostachys cinerea (6%), Chrysopogon plumulosus (5.3%), Bothrichloa inssculpata (4.5%), Pupalia lappacea (4%), Loudetia flavida (4%) are species with higher cover abundance in the Grass plain of Nechsar National Park. The hierarchical agglomerate cluster analysis using average linkage strategy provides six major plant communities and one solitary releve. The low average specie richness (23spp. Plot^{-1}) resulted in low over all average species diversity (2.92). ANOVA showed there is no variability among plant communities with respect to species diversity, richness, and evenneness at $p \leq 0.05$. Results also showed that woody species density was 1995 woody plants ha^{-1}. Mean cover of woody, grass, unpalatable forbs, and total herbaceous species was 31%, 58%, 68% and 121% respectively. The bare land cover was 12%. The high woody and unpalatable forbs cover indicated the progressively increasing grass species diversity deterioration in the grass plain of the Park. Relatively high bare land cover observed resulted in high incidence of gully erosion in the area. Analysis of variance showed significant variability among the plant community at $P \leq 0.05$ for woody, grasses, forbs, and bare land cover. Pearson correlation coefficient matrix indicated that woody species cover was negatively correlated with total herbaceous cover (grass and forbs) and bare land cover. Grass cover was negatively correlated with forbs, bare land cover, and woody species density. Total herbaceous cover was negatively correlated with bare land cover, bush density. The relationship between bush cover, woody species density, grass cover, herbaceous cover, bare land cover and related soil erosion is complex and related to climate, land escape geology and anthropogenic disturbances. Main threats to the grassland ecology of Nechsar National Park are progressive increase in bush cover, loss of grass cover, and increase in unpalatable forbs. Currently greater than 50% of the landscape of the grass plain is in a poor to fair grassland conditions. Decline in the grassland condition, unless reversed, will jeopardize the biological diversity as well as aesthetic value of the Nechsar National Park.

1 INTRODUCTION

In the past 50 years, evidences accumulated suggest that Nechsar grass plain is being altered by a phenomenon known as ‘bush encroachment (Tamirat Andargie 2001, Yishaq Doku *et al.*, 2006, Asaye Nigusse 2008). Bush encroachment is defined as the invasion and/or thickening of aggressive undesired woody species resulting in an imbalance of the grass: bush ratio, a decrease in biodiversity, and a decrease in carrying capacity causing severe economic losses. The dynamics of bush encroachment in response to grazing pressure, rainfall variability and the suppression of fire (Grover and Musick 1990) results in the gradual replacement of grassland vegetation (Scholes and Archer 1997, Oba *et al.* 2000a, Sheuyange *et al.* 2005). For example, in the Southern Ethiopian rangelands, bush encroachment has now become a serious problem for management (Oba 1998, Ayana Angassa and Baars 2000, Oba *et al*. 2000a, Gemedo Dalle *et al.* 2006). Van Wijngaarden (1985) reported that in East African savanna ecosystems increases in bush cover by 10% reduce grazing by 7%, while grazing is eliminated when bush cover reaches 90%.

Currently, invasive bush encroachment, land degradation and herbaceous retrogression due to rapidly increased livestock pressure are among severing threats to the Grass plain of the Nechsar National Park (Asaye Nigusse 2008). However, less quantitative ecological and botanical studies have been done to determine the floristic composition, status of invasive bush encroachment, its distribution pattern, and structural diversity and associated impacts of invasive bush species on herbaceous diversity in the national conservation priority areas like the grass plain of Nechsar National Park.

Gathering information on the botanical and ecological condition of the grass plain in the park and the impacts of the encroaching invasive plant species on herbaceous plant community in which larger biological diversity occurs is a vital pre requisite for conservation. Thus, any conservation strategy depends on the knowledge of the botanical composition and the condition of the ecosystem. Thus information gathered on such natural ecosystems help to utilize their biological resources sustainably. In addition, assessment of the current condition of the vegetation of any ecosystem in relation to its theoretical potential helps to take measures for appropriate management.

The result of this study is, therefore, to provide data that could serve as a basis for sustainable use of the plant resources of the park and will help to make comparison on the effects of environmental changes on the botanical diversity in the area. It also provides data as a scientific base for conservation.

General Objective

The general objective of the study is to provide natural description of the floristic composition of the grass plain of Nechsar Park; to study the relationship between invasive bush encroachment and herbaceous biodiversity and distribution pattern in the Grass Plain; to investigate the vegetation composition and pattern of distribution in a relation to the ecological factors in the grassland.

Specific objectives

- To determine the invasive bush species in the Grass plain of Nechsar Nationa Park
- To determine the cover and density of invasive bush plant species in the Grass plain of the park
- To identify major plant communities
- To describe plant species diversity
- To investigate the impact of invasive bush plant species on herbaceous diversity.

2. LITERATURE REVIEW

2.1 Ecology of savanna ecosystem

Savanna is a tropical ecosystem with a continuous layer of grasses and other herbaceous species with or with out a discontinuous layer of shrubs and /or trees (Solbrig 1996). It occupies areas lying between the tropical rain forest and semi-desert vegetation i.e., between 5^0 and 20^0 latitude north and south of the equator. It occurs in areas where rainfall ranges between 700 and 1000 mm (Kumar 1997). The vegetation consists of tall shrubs or small trees with few lianas and epiphytes. Xerophytic shrubs and grasses are more abundant. In this, ecosystem grasses and woody plants grow together in an ecological equilibrium. Generally, in natural savanna plant communities, individual woody plants grow more or less widely apart on a grassy background (Walter 1971).

Cole (1989) classified the African savanna systems on the bases of the dominant plant species. The East African savanna forms the low “tree and shrub savannas”. The community is characterized by widely spaced low growing perennial grasses with abundant annuals mixed with widely spaced, low growing trees and shrubs often less than 2 m high. *Acacia* trees and many other shrub species and Arisitida and Chrysopogon grass species dominate the African Savanna. The low tree and shrub savannas in the SW Africa and Botswana on the lower surface extending northward to Tanzania , Kenya, and narrow strips to the rift valley system in Ethiopia and West Africa.

In East Africa, the heart of the savanna zone, is in the Somali - Masai region,reginal center of endemism which contains diverse plant species (White, 1983). The rift valley is mostly at rather high altitude than the more typical Somali Masai areas and the vegetation is occupied largely by *Acacia* woodland with very few of the species of *Commiphora* spp.

2.2 Human influence in savanna

Much of the rich history of hominoid evolution has occurred in savannas (Harris 1980), and activities of humans have influenced the structure and function of savanna ecosystems. Deliberate use of fire by hominids (ca. 2.5 MYA) likely increased the fire frequency in African savannas (Brain *et al.* 1988). Current patterns of vegetation distribution across savanna landscapes may still reflect activities of prehistoric inhabitants. For example, the distinct plant communities dominated by *Acacia tortilis* within *Burkea africana* savannas of South Africa appear to have developed on Iron Age settlement sites (Blackmore *et al.* 1990). In Kenya, past distributions of temporary corrals used by nomadic pastoralists markedly influence patterns of *A. tortilis* distribution and recruitment.

Human population growth and widespread settlement have influenced tree-grass mixtures worldwide. Extensive clearing of trees for fuel, lumber, and cropland have fragmented forests and produced anthropogenic or degraded savannas (Adgill *et al.* 1985). In other areas, fire suppression, over hunting or eradication of indigenous wild savanna animals, and the introduction of livestock and exotic trees have caused herbaceous degradation and a progressive increase in woody plant density, known as bush or woody tree species encroachment. As a result, areas that were once forest may now be savanna-like, while areas that were once grassland or open savanna may now are shrub lands or woodlands with little grass biomass.

2.3 Dynamics of savanna ecosystem

In the Savanna ecosystem, which is characterized by the co-dominance of trees and grasses, woody cover is a chief determinant of ecosystem properties. Scholes *et al.* (1993) discussed that the availability of resources (water, nutrients) and disturbance regimes (fire, herbivory) are thought to be important in regulating woody cover, but perceptions differ on which of these are the primary drivers of savanna structure.

2.3.1 Causes of bush encroachment

The causes of bush encroachment are elaborated upon the background of several important ecological models.

2.3.2 The ecological models

Ecological theories are the basis for seeking explanations to promote understanding of ecosystem dynamics and the forces that change them (Sayre and Fernández-Giménez 2003). The assumption behind the idea is that ecological models could provide guidance in assessing changes and identifying key components in complex systems, to assist policy makers in the process of decision making for future management (Oba *et al*. 2000b). The way the environment responds to various disturbance forces may influence management decisions. Since savannas are dynamic ecosystems, Pickett and White (1985) describe 'disturbance' as a major driving force in shaping the spatial structure and temporal dynamics of grazing systems. Ludwig *et al*. (1997) show that the shifts between tree-grass states are mediated by disturbances such as heavy grazing pressure that diminishes perennial grasses. Under heavy grazing, the herbaceous plant abundance is reduced, which may lead to bush encroachment (Coppock 1993, 1994). Displacement of individual plant species because of disturbance may cause shifts in plant communities (e.g. Hobbs and Mooney 1985), interrupted patterns of dominance (Wiegand *et al.* 1998), opportunities for the establishment of new species and improved species richness and diversity (Ansley and Castellano 2006). Major ecological models are discussed below.

2.3.2.1 The equilibrium model

Walter's Two-layer Model commonly known as equilibrium model assumes balanced competition; the superior competitor becomes self-limiting at a biomass insufficient to eliminate the poorer competitor (Walter 1971). It is reasonable to expect greater competitive overlap between trees than between trees and grasses. Similarly, greater overlap between grasses than between grasses and trees. Since mature trees dominate over grasses, the model predicts that all savannas should tend toward woodland with sparse understory of grasses. Those not currently in this state are unstable and presumably are held away from the equilibrium point by disturbances such as fire or browsing (Archer 1989). The model maintains that, if the grass layer is overutilised, it loses its competitive advantage and can no longer use water and nutrients effectively. This results in a higher water and nutrient infiltration rate into the subsoil. Such a scenario will benefit trees and bushes and allow them to dominate. The equilibrium ecological model considers high livestock population (and thus heavy grazing) as a factor contributing to the expansion of bush encroachment.

2.3.2.2 The non-equilibrium model

Because of the inadequacy of previous explanations for the occurrence of bush encroachment, several new models have been put forward to explain tree grass coexistence. The work of Ellis and Swift (1988), and Westoby *et al.* (1989), among others, has generated a new debate on the limitations of the equilibrium model, providing the alternative non-equilibrium theory. The non-equilibrium behavior of savanna ecosystems implies that they are less predictable, with a limited capacity for influences that could be induced by stocking density (Ellis and Swift 1988, Briske et al. 2003). The dynamics can be described best by the state-and-transition model, which identifies key components that drive the dynamics of bush encroachment. The State-and-Transition Model recognizes the dynamic nature of savanna ecosystems. According to this model, savannas are event-driven where rainfall and its variability plays a more important role in vegetation growth (and composition) than the intensity of grazing. It implies, therefore, that bush encroachment is not a permanent phenomenon and a savanna could be changed to its grass-dominated state by favorable management or environmental conditions. However, the mechanisms of bush encroachment have been a subject of much conjecture (Noy-Meir 1982, Archer 1995, Skarpe 1992, Westoby *et al.* 1989, Oba *et al.* 2000a).The alternative model suggests that the mechanisms of bush encroachment could be understood in terms of the state-and-transition model, which is based on the non-equilibrium ecological model. This model implies that rainfall variability and time are more important in driving bush encroachment than grazing pressure (Westoby *et al.* 1989, Asefa *et al.* 2003). Vegetation dynamics of savanna ecosystems can also be triggered by management practices due to human interferences. The state-and-transition model describes the mechanisms of bush encroachment in terms of spatial and temporal variability that combines different aspects of ecological processes in response to disturbances. Disturbance forces have shifted vegetation structure and composition along different trajectories and along alternative pathways. The forward and reverse shifts all result from different types of disturbances. This model therefore, widely serves as a conceptual framework for describing the dynamics of savanna ecosystems that incorporate multiple successional pathways.

2.3.2.3 Patch-dynamic model

Wiegand *et al*. (2005) have hypothesized that bush encroachment in many semi-arid and arid environments is a natural phenomenon occurring in ecological systems governed by patch-dynamic processes. Wiegand *et al*. (2005) hypothesized that any form of disturbance (example, grazing or rarely fire) can create space, making water and nutrients available for tree germination. Under low soil nitrogen conditions, the nitrogen-fixing trees have a competitive advantage over other plants and, given enough rainfall, may germinate in mass in these patches created by the disturbances.

Rainfall in savanna regions is often patchily distributed, both in time and in space (Sharon 1981, Prins and Loth 1988, Ward *et al.,* 2004). Therefore, the spatial overlap of high frequency rainfall events in a single year is a rare occurrence. In addition to local seed availability, this rainfall frequency is a necessary condition for the creation of a bush encroachment patch. The patchiness of rainfall leads to patchy vegetation patterns (often only several hectares in size) within an intermediate range of long-term rainfall levels only. If average rainfall is too low, there is insufficient soil moisture to support tree growth, while above a certain amount of rainfall, dense woodlands with mixed age distribution develop (Belsky 1990).

Competition experiments have shown that mature trees are competitively superior to grasses while grasses tend to outcompete immature trees (Moore *et al.* 1988). This asymmetry of competitive effects creates instability in the interactions between trees and grasses. Grazing effectively weakens the suppressive effect of the grass layer on young trees in a patch of a few hectares, leading to the conversion of an open savanna patch into a tree-dominated thicket (bush encroachment).

With time, tree growth and inter-tree competition will convert the bush-encroached patch to an open savanna (Scholes and Archer 1997). This prediction is supported by observations on bush-encroaching *Acacia reficiens* in arid Namibia, where mean distance between nearest neighbors increases with increasing tree size and trees become more evenly spaced with increasing size (by implication, weaker trees that are close to stronger neighbors are eliminated). These observations are supported by experimental data on this species that show that trees with nearest neighbors removed grew significantly faster on average than controls with no neighbors removed ($F = 4.627$, $P = 0.032$). For trees with neighbors removed, the increment in canopy diameter one year after removal was 25.31 ± 9.60% while the canopies of controls increased by 4.52 ± 8.26 % (Wiegand *et al.* 2005).

At the scale of the whole landscape, savannas can be stable, persisting over millennia because the landscape consists of many patches in different states of transition between grassy and woody dominance. According to this concept, bush encroachment is an integral part of savanna dynamics.

2.3.2.4 Disturbance models

One of the most widely cited disturbance models of tree-grass coexistence in savanna is that of Higgins *et al. (*2000). They simulated the effects of fire intensity on tree recruitment. Further, by including tree resprouting in their model, the role of fire was shown to limit tree recruitment, allowing adult mortality to remain low.

It is variation in rainfall and fire intensity that lead to variations in seedling establishment and tree recruitment that, against a background of low levels of adult mortality, allow a storage effect (Warner and Chesson, 1985) to promote coexistence. Warner and Chess (1985) considered the storage effect to promote coexistence of species when variable conditions that are only occasionally favorable for reproduction by long-lived organisms are 'stored' as long lived adults or dormant stages until conditions again become favorable.

Higgins *et al*. (2000) hypothesies that grass-tree coexistence is driven by the limited opportunities for tree seedlings to escape both drought and the flame zone into the adult stage. Bush encroachment occurs due to increased tree recruitment caused by reductions in grass standing hence fire intensity. They predict that rainfall-driven variation in recruitment is more important in arid savannas, where fires are less intense and more infrequent. For the storage effect as modeled by Higgins *et al.* (2000) to hold: (1) the environment must vary in such a way that each species encounters favorable and unfavorable conditions for reproduction, and conditions favorable for one species must be unfavorable to others, (2) the organisms must be long-lived, either as adults or dormant propagates (e.g. seeds), so that they can endure unfavorable conditions. The storage effect works best if established adults do not compete strongly, because strong competition could drive reproductively mature organisms extinct before favorable environmental conditions recur (Warner and Chesson, 1985). This last-mentioned point militates against the storage effecting savanna tree-grass coexistence because trees are known to compete strongly (Smith and Goodman 1986, Wiegand *et al*. 2005).

Furthermore, in the Higgins *et al.* (2000) model, stem growth rates >50 cm per annum (stem diameter) for encroaching species are required for trees to persist, and>70 cm per annum for tree dominance. This is unrealistic; measured mean annual stem diameter increments in *Acacia tortilis* and *A. radiana,* for example, are as little as 0.39 cm (Kiyiapi 1994, Wiegand *et al.* 2000). In addition, adult tree mortality rates must be very low for coexistence (<0.05), which may be lower than field data suggest (Higgins *et al.* 2000).

Another disturbance-based model that focuses on the role of fire (and its interaction with herbivory) is that of van Langevelde *et al.* (2003). These authors argue that there is a positive feedback between fuel load (grass biomass) and fire intensity. Increased levels of grazing reduce fuel load, making fires less intense and thus less damaging to trees. This leads to an increase in woody vegetation and a switch from open savanna to woodland. Browsers may enhance the effect of fire on trees because they reduce woody biomass. Indirectly, grass biomass is increased (assuming that there is strong competition between trees and grasses). As a consequence of increased fuel load (because there is more grass), fires are more intense and, consequently, more biomass is removed by fire. The ecosystem then switches from one dominated by trees to a mixture of trees and grasses. This model, like other fire-based models, does not explicitly take the effects of timing of fire into account. However, Van Langevelde *et al*. (2003) do recognize that changes in the timing of fires may enhance bush encroachment (Archer 1996).

Traditionally, anthropogenic fires take place at the end of the dry season (Homewood and Rodgers 1991, Smith 1986). However, people in a number of ecosystems now light fires at the end of the wet season or beginning of the dry season to obtain nutritious post-fire regrowth (McNaughton 1985). Higher fuel moisture and relative humidity at the end of the wet season should decrease the fire intensity per unit fuel load and, according to Van Langevelde *et al.* (2003), lead to the dominance of trees. Disturbances have been mooted as major determinants of savanna structure in a number of other models, with savannas being portrayed as inherently unstable ecosystems that oscillate in an intermediate state between those of stable grasslands and forests because they are pushed back into the savanna state by frequent disturbances such as human impact (Scholes and Archer 1997, Jeltsch *et al*. 1998, van Langevelde *et al*. 2003), herbivory,or drought (Scholes and Walker 1993), and spatial heterogeneities in water, nutrient, and seed distribution.

These disturbance-based models all suggest that bush encroachment occurs as disturbances shift savannas from the open grassland towards the forest end of the environmental spectrum.

2.4 Multivariate Techniques for Vegetation Analysis

In nature, individuals of species are usually grouped into population. The ratio of population mixtures varies from habitat to habitat. Some plants are more successful in particular habitat as compared to other habitats, which is largely governed by phylogenetic and physiological characteristics of the species (Kumar, 1997). Plant association, a basic unit of vegetation is defined as a plant community of definite floristic composition with uniform area of vegetation (Pandya, 1961; Pandya *et al*., 1968).

A plant community is characterized by its essential homogenous physiognomy and ecological structure and by its floristic composition, at least with regard to dominance (Tothill 1978). The distribution and association of plant species is explained by common requirements for environmental gradients. Kershaw (1973) discussed the four major causal factors for positive or negative species association. These include similar or dissimilar environment requirements, modification of the environment by one species allowing establishment by other species, production of toxins and competition. The pattern of the distribution and association of different species is explained using different multivariate analysis techniques.

2.4.1 Classification

Classification has been widely used in the past as a necessary tool to produce some order into a collection of facts and to enable one to communicate descriptions and ideas on relationship about the type of vegetation recorded and make comparisons with similar or dissimilar samples from elsewhere (Duffey 1974).

Cluster analysis is the general term applied to the many techniques used to build classifications.

The concept of classification in ecological works aims at grouping individual stand or species into homogenous categories based on their similarity with one another. The method of classification could be hierarchical or reticulate, divisive or agglomerative and monothetic or polythetic (Krebs 1989). In hierarchical classification methods, the groups are themselves arranged into hierarchy - like tree. The classes at any one level are subclasses of a class at higher level. Reticulate classification however, defines clusters separately and the link between them is expressed in the form of network rather than a tree. Divisive classification begins with the whole set of samples and divides it into classes from up to bottom; in agglomerative classification however, it starts at the bottom and work upward, beginning by joining the two most similar units into a single group. In a monothetic classification two sister groups are distinguished by a single attribute, such as the presence of one species however, in a polythetic classification, overall similarities are used, based on all the attributes. Measures of similarity in any classification may be expressed based on qualitative (or binary) data or quantitative data based on some measure of importance such as population size, biomass or cover. The association between pairs of units could be described as a similarity, proximity, dissimilarity, distance or association (Digby and Kempton 1996).

A Hierarchical-agglomerative-polythetic technique of classification has been widely used for plant community studies by many ecologists. Whittaker (1987), Krebs (1989) and Digby and Kempton (1996) recommended this technique for ecological studies to cluster species and samples. The technique had been applied to classify the tropical vegetation. Sebsebe Demissew (1980), Zerihun Woldu(1985) and Tamirat Bekele (1993) for example, used the technique for different vegetation studies in Ethiopia.

2.4.2 Measure of Species Diversity

Diversity in ecological research could refer to species, habitat or genetic diversity indicating variability between species, habitats and individuals respectively (Spelleberg, 1994). Species diversity could be viewed from different approaches in terms of alpha, beta and gamma diversity (Rosenzweig, 1995). *Alpha diversity* refers to the diversity of species within particular habitat or community. *Beta diversity* is a measure of a rate and extent of change in species along a gradient from one habitat to another: it is between habitat diversity that measures turnover rates. *Gamma diversity* on the other hand is a diversity of species in comparable habitat along a geographical transects and is dependent on the two.diversity types.

Diversity indices are mathematical expressions that summarize data recorded in one or sets of figure. Among the different coefficients widely used to compute diversity of a community are species richness, evenness, and heterogeneity (Krebs, 1989).

Species richness is the simplest concept of species diversity that implies the number of species in a community. Heterogeneity is a measure of the probability of which two individuals randomly picked from a community belong to different groups (species). Evenneness is a measure of equitability. It attempts to quantify the unequal representation of species in a community against a hypothetical community in which all species are equally common (Lioyd and Ghelardi, 1964).

3. MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location

Nechsar National Park was established as a wildlife conservation area in 1974 for the protection of one of the endangered mammals, the Swayne's Hartebeest (*Alcelaphus buselaphus swaynei*). The park has an area of 514 km^2 (SNNPRS BOA 1996). It is located near Arbaminch town, 505 km south of Addis Ababa. It is positioned in the Ethiopian Rift Valley between 5^0 5' and 6^0 N and 37^0 32' and 37^o 48' E (Figure 1). The Nechsar plain of the park is bounded by the Amaro hills in the southeast, Harre Mountain in the east, undulated Degabulle terrain in the west and Lake Abaya and Lake Chamo to the north and south respectively (Bolton 1970). The study site for this specific study was the Grass plain located at the eastern part of the park. The total area included in the study is estimated to be about 270 hectare between 1,200- 1400 m elevation extending from Degabule in the west to the Harre hills in the east and from Dachie in the north down to the course of the dried-up Mio-River in the south. The name Nechsar means white grass in Amaharic and reflects the striking pale yellow color of the plain. The grasslands also extend onto the hill-slopes surrounding the plains (Bolton 1972) (Figure 2.)

N E C H S A R N A T I O N A L P R K

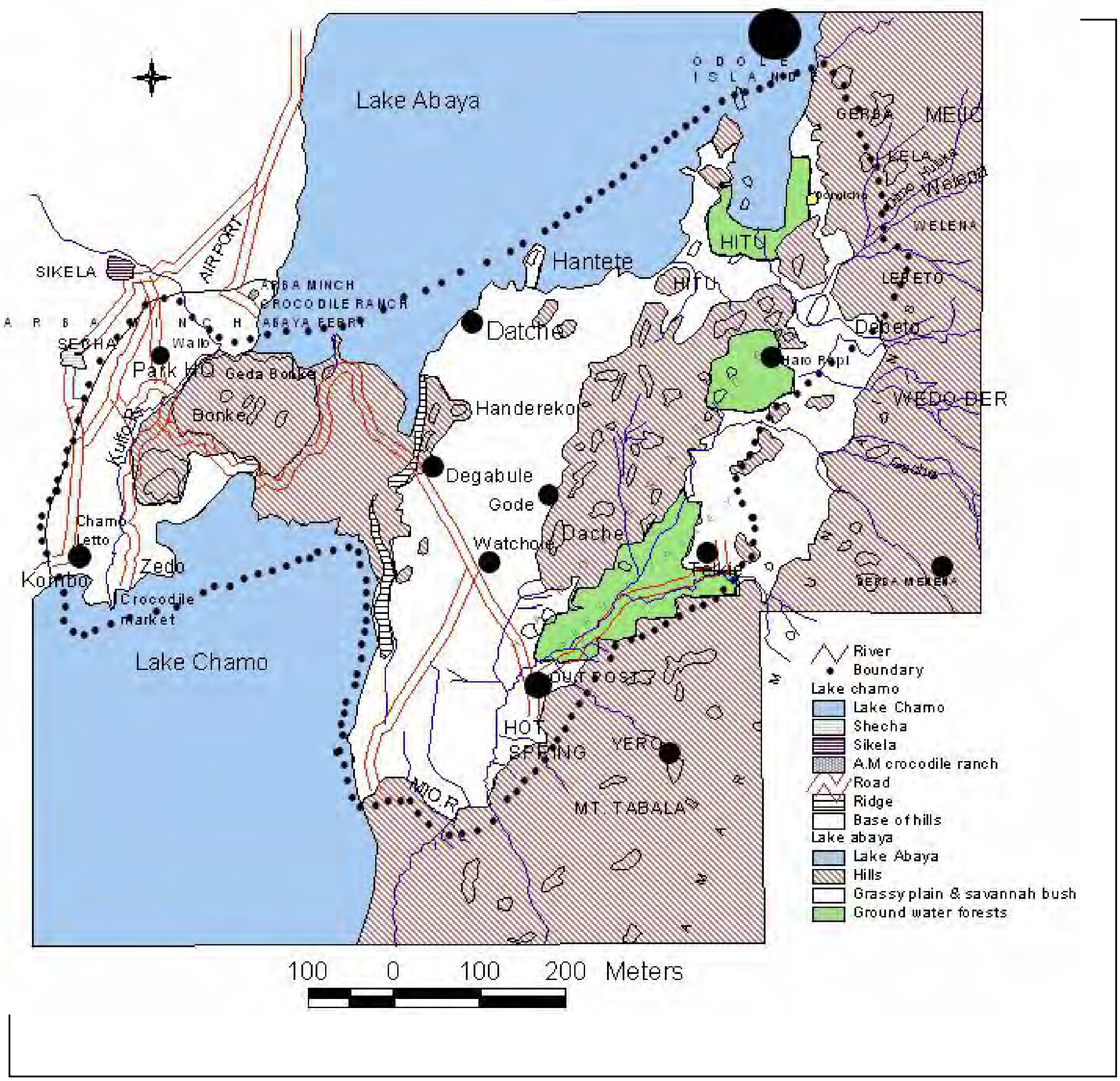


Figure 1. Location Map of the study area

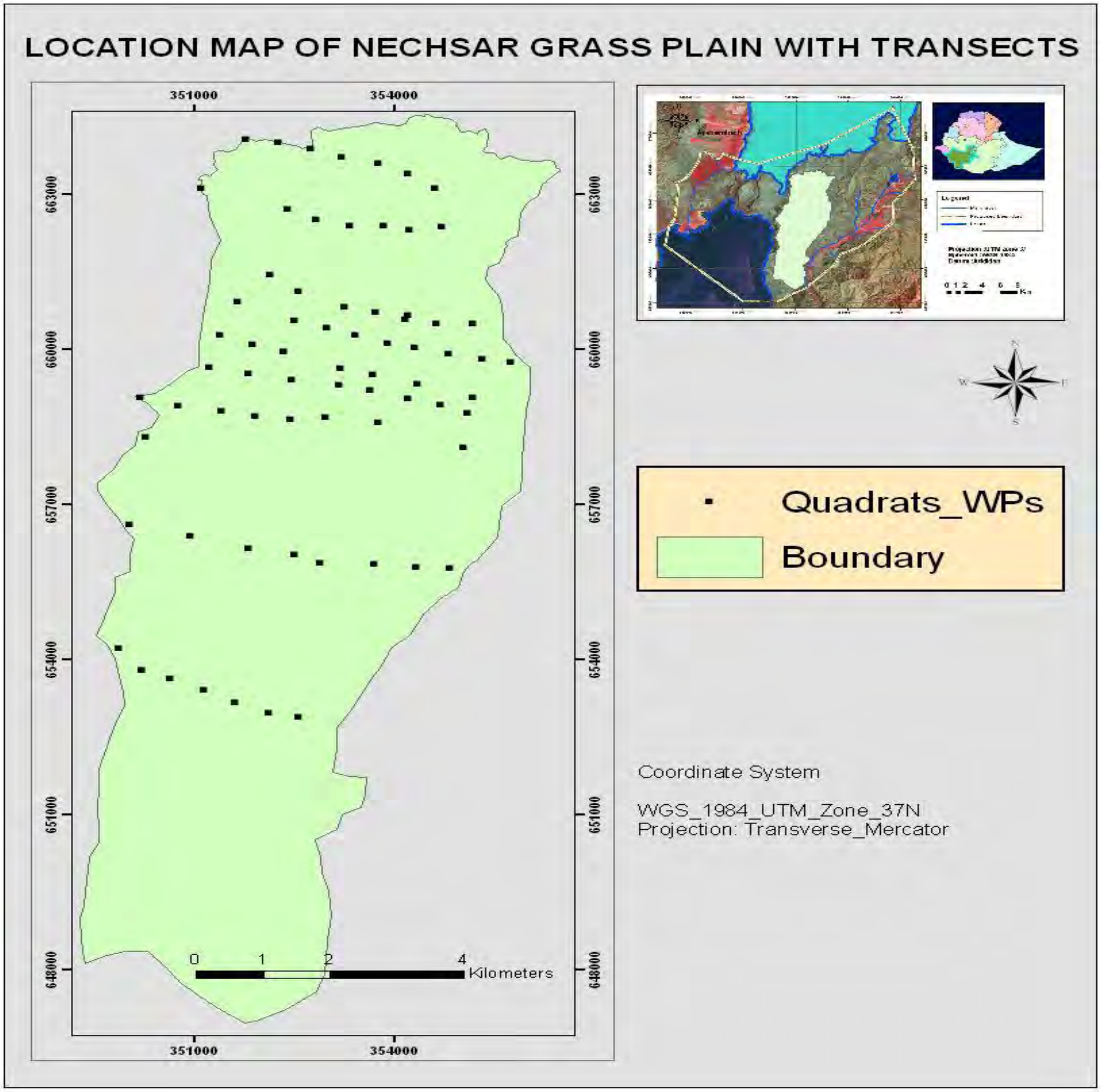


Figure 2 Location map of Nechsar grass plain with transects

3.1.2. Climate

According to Ethiopian climatic classification, the Abaya Chamo basin is characterizing as hot semiarid, warm temperate, tropical climate (EPA 2005). The climate diagram below (Figure 3) is drawn from from the rainfall and temperature information collected from the Arbaminch metrological station for the year 1998-2007GC. It summarizes the general climate information for the rainy and the dry seasons in the study area. According to the diagram when temperature exceeds the rainfall, the area covered in this time is considered dry season in while in contrast, when rainfall exceeds temperature, there is a wet /rainy season.

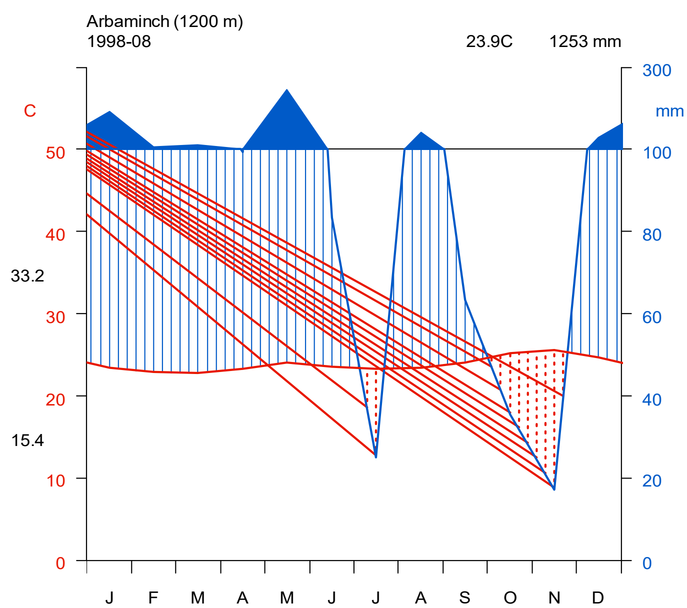


Figure 3 Climatic Diagram of Nechisar Park (Data Obtained from Arba Minch University Metrological Station).

3.1.4 Geology and Soil

Environmental Protection Authority (2005) describes that the Ethiopian Rift Valley is part of the great East African Rift Valley, which was formed as a result of Tertiary-Quaternary tectonic movements. The regression of the Mesozoic sea to the southeast and the occurrence of a major up lift, which is known as the Arabo-Ethiopian swell, preceded the formation of the rift. The Tertiary uplift and formation of the rift was followed by the extrusion of large masses of basaltic magma through fissures. As a result, in the Rift Valley lakes basins, including that of Lake Abaya and Lake Chamo, basalts, ignimbrites, pyroclasts and lacustrine sediments overlie the ancient basement rock. Other volcanic products such as ash flow, tuffs, trachytic lava flows, alkaline and per alkaline silicics, rhyolites and pumicous materials are found distributed through out the basin. Young volcanic and sedimentary rocks (Miocene to Recent) dominate the Rift Valley basin that lies within old (Precambrian) shield rocks. Quaternary basalt flows (recent basalts) are found near Arba Minch town and the hill separating the two lakes “the Bridge of God”. The rift valley floor near Lakes Abaya and Chamo are filled with alluvial sediments.

Makin *et.al.* (1975) described soil types in the Rift Valley as closely related to soil parent materials: basalt, ignimbrite, lava, gneiss, volcanic ash and pumice, riverine and lacustrine alluvium. The soil of Nechsar Plains and surrounding bushland is black cotton soil with high clay content. According to Bolton (1970) the rugged mountainous parts of the park have brown calcareous loam derived from volcanic rocks. The soil ranges from patchy dark clay alluvial soils along the river basin to dominating dry cotton soils with poor drainage.

3.1.5 Topography and Hydrology

Asaye Nigusse (2008) described the topography of the park as an area that has an altitude ranging between 1094 m and 1383 m above sea level m. a. s. l while the 90-meter contour interval SRTM gives an elevation that ranges between 944 m-3478 m a.s.l. covering the Nechsar Park and surrounding highlands as shown in the DEM (Digital Elevation Model) hill shade values, which is scaled in meter (Figure 4).

The Nechisar plains are bounded in the north by Lake Abaya and in the south and southwest by Lake Chamo. It is also bounded by the Amaro hills in the east, and undulated Degabulle terrain in the west (Bolton 1970). Lake Chamo receives runoff from river Kulfo originating from areas receiving rainfall following the climatic pattern of the southern parts of Ethiopia. This indicates that it receives runoff only once a year, unlike Lake Abaya. Furthermore, Lake Abaya receives runoff from four rivers, while Lake Chamo receives runoff from only two rivers. Lake Abaya receives 86.50 million m^3 of discharge annually, while Lake Chamo receives only 29.25 million m^3 of discharge. This partly explains why Lake Chamo is more sensitive to climatic fluctuations than Lake Abaya. Kirubel Tesfaye (1985) describes the river Seremele that flows along the eastern most corner of the plain as one of the

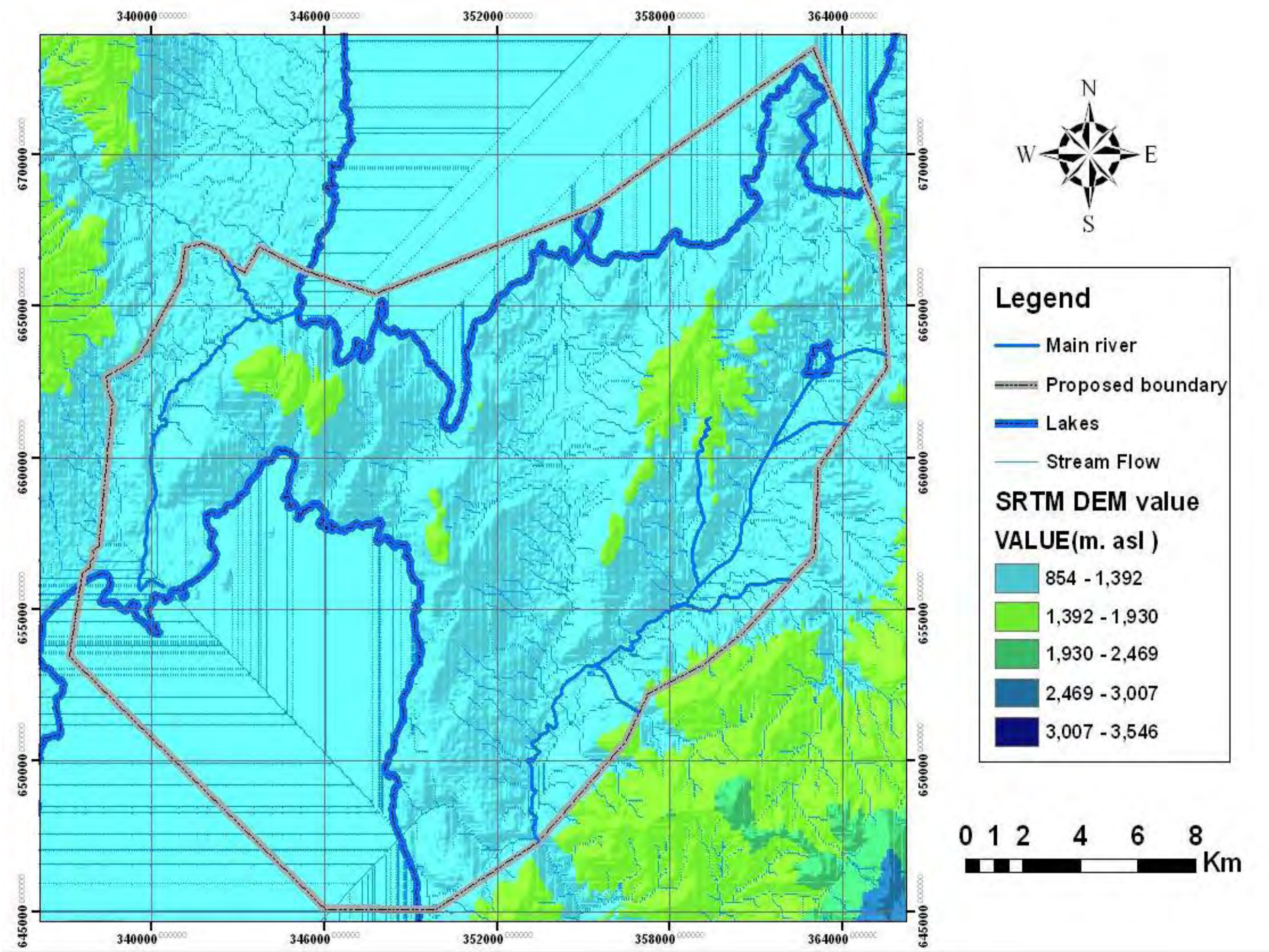


Figure 4 Topography and hydrology of the study area (APC,2006)

permanent sources of water and it has both ecological as well as social influence concerning the settlement pattern in the study area.

The seasonal river, flood plains and valley bottom are good providers of dry season grazing areas for domestic and wild herbivores. The Kulfo River flows through the north of Arbaminch and then cuts across the neck of the narrow isthmus of land and ends in a swamp on the shore of Lake Chamo. Lakes and lakeshore areas are interesting component of the great biodiversity of the park.

3.1.6. Socioeconomics

According to SNV (Netherlands Development Organization) (2006) reported that Arbaminch Zuria Woreda covers an estimated area of 168,172 ha with estimated population of 232,000 with 50.8% male and 49.2% female proportion. Most of the area is mid-highland whereas 33% of the land is classified as low land and 14% as high land. The major crops growing in the area are maize, sorghum, teff, beans, bananas and mangos. The area is famous for its fish from the lakes and for the production of fruits such as banana, mango and highland fruits like apples and pears. The area is also on an important tourist route from Addis Ababa to Southern Ethiopia (Omo etc.).

Since February 2005, African Parks (AP) has taken over the formal management of Nechsar National Park near the town of Arbaminch. According to Environmental Protection Authority (2005) socioeconomic study showed that the economic bases of the community in wereda adjacent to the national park are farming, fishing, and service (hotels and tour operators) and petty trade. In the case of Nechsar, the communities moving into the park came from two distinct ethnic groups, with different traditions of land use: the Kore people from the Amaro Mountains who cultivated land along the Sermele river floodplain and the Guji Oromo people who are nomadic pastoralists grazing approximately 4000 - 5000 head of stock inside the park. However, both these communities lived without schools, clinics and other essential services, and the government plan to resettle them to suitable areas near the Park where basic services can be provided was not yet succeeded.

3.1.3 Biological and Habitat diversity

Duckworth (1992) indicated that the Nechsar plain has five major habitats, the first is the eastern shores of the two rift valley lakes that are an abrupt rise into the Nechsar plains that are the dominant feature of the park and the main source of feed for grazing animals, and it is the Degabulle Terrains. The second habitat type is the grass plain that covers an area of 275 km^2 and is covered by the grass *Chrysopogon aucheri* that whitens during the dry season and grows on friable black soils. These larger, central plains support a population of Zebra, Swayne`s Hartebeest, Grants gazelle and other plain games. The third habitat is the eastern part of the plain, the area gradually changes to a fourth habitat type that is dry Acacia savannah and then to the fifth habitat type which is the thickly wooded valleys and foothills of the imposing Amaro Mountains that are the eastern wall of the Great Rift Valley. The eastern park boundary runs along the top of the first string of the foothills. At the foot of Mount Tsebele, there are hot springs that are regularly visited by local people for medicinal use.

The African Parks Conservation (2006) reported that there are three major habitat types in Nechsar National Park. The first habitat is the evergreen groundwater forest in the western sector, which supports an exceptionally diverse range of plant species. This habitat is dominated by *Ficus sycomorus* and *Lecanodiscus fraxinifolius* species of trees that are up to 30 m tall. This forest is said to be unique in Africa and its existence, is closely associated with the series of freshwater springs, known as "Arba Minch", meaning" Forty Springs". Originating from the western edge of the forest, at the foot of the western escarpment, these springs provide the source of water supply to Arbaminch town, as well supporting the natural forest biodiversity. The second habitat is the narrow isthmus (less than 5 km wide separating the two lakes: Abaya and Chamo), which is mostly old lava flows and is covered by dense thickets that in places are almost impenetrable. This is the main habitat in the park of Guenther`s dikdik and is also excellent habitat for black-rhino.

Lastly, the third habitat type is the wet lands and aquatic environments in and around Lakes Chamo and Abaya it includes the Kulfo River flows through the north of Arba Minch and then cuts across the neck of the narrow isthmus of land and ends in a swamp on the shore of Lake Chamo. The lakes and lakeshore areas are an interesting component of the great biodiversity of the park.

I) Flora

Tamirat Andargie (2001) classified the vegetation of the eastern part of the Nechsar plain into six major plant community types namely, *Cenchrus cillaris - Balanites aegyptiaca* community type. This community type was a woodland located at the most eastern part of the plain. The community was described as a high cover of *Balanites aegyptiaca, Acacia senegal, A. mellifera, A. tortilis, Cadaba farinosa, Abutilon figarianum, Cissus quadrangularis, Digitaria abyssinica and Justica flava.*The second plant community was *Arstida kenyensis* community*.* It was grassland that was located in the eastern plain lying south-west along the lengeth of the park and north of the hot spring at the bottom of the Amaro Mountain (near the camping site). *Arstida kenyensis, Digitaria velutina, Ocimum urticifolium, Abutilon figarianum, Indigofera ambelcensis, and Chloris roxburghiana*

Figure 5. Some flora of the grass plain of Nechsar National Park

were dominant vegetation in the community type. The third plant community type was *Chrysopogon plumulosus - Ischaemum afrum- Themeda triandra.* It was also a grassland dominated by *Chrysopogon plumulosus, Ischaemum afrum, Themeda triandra Pennisetum mezianum, Lintonia nutan, Abutilon figarianum Triumfetta flavscens, Rhynchosia malacophylla, and Aerva lanta.* The fourth plant community type was *Chrysopogon plumulosus-Moncymbium ceresiforme.* It was a woodland that was located at the Belti plain, isthmus of land between Lake Abaya and Lake Chamo extending to the edge of Lake Abaya. Its vegetation was characterized by a high cover of Acacia nilotica, A. senegal, A. mellifera, A. oerfota, *Chrysopogon plumulosus, Digiteria velutina, Cenchrus ciliaris, Lintonia nutans* The community was entirely dominated by grass species *Chrysopogon plumulosus, Ischamum afrum* and herbaceous species, *Rhynchosia malacophylla,and Lintonia nutans.* The fifth community type was described as *Sehima nervosum* type*,* this community type was located in the Degabulle hills and its escarpment near Lake Abaya the major vegetation was *Sehima nervosum, Themeda triandra, Tephrosia uniflora, Cymbopogon cesium, Loudetia flavida, Balanites rotundifolia,* and the sixth community type was *Loudeta flavida* community located in the surrounding Gada mountain. The dominant vegetation was *Acacia senegal, A. seyal, Commiphora africana, Ozoroa insignis, Combretum molle, Rhus natalensis, Harrisonia abyssinica, Loudeta flavida, Moncymbium ceresiforme and Cymbopogon cesium.*

II) Fauna

According to Environmental Protection Authority (2005), Nechisar National Park is popular for its wilderness and the unique scenery being located on the hills and plains between the two majestic lakes of Abaya and Chamo. The high population of crocodiles in the lakes and the Nile Perch are unique to the waters of Lake Abaya and Chamo. The species diversity of mammals is very impressive. The mammal diversity is next to the Mago National park. The diversity of the mammalian density owes to its inaccessibility to people other than the pastoralists who probably lived in harmony with the animals.

According to African Park Conservation (2006) report, due to geographical isolation and wide variety of ecological environment, the park supports a variety of wild animals (mammals, birds, reptiles, amphibians and fish). Large mammals currently present are the common Zebra, Swayne`s Hartebeest, Grant`s gazelle, Greater kudu, Guenther`s dikdik, Anubis baboon, Colobus monkey, Hippopotamus, Spotted hyena, Mountain reedbuck, Black-backed jackal, Side-striped jackal, Golden jackal, Defassa waterbuck, Bushbuck, Klipspringer, Warthog and Bush pig are said to be still present and Lions are occasionally seen. Nechsar is particularly important as a sanctuary for Swayne`s Hartebeest (sometimes also referred to as the Qorkay) that is endemic to the Horn of Africa but currently not found in Djibouti and Somalia and only survives in three isolated populations in Ethiopia. The total population in Ethiopia probably does not exceed 250 animals (African Parks Conservation 2006).

The open plains support three species that are little known birds in Ethiopia; they include isolated population of White-tailed lark, the endemic Nechsar nightjar (known from only one record of a broken wing found on the plains in 1990) and the rare star-spotted nightjar. There are also a number of other special bird species in the park including Lammergeyer, Red-winged francolin, Whitefronted black chat, African cuckoo hawk, Bat hawk, African swallow-tailed kite, Ovambo sparrowhawk, Finfoot, Scarce swift, Grey cuckoo shrike and Reichards.seed-eater.

Lake Chamo, which is part of Nechsar Nationa Park, supports large population of crocodiles (many individuals in excess of 5 m in length) with a particular concentration at the site known as the Crocodile Market, the largest hippo population in Ethiopia, and abundant fish including Nile perch. The bird life on the lakes and in the groundwater forest of Nechsar national park is very good with 343 species recorded. Nechisar is one of the sixty-nine Important Bird Areas in Ethiopia. The special migratory species are Lesser kestrel, Pallid harrier and

Lesser flamingo on the lakes. Figure 6 shows the wildlife distribution in the park where African Parks conservation collects this data for monitoring the wildlife movement and their density in the park.

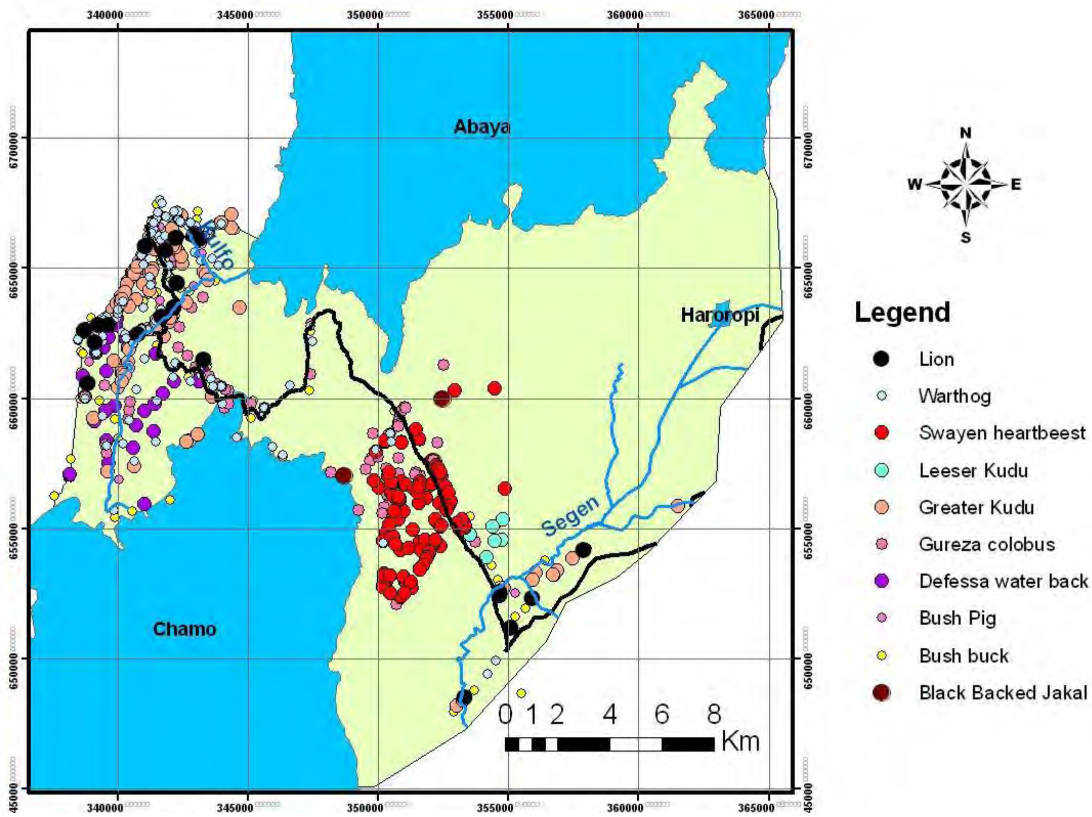


Figure 6 Wild life distribution in the grass plain of Nechsar National Park (APF, 2006)

3.2 Sampling techniques

A reconnaissance survey was made to the study area before the actual data collection was carried out. During this survey, visual observation of the pattern of the invasive bush species encroachment and ecological condition were assessed in the Grass plain.

The method of vegetation sampling was based on Braun-Blanquet (1932) as described by Muller-Dombois and Ellenberg (1974). This approach also has been applied successfully in Ethiopian vegetation study by Sebsebe Demisew (1980), Zerihun Woldu (1985), Tamirat Bekele (1994), and Tamirat Andargie (2001).

Floristic data collection was made between August and November that was after the first rainy season in the area when maximum vegetation cover was expected. Preferentially sampling technique was used as a sampling design. Transects were laid down west to east across visually observable vegetation gradient in the grass plain. The first relev`e was established and the subsequent relev`es were established at 500 m intervals on a linear transect. The size of the relev`e is 20 m x 20 m which was 400 $m^2$. For the herbaceous species, 400 $m^2$ releve`s size was further subdivided to 5 m x 5 m = 25 m^2 subplots which was counted 16 subplots from each relev`e. Among 16 subplots, data was taken from five subplots four from each corner and one from the center. The total number of transects included were ten and the total number of releve's were seventy-five.

3.3 Data Collection

Data were collected in two rounds in August and November after a rainy season in the area. Data on floristic composition, percentage cover of species, density of woody plants, tree height and DBH, percentage bare ground cover, position, and percentage stone cover (ground cover with stone),were collected from 75 plots each with 20 m x 20 m. Altitude was recorded using Thommen classic altimeter. Position and altitude were recorded using Garmin GPS. At the beginning, 50 m long meter tape was stretched and used as a base line, from where plastic colored ropes were used to mark the plot at 5 m distance on both sides. Then all plant species rooted within the plot were recorded. Tree/ bush were defined as a woody plant with a diameter at a breast heightt (DBH) ≥ 2.5cm. Saplings are young woody plants with DBH < 2.5 and height > 1 m where as seedlings as woody plants with DBH < 2.5 cm and height ≤ 1m. This method of size classification was applied by Gemedo Dalle *et al.* (2006). The height and DBH of woody plant species was taken by a meter tape of 50 m length. Covers of each woody plant, herbaceous plant, bare land cover, and stone cover were visually estimated from the total plot using 5 m x 5 m. Evidences of human and livestock activity of significance were assessed and recorded. Information about land use practices and invasiveness of bush species in the grass plain, including settlement history, livestock population was communicated through group discussion and key informant interview with peoples from park management and the communities in the park.

3.4. Plant species identification

All plant species encountered in the study area were collected. The specimens were pressed, dried and identified at the National Herbarium (ETH). Identification was made by comparison of specimens with already identified speciemens; and referring different flora publications. For this study, nomenclature follows Flora of Ethiopia and Eritrea.

3.5. Data Analysis

Cluster analysis of releve`s was carried out using, SYNTAX ecological package to identify plant community types (Podani 2000). Classification of stand was done by divisive – hierarchical technique using average linkage clustering strategy (Digby and Kempton 1996, krebs 1989). The most abundant plant species were used for naming of the community types. Attempts were made to identify possible factors for the formation of plant community types.

3.6 Diversity Indices

Estimation of species diversity for each community was computed using Shannon-Wiener measure of Diversity (H') given by $-\sum$ (pi*ln (pi)) where, pi was the proportion of total sample belonging to i^{th} species. Shannon-Wiener Measure of of Evenness (J') is computed as H'/H max where, H max is the maximum possible value of Shannon function given by e^S (S is number of species in the community). The estimated species percentage- cover value was transformed into Van der Mareel (1979) scale for cluster analysis. The scale for the percentage cover value is given as follow 1 = rare species, 2 = 0-3% cover, 4 = 5-9% cover, 5 = 9-19% cover, 6 =19-37% cover, 7 = 38-63% cover, 8=63-88% cover and 9 = more than 88% cover.

3.7 Other statistical tests

Preliminary descriptive statistics for relative frequency (RF) of distribution, total density of bush species and cover abundance was calculated. Analysis of variance (ANOVA) for ecological variables and the variability between different community groups was computed using SPSS computer Software program (SPSS, 1989-96). Spearman's correlation matrix between the environmental factors was computed using MINITAB computer program (MINITAB, 1995).

4. RESULTS

4.1 Floristic composition

In the study, 131 plant species representing 44 different families were recorded from the 75 relev`es (Appendix 1). From the total number of species recorded in the grass plain of Nechsar National Park, family Poaceae (26 species.) comprises the highest species number followed by the family Fabaceae (15 species.), Malvaceae (9 species.) and Lamiaceae (6 species.) (Appendix 1). Herbs are the dominant life forms (65%) followed by woody species (31.3 %) in the area in terms of cover abundance (Figure 7). Among the woody species, 8.4 % are trees and 22.9% are shrubs or bushes (Figure 7). The genus *Acacia* in Fabaceae had the highest number of species (5 species).

Table 1 Plant family composition in the grass of Nechsar National Park

NO.	Family Name	Percent
1	Poaceae	19.85
2	Fabaceae	11.45
3	Malvaceae	6.87
4	Lamiaceae	4.58
5	Euphorbiaceae	3.8
6	Amaranthaceae	3.82
7	Acanthaceae	3.73
8	Capparidaceae	3.05
9	Cucurbitaceae	3.05
10	Anacardiaceae	2.29
11	Asclepiadaceae	2.29
12	Asteraceae	1.53

13	**Balanitaceae**	**1.53**
14	**Salvadoraceae**	**0.76**
15	**Tiliaceae**	**3.82**
16	**Verbenaceae**	**1.53**
17	**Nyctagenceae**	**2.29**
18	**Solonaceae**	**1.53**
19	**Others**	**22.14**

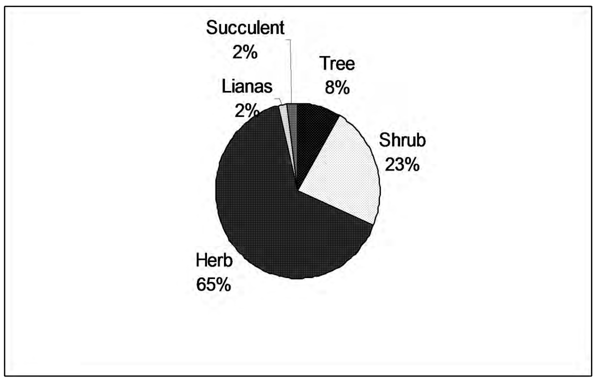


Figure 7 Distribution of plant life forms in the grass plain of Nechsar National Park

The species frequency distribution showed that only few species have higher percentage occurrence and the majority of the species have small representation. 74% of the species have relative frequency between 0.1 and 0.2%. 0.8% of the species have relative frequency between 0.9 and 1% (Figure 8). *Abutilon anglosomaliae (RF = 0.95)*, *Bothriochloa inssculpata (RF = 0.81), Rhynchosia malacophylla (RF = 0.79), Endostemon tereticaulis (RF = 0.72), Commelina diffusa (RF = 0.70), Digitaria abyssinica (RF = 0.67), and Pupalia lappacea (RF = 0.61)* are among plant species frequently encountered all over the grass plain and have relative frequency greater than 0.6 (Figure 8).

The Whittaker plot of species-abundance curve shown in Figure 9 has a logarithmic distribution very slightly deviated from the theoretical plot, which is more or less a straight line (Figure 9). Nine species contributed to 38.5% of the total species cover. Among them Abutilon *anglosomaliae* (6.5%), *Dicrostachys cinerea* (6%), *Chrysopogon plumulosus* (5.3%), *Bothriochloa inssculpata* (4.5%), *Pupalia lappacea* (4%), *Loudetia flavida* (4%) are species with higher cover abundance in the grass plain of the Park.

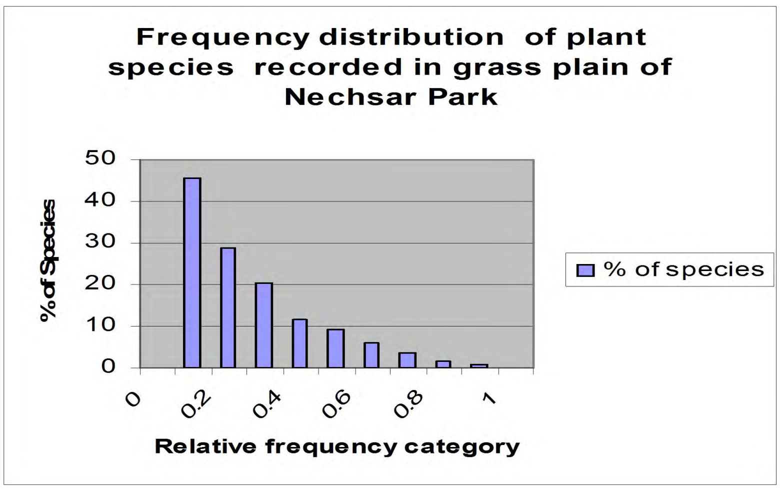


Figure 8 Frequency distribution of plant species in the grass pain of Nechsar National Park

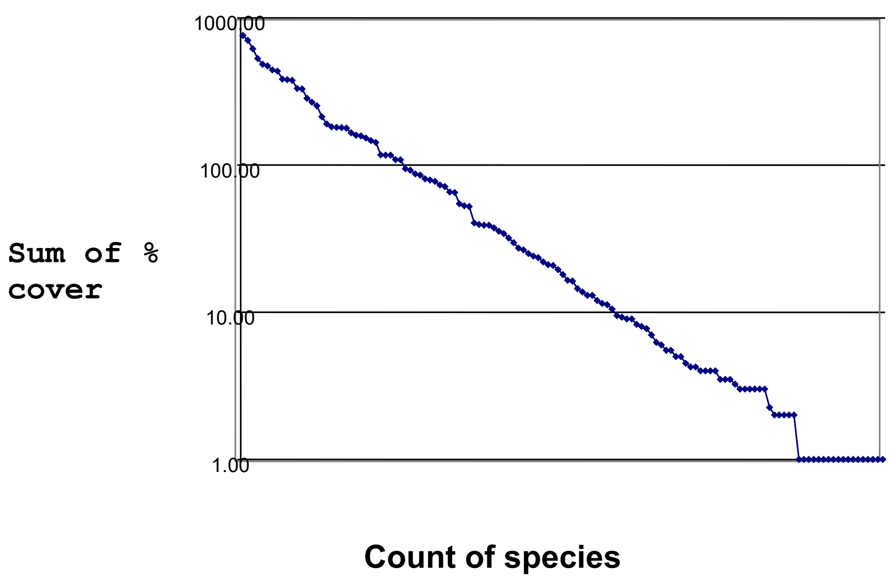


Figure 9 Whittaker plot of species - abundance data for the plant species recorded in Nechsar National Park

4.2 Description of community types

The cluster analysis of the quantitative vegetation data produced six major clusters of vegetation groups at 0.25-similarity level (Figure 10). The homogeneous groups that resulted from the analysis were identified as plant community types and subsequently designated as 1, 2, 3, 4, 5, 6 and one single relev`e as the seventh communityas outlier. Each community was named by the dominant plant species occurring in the group. The average percentage cover value of the species was used to determine the dominant species in each community. The Synoptic abundance cover value (Table 2) was used to clearly determine the dominant, species in the community. The six community types were described below.

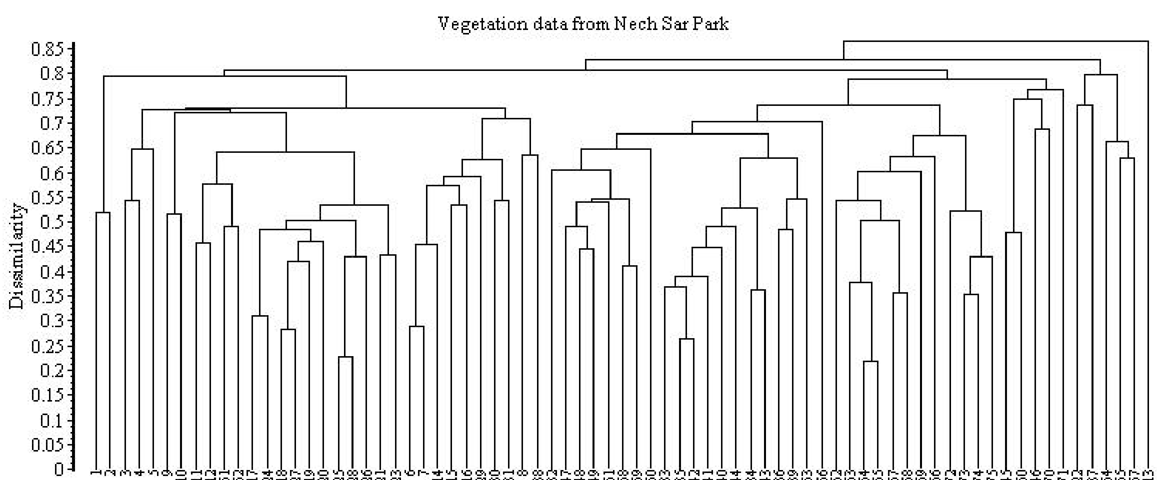


Figure 10 Dendrogram showing the classification of the releves in the grass plain of Nechsar National Park Using Syntax similarity ratio

Table 2 Synoptic cover - abundance value for species reaching of ≥2% at least one community.

Botanical Names	C-1	C-2	C-3	C-4	C-5	C-6	C-7
Acacia nilotica	**46.75**	3.42	14.65	0.28	18.2	1.65	0
Chloris roxburghiana	**13.75**	0.42	13.15	1.45	1.2	0.2	0
Heteropogon contratus	**14.5**	0.68	0	0.85	7.2	0	0
Conchorus trilocularis	**6.75**	0.6	0.4	1.45	0	0.4	0
Ziziphus spina-christi	**4**	0	0	0	0	0	0
Boerhavia diffusa	**3**	0	0	0	0	0	0
Chrysopogon plumulosus	6	**22.55**	0	35	0	2.4	0
Abutilon anglosomaliae	11.75	**18.7**	10.4	6.12	1.65	7	1
Cyperus obtusiflorus	1	**4.76**	1.75	4.05	0	0	0
Acacia seyal	3	**4.4**	3	1.74	0	0	0
Lintonia nutans	0.5	**3.78**	0.525	3.18	2	3.8	0
Dyschoriste multicaulis	0	**3.78**	0.85	1.62	2.7	2.6	0
Endostemon tereticaulis	2.5	**3.55**	3.1	1.13	0.65	1.65	0
Dicrostachys cinerea	0	11	**34.53**	3.03	7.6	0.65	0
Achyranthes aspera	0	1.4	**17**	2.64	2.64	4	0
Acacia mellifera	1	0.66	**12.65**	1.2	1.2	2.65	0
Pupalia lapacea	1	9.05	**10.8**	5.55	1.2	5.3	0
Commelina diffusa	0	4.73	**10.05**	3.72	2.2	1.2	0
Plectranthus barbatus	0	0.55	**5.4**	2.94	2.94	4.7	0
Setaria verticillata	0	0.92	**2.875**	0.94	0.94	0.8	0
Bothriochloa insculpata	0	4.48	4.48	**11.76**	6.1	1.15	0
Loudeta flavida	0	0	2.6	**10.63**	**10.63**	21	0
Digitaria abyssinica	0	0	1.2	**9.73**	9.6	3.3	0
Triumfetta flavescens	0	4.01	2.27	**9.58**	1.65	0	0
Rhynchosia malacophylla	0	4.08	1.15	**8.28**	1.2	0.45	0
Themeda triandra	0	3.02	0	**8.19**	0	0	0
Leucas glabrata	0	0.11	0.5	**4**	0.5	0	0
Sehima nervosum	2.5	0	4.4	0.45	**20**	0	0
Acacia senegal	0	0	1.32	1.9	**16.2**	0.45	0
Pennisetum cladestinum	0	0	1.2	1.04	**7.5**	0.7	3.5
Bothriochloa insculpata	0	4.48	4.48	11.76	**6.1**	1.15	0
Rhus natalensis	1.5	0.1	0.42	0	**5.45**	1.15	0
Cynodon dactylon	0.5	0	1.9	1.64	**5.4**	0	0
Acacia oerfota	0	0	0	2.53	0	**37.6**	0
Barleria acanthoides	0.5	0.66	0	1.03	0.4	**7.4**	6
Cenchrus pennisotiformis	0	0.1	0.22	2.59	0	**6**	0
Ruellia patula	1	0.68	0.2	0.47	0	**4.7**	0
Pentarrihum somalense	0	0	0	0.39	0	**4.4**	0
Tetropogon vilosus	0	2.4	2.42	0.54	0	**4.1**	0
Lintonia nutans	0.5	3.78	0.525	3.18	2	**3.8**	0
Sericcomopsis hidebrandtii	0	0	0.2	0.39	2.4	**3.55**	0
Enneapogon cenchroides	0	0.21	6.15	6.67	0.2	7.1	**31**
Polygala erioptera	0	0	0	0	0	0	**16**
Aeschynomene schimperi	0	1.01	1.425	2.08	0	1.4	**3.5**
Tepherosia unifloria	0	2.74	0.325	0.32	0	0	**3.5**
Bidens biternata	0	2.55	0.1	0.06	0	0	**2.25**
Indigofera ambelacensis	1	0.37	0.3	0.16	0	0	**2.25**

Type 1. *Acacia nilotica-Heteropogon contortus(n = 2)*

This community type is a woodland represented by two relev`es and thirty four plant species. It is located at the southern escarpment of Lake Abaya at the foot hill of Dachie Mountain facing towards the east. High stone cover (9%) and bare land cover (25%) also characterize the Community 1. The altitude ranges from 1,262 to 1,300 m. a. s. l. The community is characterized by high cover of *Acacia nilotica, Grewia velutina, Rhus natalensis, and Dobera glabra* in the shrub layer. *Boerhavia diffusa, Cochorus trilocularis Abutilon bidenatum,* and *Achyranthes aspera* in the non-grass herbaceous layer and *Heteropogon contortus, Eragrostis schweinfurthii, Chloris roxburghiana, Chrysopogon plumulosus* and *Sehima nervosum* as a grass co-dominant.

Type 2. *Chrysopogon plumulosus -* Abutilon *anglosomaliae* (n = 20)

This community type is an open grassland represented by twenty relev`es and eighty four plant species. It is located at the north central part of the grass plain of the park. This area is the flat plain characterized by heavy livestock grazing pressure and the soil is characterized by alluvial and clay deposits. High bare land cover (22 ± 17%) also characterizes the area. Its altitude ranges between 1,203, 1,283 m a.s.l. The land is highly degraded, and several gullies are observed following livestock truck and roads in the field. The community is dominated by *Chrysopogon plumulosus, Lintonia nutans, Tetropogon vilosus, Digitaria abyssinica, Aristida kenyensis, Cynodon dactylon, and Cyperus obtusiflorus* in the grass layer. *Abutilon anglosomaliae, Pupalia lapacea, Commelina diffusa, Barleria acanthoides, Dyschoriste multicaulis, Rhynchosia malacophylla, Bidens biternata* co-dominated the herbaceous non -grass layer in the community. The bush layer is highly dominated by *Dichrostachys cinerea, Acacia seyal, Acacia nilotica, Solanium incanum, and Acacia mellifera.*

Type 3*. Dichrostachys cinerea-Achyranthes aspera (n = 10)*

The community is represented by ten relev`es and eighty three plant species. It is located at the east and west extreme corner of the northern part of the plain. It is at the bottom of the undulated Degabule and Harre terrain bordering the grass plain. These areas were believed to be where there were previous settlers and current settlements are widely observed. The altitude of the area ranges between 1256.4 and 1287 m a.s.l. The bare land covers (10 %) relatively low because it is covered by bushes.

The bush layer of the community is dominated by *Acacia mellifera, Acacia nilotica, Dichrostachys cinerea, and Acacia seyal.* The non-grass herbacious associates are *Achyranthes aspera, Commelina diffusa, Pupalia lapacea, Endostemon tereticaulis, and Monechma debile. Chrysopogon plumulosus, Enneapogon cenchroide, Loudetia flavida, Setaria verticillata* represented the grass layer.

Type 4. ***Bothrichloa insculpta - Loudetia flavida (n = 32)***

This community comprises thirty two relev`es with ninety two species. It is located in the Degabule hills and open grassland inclined towards southern part of the grass plain in a way to Sermale River. This community type covers relatively wider areas in the grass plain. The community is characterized by high altitudinal variability that ranges between 1202 to 1308m a. s.l. The part of the community bordering Degabulle hills and the Chamo lakes has relatively high stone cover. The bare cover in this community is relatively very low.

The community type was entirely dominated by grass species including *Bothrichloa insculpta, Loudetia flavida, Digitaria abyssinica, Themeda triandra, and Eneapogon cenchroides*. Other herbaceous co-dominants and frequently encountered species include *Triumfetta flavescens, Pupalia lapacea, Plectranthus barbatus, Rhynchosia malacophylla, Commelina diffusa, Cyperus obtusiflorus, and Abutilon anglosomalie. Dicrostachys cinerea, Acacia oerfota, Acacia seyal, Acacia senegal, and Acacia mellifera* are bush species associates in the community.

Type 5. ***Sehima nervosum – Acacia senegal (n = 5)***

This type is woodland represented by five relev`es and fifty eight plant species. It is located at the escarpment of Gada Mountain facing the grass plain and down Sermale River at the interface between woodland and grassland. This type is characterized by a high cover of *Sehima nervosum, Loudetia flavida, Heteropogon contortus, Panicum coloratum, Pennisetum cladestinum, and Digitaria abyssinica*.The community is also co-dominated by *Acacia senegal, Acacia nilotica,* *Acacia mellifera, Balanites aegyptiaca, Maerua oblongifolia and Rhus natalensis*. Other non-grassy herbaceous plant species associate includes *Crotalaria pycnostachya, Monechma debile, Phyllantus maderasepantensis, Plectranthus barbatus, and Ruellia patula.*

Type 6. Acacia oerfota (n = 5)

This community is a grassland represented by five relev`es and sixty plant species. It is located at the eastern part of the grass plain near the foothill of Harre Mountain where pastoralist settlement is common. The altitude for type 6 ranges from 1197 to 1261m a.s.l. It has also relatively high bare land cover (9.0±8 %). A high cover of *Acacia Oerfota, Acacia mellifera, Acalypha fruticosa, Pentarrihum somalense, Maerua crassifolia, and Maerua oblongifolia* at the bush layer characterizes the community. The non-grassy herbaceous layer is characterized by *Abutilon anglosomaliae, Sericocomopsis hidebrandtii, Achyranthes aspera, Barleria acanthoides, Dyschoriste multicaulis, Pupalia lapacea, and Ruellia patula and Abutilon anglosomaliae. Eneapogon cenchroides, Cenchrus pennisetiformis, Arstida kenyiensis and Tetropogon vilosus,* are the grasses represented in the community.

Type 7. *Enneapogon cenchroides - Polygala erioptera* (n=1)

The community is represented by a single relev`e. It is grassland on which the basal root of *Enneapogon cenchroides* and *Polygala eriptera* covers some part of the releve. As compared to other relev`es, it is represented by very few plant speies It is also where the cattle and Zebras found in aggregation, and heavily trampling the land, consequently most of the land is bare in this releve.

4.3 Plant diversity

The overall species diversity, richness, and evenness values of the grass plain were 2.92, 22.73, and 0.94 respectively. The Shannon-Weiner diversity model computed for different community groups showed that the species richness and diversity were high in community type 3 (27.4 and 3.0 respectively), which is dominated by woody plant species (Table 3). The statistical test showed that there was no significant variation in species richness, evenneness and diversity among the six communities (Table 4). *Abutilon anglosomaliae, Bothrichloa insculpata, Rhynchosia malacophylla, Endostemon tereticaulis, Monechma debile, Commelina diffusa, Digitaria abyssinica, Aeschynomene schimperi* are species rich and diverse herbaceous species on the overall grass plain of the park. *Dicrostachys cinerea, Acacia mellifera, and Acacia nilotica* are the most diverse woody species on the grass plain.

Table 3 Mean diversity Indices for different plant community types in Nechsar National ParkPark

Community type	Species richness	Species evenneness	Species diversity
1	34	0.935	2.8
2	84	0.9437	2.9
3	83	0.9337	3.0
4	92	0.9456	2.8
5	58	0.9474	2.9
6	60	0.9418	2.9

Table 4 ANOVA summary for species diversity, richness and evenneness for the Gras plain of Nechsar National Park

Source	DF	SS	MS	F	P	Remark
Species diversity	5	0.3545	0.0709	1.82	0.120	NS
Species richness	5	174.8	35	1.56	0.183	NS
Species evenneness	5	0.00591	0.00118	0.61	0.694	NS

NS= Non significant at $P \leq 0.05$

4.4 Density of woody plants

The over all mean total density of woody plants in the grass plain of Nechsar National Park was 1995 ha^{-1} (Table 5) with a range of 572 – 7767 among community types (Table 6). Variability in woody plant density was high within the community types in the grass plain, which was reflected in high standard deviations. Based on the total density of woody plants, Community type 3 has relatively high number of woody tree species (Table 6). Analysis of variance showed that density of woody plants differed significantly across the community types (Table 8). The comparison of plant communities based on the mean woody species density showed that plant community type 1 is significantly different from community type 2, 3, 4, 5, and 6. Plant community type 2 is also significantly different from community type 3, 4, 5, and 6 in mean woody species density and community type 3 significantly differs from community type 4, 5. and 6 (Table 9). Density of bush in community type 3 alone contributed to 60% of the total bush density in the study area (Table 6). The most abundant woody species in this community are *Dicrostachys cinerea, Acacia nilotica and Acacia melifera.*

Table 5 Descriptive statistics of bush density (n/ ha^{-1}) in the Grass plain of NP.

	N	Minimum	Maximum	Sum	Mean	Std. Deviation
Bush density	75	.00	19800	149800	1995	4048

Table 6 Mean density (n/ha± SD) and variability of woody species for the six plant communities in the grass plain of Nechsar National Park

Community	Tree/shrub	Seedling	Sapling	Total density
Type 1	250±18	262±335	187±247	700 ± 600
Type 2	570±2758	427±681	1440±1219	2437±3650
Type 3	1765±4446	153±1456	5122±1780	7767±7000
Type 4	1762.5±140	105±448	55±650	572±1700
Type 5	135±623	180±195	555±126	870±925
Type 6	80±340	85±57	280±57	595±275

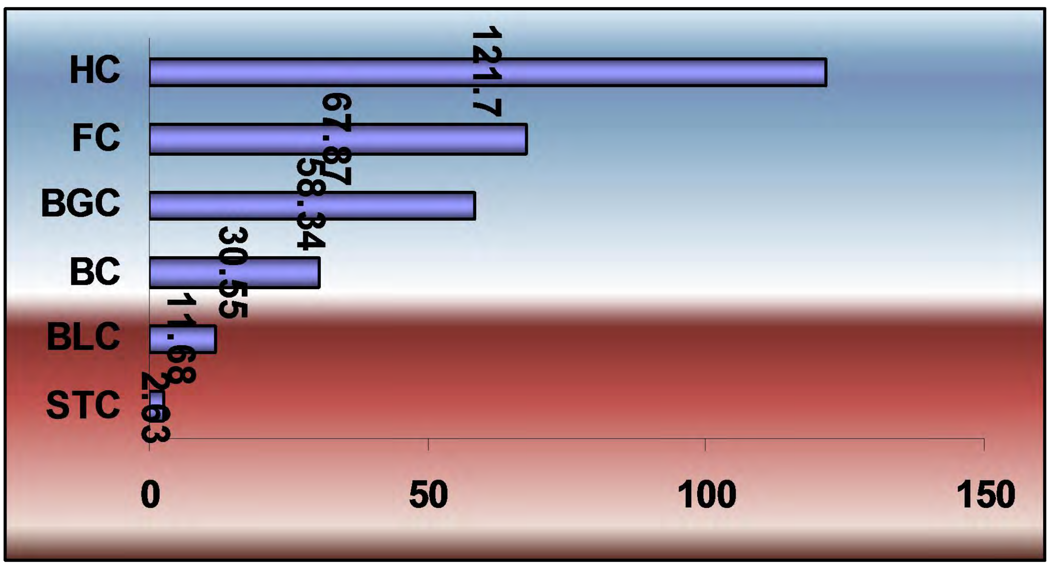
4.5 Cover of woody plants and ecosystem structure

The mean canopy cover of woody plants in the study area was about 31% (Table 7). The forbs cover (68%) exceeds grass cover (58%) on the overall grass plain of the park. Among the plant species recorded in the grass plain: woody species, annual forbs, perennials forbs, and grass species comprised 43, 30, 32, and 26 in species count respectively. The annual forbs relatively constitute high value in terms of both cover abundance and species diversity (Table. 13). The mean cover of woody species, basal grass cover, forbs cover, bare land cover, showed significant variability across the community types (Table 8). The comparison of plant communities based on the mean percent grass cover showed that plant community type 1 is significantly different from community types 2, 4, and 5. Plant community type 2 is also significantly different from community types 4, and 5 in mean woody species density and community type 3 also significantly differs from community types 4, and 5 (Table 9). Plant communities also vary in their percent mean bush cover. Community 2 significantly differs from community types 3 and 6.

Plant community type 3 also showed significant difference from community type 4. Community type 4 in turn also significantly differs from plant community types 6 in bush cover (Table 9).

Table 7 Descriptive Statistics of Vegetation characteristics of the Grass plain of NP in (% cover /Plot)

	Mean	Std. Deviation	N(releve)
Bush cover	30.54	37.21	75
Basal grass cover	58.33	24.55	75
Forbs cover	67.87	25.54	75
Herbaceous cover	121.74	31.95	75
Bare land cover	11.68	11.95	75
Stone cover	2.63	5.22	75
Altitude	1250.59	43.49	75



HC: Herbaceous cover, FC: Forbs cover, BGC: Basal grass cover, BC: bush cover, BLC: Bare land cover, STC: Stone cover

Figure 11. The Over all ecosystem structure of the grass plain of Nechsar National Park

Table 8 ANOVA summary of bush cover and associated ecosystem structures in Grass plain of Nechsar National Park

Variable	DF	SS	MS	F	P
Woody species density	5	673458	134692	7.24	**0.000**
Bush cover	5	41436	8287	8.3	**0.000**
Grass cover	5	18551	3710	9.9	**0.000**
Forbs cover	5	41436	8287	8.32	**0.000**
Herbaceous cover	5	16409	3282	3.83	**0.004**
Bare land cover	5	3422	684	6.29	**0.000**
Stone cover	5	267	53	2.12	**0.07**
Altitude	**5**	**10674**	**2135**	**1.09**	**0.372**

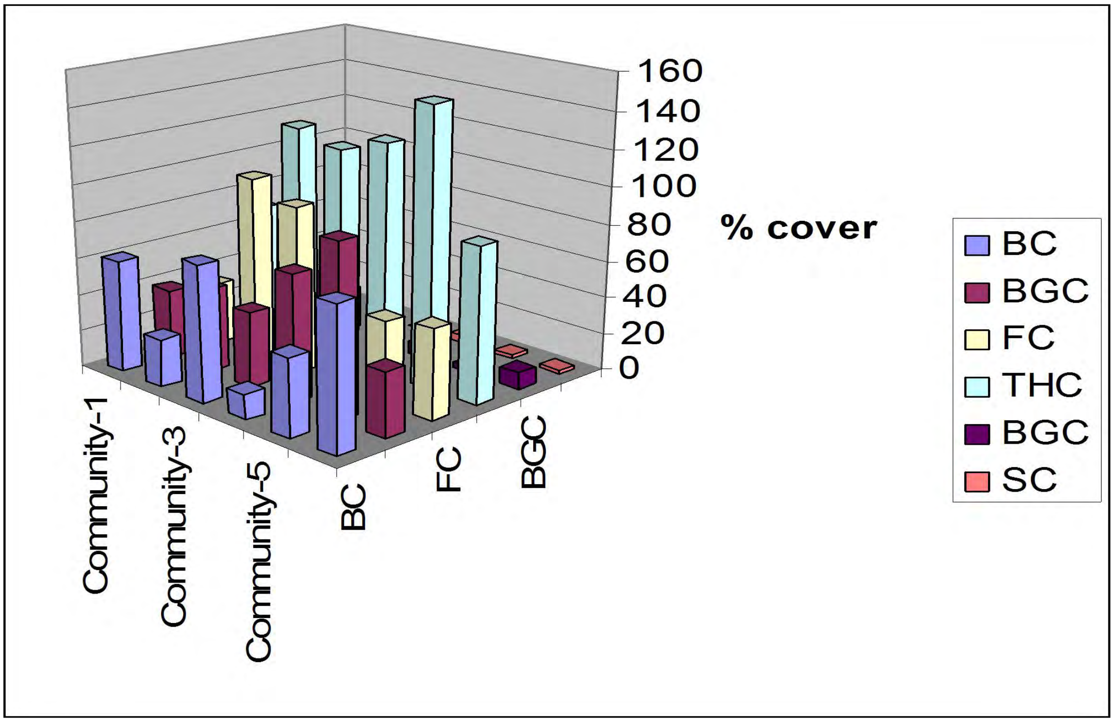
Table 9 T test summery for different variables (Mean /Plot) between communities at P ≤ 0.05 in the grass plain of Nechsar National Park

Community type	Bush cover	Woody species density	Grass cover	Forbs cover	Total herbaceous cover	Bare land cover
1	62a	28a	38a	35a	73a	23a
2	26aa	98aa	47ba	100ba	123aa	22aa
3	74aba	311bba	41aaa	91cba	126aaa	11aba
4	14aaba	23acba	68ccba	66acba	117aaaa	7bcba
5	42aaaaa	35adcaa	93ddcaa	46adca	150aaaaa	3cdcba
6	77acaba	24aedaa	36aaacb	49aeda	85abbbb	10decaa

Variability was low in percentage bush cover within a community, which is reflected in low standard deviations (Table 10). Mean percentage cover of woody plants is higher in community 6 (77%) and community 3 (74%). Generally, *Dicrostachys cinerea, Acacia nilotica, Acacia mellifera, and Acacia oerfota* each contribute 31, 17, 13 and 9% of bush cover and considered as the major encroachers in grass plain of Nechsar park (Table 11). There was variability in woody species composition and cover abundance across the community types. *Acacia nilotica,* 77% in community 1*, Dicrostachys cinerea*, *48%, 46% and 23%*, in communities 2, 3, and 4, respectively and *Acacia oerfota,* 36%, 48% in communities 5 and 6 respectively contribute higher cover abundance from the total bush cover in each community.

Table 10 Mean cover (% ±SD Plot^{-1}) and variability of ecosystem structure for the six plant communities in the Grass plain of Nechsar Park

Community	Bush cover	Basal grass cover	Forbs cover	Total herbaceous cover	Bare ground cover	Stone cover	Altitude
Type 1	61±45	38±3	34±10	72±13	25±2	9.0±12	1281.5±19
Type 2	26±35	46±13	100±42	122±30	22±17	.80±2	1243.7±40
Type 3	74±32	41±19	91±24	116±21	10±3	.10±0.4	1256.4±31
Type 4	14±26	69±21	65±20	125±31	7.0±7	4.0±6	1255.9±53
Type 5	42±38	93±28	45±16	150±32	3.0±2	2.0±4	1225.0±29
Type 6	77±38	35±14	49±15	84±17	9.0±8	2.0±5	1224.4±27



BC; bush cover, BGC: basal grass cover, FC: Forbs Cover, THC: Tota Herbaceous cover, BGC; bare ground cover, SC: Stone cover

Figure 12 The Variablity in the structure of woody tree species across community types in the grass plain of Nechsar National Park

Table 11 List of woody plant species with their average % cover and frequency in the Grass plain of Nechsar Park

Botanical Names	Average % cover	Frequency
Acacia mellifera (Vahl) Benth.	3.78	24
Acacia nilotica (L) Willd.	5.00	23
Acacia oerfota (Forssk) Schweinf.	2.53	4
Acacia senegal (L.) Willd.	2.03	7
Acacia seyal Del.	2.39	14
Acacia tortilis (Forssk.) Hayne	0.01	1
Acalypha fruticosa Forssk.	0.15	5
Aerva javanica (Burm.f.)Schultes	0.02	2
Balanites eagyptiaca (L.) Del.	0.04	2

Balanites rotundifolia (Van Tieghem) Blat.	0.04	3
Capparis fascicularis D.C.	0.29	11
Comiphora africana (A. Rich) Engl.	0.05	3
Cycnium erectum Rendle	0.05	3
Dichrostachys cinerea Wight & Arn.	9.37	24
Dobera glabra (Forssk) Poir.	0.12	8
Flueggea virosa (Willd) Voigt.	0.04	3
Gomphocarpus phillipsiae (N.E.Br) Goyder.	0.01	1
Grewia erythracea Schweinfurth	0.02	2
Grewia velutina (Forssk) Vahl.	0.15	5
Grewia vilossa Willd.	0.05	3
Harisonia abyssinica Oliv.	0.01	1
Hibiscus canabinus L.	0.01	1
Hibiscus micranthes L.F.	0.36	14
Maerua crassifolia (Forssk) A.Rich.	0.54	9
Maerua oblongifolia (Forssk) A.Rich.	0.18	4
Maerua triphylla Gilg.	0.14	3
Mayteneus senegalensis (Lam.) Exell.	0.05	1
Ozoroa insignis Del.	0.01	1
Pentanisia ouranogyne S. Moore	0.27	8
Pentarrihum somalense N.E. Br.	0.52	20
Pterodiscus saccatus S.Moore	0.06	5
Rhus natalensis Krauss.	0.47	8
Salvadora persica L.	0.03	1
Sclerocarya birrea A.Rich.	0.04	2
*Seddera bagshawe*i Rendle	0.01	1
Sida alba L.	0.17	7
Solanium incanum L.	0.45	9
Solanium lonzae J-P Lebrum	0.33	10
Ximenia caffra Sond.	0.10	4
*Ziziphus spina-christ*i (L.) Desf.	0.10	2
	3.78	

Table 12 List of Perennial forbs with their sum of % cover and frequency in Grassplain of Nechsar Park

Species scientific name	Average cover	Frequency
Achyranthes aspera L.	9.96	34
Adenium obesum (Forssk.) Rome & Schultes	0.48	1
Aerva lanta (L.) Juss. Ex.J. A. Schultes	1.96	28
Aeschynomene schimperi Hochst. ex.A.Rich.	3.53	45
Barleria acanthoides Vahl.	4.83	3
Ceratostigma abyssinicum (Hochst) Schweinf & Aschers	0.03	1
Chasmanthera dependens Hochst.	0.03	1
Cissus quadrangularis L.	0.59	5
Cochorus trilocularis L.	2.34	27
Commelina diffusa Burm.f.	10.0	53
*Commicarpus plumbagineus (*Cav.) Standl.	0.39	11
Conyza bonariensis (L.) Cronq.	0.5	6
Dyschoriste multicaulis (A.Rich.) O. Kuntze.	0.88	24
Endostemon tereticaulis (Poir.) M. Ashby.	4.78	54
Heliotropium rariflorum Stocks	0.36	11
Hibiscus dongolensis Del.	0.80	15

Indigofera schimperi Jaub.& Spach.	3.28	36
Lecuas glabrata (Vahl) Sm.	4.31	26
Mollugo nudicaulis Lam.	0.06	2
Oxygonium sinatum (Mmeisn) Dammer	0.90	16
Pavonia burchellii D.C Byer.	0.03	1
Pavonia melhanioides Thulin.	0.28	3
Plectranthus barbatus Andrews	5.39	23
Polygala erioptera D.C.	0.72	2
Rhynchosia malacophylla (Spreng.) & Boj.	11.5	59
Ruellia patula Jacq.	1.98	21
Sarcostemma viminale (L.) R.Br.	0.09	3
Sericocomopsis hidebrandtii L.	1.18	11
Tepherosia uniflora Pers.	2.21	21
Tribulus terrestris L.	0.03	1
Tricliceras pilosum (Willd) R.Fernand.	0.18	5
Triumfetta flavescens Hochst.	13.1	43
Zaleya pentandra (L.) Jeffrey	0.13	1

Table 13 list of annual forbs with thieraverage % cover and frequency in the grass plain of Nechsar National Park

Species scientific name	**Average % cover**	**Frequency**
Abutilon anglosomaliae Cufod.	24.47	71
Abutilon bidentatum (Hochst.) A .Rich.	2.97	22
Alectra parasitica Hochst ex.A.Rich.	0.03	1
Alysicarpus rogosus Willd ssp. Rugosus.	0.03	1
Barleria eranthemoides R.Br.ex C.B.Clark.	0.12	2
Bidens biternata (Lour.) Merr.& Sherf.	2.29	8
Boerhavia diffusa L.	0.19	2
Cardiospermum halicacabum L.	0.03	1
Chenopodium opulifolium Koch. & Ziz.	0.03	1
Crotalaria pycnostachya Benth.	2.54	15
Cuccumis prophetarum L.	0.06	2
Cucumis dipsaceus Ehrenb. ex Spa.	0.16	5
Dalechampia pavoniifolia (Chiov.) M. Gilbert.	0.17	2
Euphorbia acalyphoides Boiss.	0.03	1
Indigofera ambelacensis Schweinf.	0.67	15
Ipommoea aquatica Forssk.	1.25	22
Kalanchoe lanceolata (Forssk.) Pers.	0.10	2
Leucas martinicenisis (Jacq.) R.Br.	0.46	2
Mattiola rivae Engl.	0.03	1
Mukia maderasepatana (L.) M.J. Roem.	0.06	2
Monechma debile (Forssk.) Nees.	5.81	24
Ocimum americanum L.	0.26	5
*Pavonia procumbens (*Wight & Arn.) Walp.	0.03	1
Phyllantus maderasepantensis L.	1.03	15
Plectranthus punctatus (L.F.) L` H`er.	5.74	23
Portulaca quadrifida L.	1.70	22
Priva adhaerens (Forssk.) Chiov.	0.03	1
Priva tenax Verd.	0.03	1

Pupalia lapacea (L.) A.Juss.	15.5	46
Solanium nigrum L.	0.52	5
Tepherosia villosa (L.) Pers.	0.58	9

Table 14 List of grasses with their sum of cover and frequency in the grass plain of Nechsar National Park

Species scientific name	Average % cover	Frequency
Arstida kenyiensis Henr.	2.09	12
Bothriochloa insculpta Hochst.ex A.Rich.	21.14	61
Brachiaria lachnantha (Hochst.) Stapf.	0.14	1
Cenchrus ciliaris L.	0.94	5
Cenchrus pennisetiformis Hochst.	4.69	10
Chloris roxburghiana Schult.	3.48	12
Chrysopogon plumulosus Hochst.	24.66	31
Cynodon dactylon (L.) Peres.	4.67	25
Digitaria abyssinica (Hochst. ex. A.Rich.) Stapf.	17.66	50
Enneapogon cenchroides C.E Hubb.	15.36	25
Eragrostis Schweinfurthii chiov.	0.28	5
Heteropogon contortus (L.) Roem. & Schult.	5.85	19
Leptochloa rupestris C.E Hubb.	0.38	2
Lintonia nutans Staff.	8.52	41
Loudetia flavida (Stapf.) C.E Hubb.	18.89	26
Panicum atrosanguiunem A. Rich.	0.12	2
Panicum coloratum L.	2.18	6
Pennisetum clandestinum Chiov.	3.42	18
Sehima nervosum (Rutt.) Stapf.	7.26	11
Setaria verticillata (L.) P. Beauv.	3.22	27
Sporobolus pyramidalis P.Beauv.	0.22	3
Tetropogon villosus (L.) Pers.	4.35	18
Themeda triandra Forssk.	10.69	14
Sedge		
Cyperus obtusiflorus Vahl.	10.1	40

4.6 Population structure of woody tree species

About 54% of individual woody species are cathagorized as a tree, 23% of individual woody species are saplings and 22% of the individual woody species are seedlings (Table 15).

Table 15 Descriptive statistics of population structure of woody species / plot in the grass plain of Nechsar National Park

Population structure	N	Minimum	Maximum	Mean	Std. Deviation	Percent
Seedling density	75	0	200	17	36.44	22
Sapling density	75	0	236	18.92	44.19	24
Tree density	75	0	460	42.71	102.92	54

For all woody species taken together, the population structure had nearly J-shaped, i.e. with the highest number of individual woody species in tree/bush class (Figure 13). The variability in population structure was observed between plant community types (Figure 12) on the grass plain.

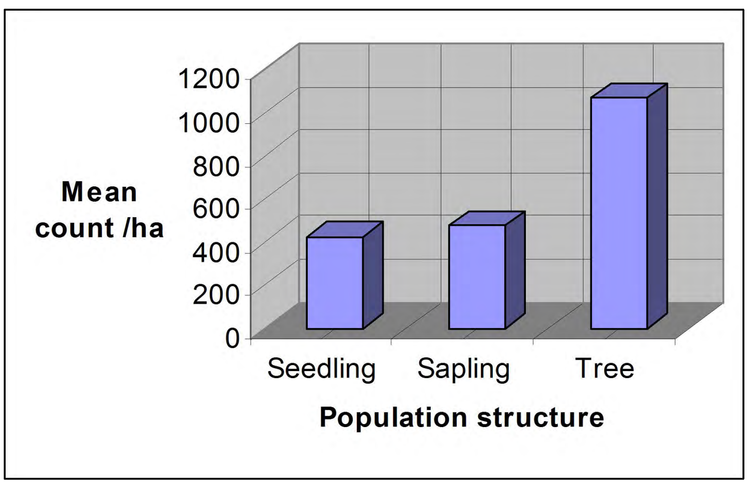
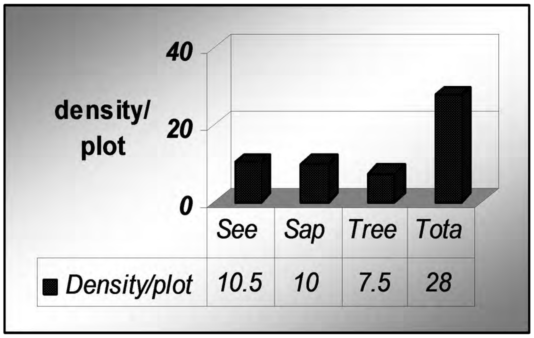
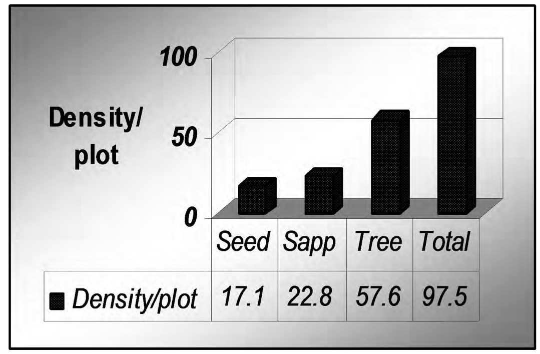


Figure 13 The structure of woody tree species in the grass plain of Nechsar National Park



Community –I



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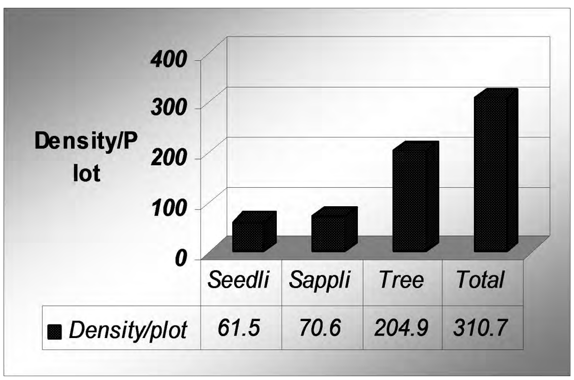

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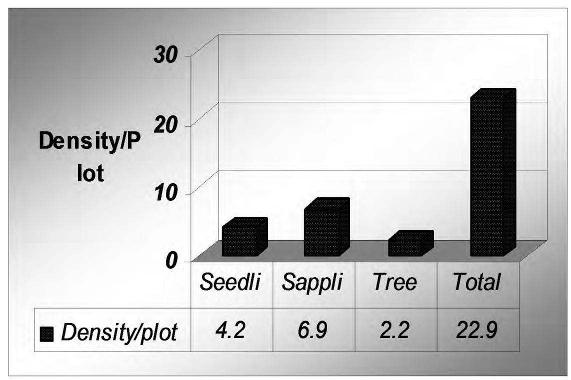

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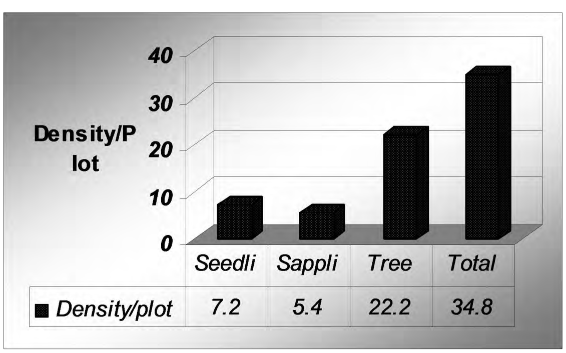
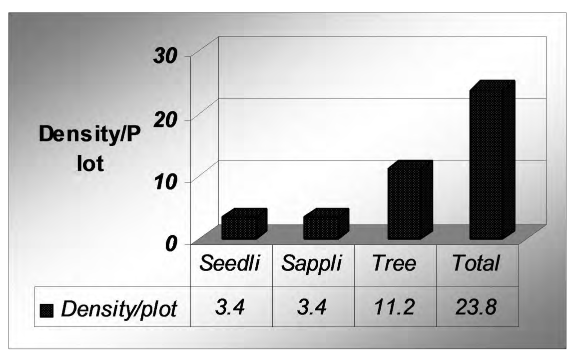


Community-V



Community-VI

Figure 14 The variability in the structure of woody tree species across community type in the grass plain of Nechsar National Park

4.7 Impact of woody plants on herbaceous cover and ecological conditions

Pearson correlation coefficient matrix at ($P \leq 0.01$) showed that grass cover was significantly negatively correlated with bush cover. However, total herbaceous, forbs and bare land cover was negatively correlated but not significantly with bush covers (Appendix 2). Basal grass cover was significantly negatively correlated with forbs and bare land cover. However, bush cover significantly positively correlated with total herbaceous cover. Among the ecological parameters considered only bush density showed significantly negative effect on the over all diversity of the plants on the grass plain (Appendix 2).

5. Discussion

5.1 Floristic composition and diversity

The grass plain of the park has a diverse species composition. 131 plant species representing 44 different families were recorded. Compared to other savanna grasslands the study shows better species richness in Nechsar National Park. Schoelder (1999) had recorded 121 plant species in Omo National Park among which grass species were 27. The finding was also in agreement with previous work in the same area. For example, Tamirat Andargie (2001) recorded 199 plant species representing 42 families in both Grassland and Woodland vegetation of Nechsar plain of Nechsar Park. Among them 52 species were grasses. The main difference between this study from that of Tamirat Andargie (2001) is the size of study area. He collects floristic data from both grassland and wood land savanna. But this study is limited to grassland alone.

Generally, shrubs and non-palatable forbs dominated the floristic composition of the grass plain suggesting heavy disturbances in the grass plain of the park. *Acacia mellifera, A. nilotica, A. oerfota, Dicrostachys cinerea, and A. seyal,* were among the major invasive encroachers that proliferated and distributed all over the plain. Their distributions were actually governed by slope, soil properties, soil moisture, human settlements and disturbance patterns. These species were reported as invasive (Assefa et *al.* 1986, Ayana Angassa 2005, Gemedo Dalle *et al.* 2004, Coppock 1994) from savanna rangelands in southern Ethiopia. Key informants from pastoral communities dwelling in the park, the park management and experienced scouts perceived that most of the bushy invasive species have been progressively increasing in the grass plain.

Dicrostachys cinerea (RF = 0.32) was the most abundant woody plant species distributed through out the grass plain. It occurs in a thicket or in a cluster form scattered throughout the plain. When Tamirat Andargie (2001) made a study in the park, the species was the least abundant woody tree species in the Grass plain. This implies that the species is rapidly encroaching in the Grass plain during the last seven years. The other dominant woody tree species in the grass plain were *A. mellifera, A. nilotica, A. seyal,* and *A. oerfota. A. mellifera* and *A. nilotica* were the most abundant and frequently occurred species on the fertile part of soils of the grass plain. On the other hand, *A.oerfota* was solely localized in the eastern part of the park on the hillsides of Harre Mountain.

The floristic composition of the herbaceous layer was also poorer in grass composition suggesting continuous grazing or trampling, which affected regeneration of grasses. Moreever, the relatively high cover of unpalatable annual forbs in the grass plain indicated continuous disturbances and encroachment. For example, the species *Abutilon anglosomaliae* (RF = 0.95), was the most abundant and the most frequently distributed species in the open grass plain mainly on the clay and moist soils of the plain. The soil where the species dominates has high in moisture content, the area has relatively high in bare land cover (22%) and characterized by incidence of gully erosion following the cattle truck and human foot paths (Figure 14).

Figure 15 Population of *Abutilon anglosomliae* taken from the grass plain of Nechsar National Park

The the whole area or where Abutilon anglosomaliae grows was previously described as nutrient poor, moist and with alluvial lacustrine clay soil of the grass plain (Bolton 1970; Tamirat Andargie 2001). Similarly, Grime (1979) indicated that species that grow under these conditions are a stress tolerant –ruderals. These are a characterstics of disturbed and stressed environment. Previously, Tamirat Andargie (2001) characterized this part of the grass plain as *Aristida kenyensis* dominated community. However, *Aristida kenyensis* is dominated by annual and short – lived forbs during the fieldwork of this study. The dominant species were *A. anglosomaliae, Pupalea lappacea, Bidens biternata, Endestemon tereticaulis*, and *Barleria acanthoides*.

Figure 16 Goat Population on the northern part of the grass plain of Nechsar National Park

Generally, a few bush and herbaceous species such as *Dichrostachys cinerea, Acacia. mellifera, and Abutilon anglosomalie* dominated indicating a dynamic nature of the grass plain from the grassland to bushland or thickets. *D. cinerea*, was observed in cluster/patches all over the grassplain, suggesting its dominance and the decline in herbaceous species and grass productivity. Local informants are also well aware about the deterioration of grass diversity of the grass plain. In this area, there is a trend showing the decline in the abundance and distribution of some grass species such as *Themeda triandra* and *Cymbopogon spp*. As a result they are becoming less frequent and localized in areas where there is no much grazing pressure. These species are the once that were abundant all over the grass plain. The grazing pressure from domestic livestocks might also have caused the species decline. Ewusie (1980) showed that these species are more palatable and easily uprooted, and vulnerable to destruction.

Members of the family Poaceae were also the dominant and abundant plant species comprising the highest proportion of the species number in the study area. The 26 recorded grass species make 58% of the ground cover in the grass plain of the Park. This shows that members of the family Poaceae are the most successful taxonomic group in the study area followed by the Family Fabaceae, Malvaceae and Lamiaceae. Huber (1994) also discussed that in any East African savanna system Poaceae is the dominant plant family in which the number of the species figures between 30 and 60. Tamirat Andargie also identified 52 grass species. The current finding resulted slightly below 30 which is 26 grass species because of the fact that the sampling area is limited to the grass plain only, excluding the savanna woodland. Plant nutrients, soil moisture and fire and disturbances are the determinant factors in savanna vegetation formation. However, the family Poaceae has developed a better reproductive adaptation in response to the constraints from the above factors. Bolton (1969) describes the grass plain as edaphic grassland that was characterized by poor soil fertility that might be attributed to formation of open grassland. Tamirat Andargie (2001) also discussed that the openness of the canopy on the grassland and poor soil fertility in the grass plain contributes to the dominance of grasses in the area. The poor soil conditions especially, in alluvial areas where heavy clay soils near the surface impede drainage, restricts root development of trees allowing the grasses to dominate the area with the minimum competition. The clay soil proportion of the flat plain constituted up to 60% (Tamirat Andargie, 2001).

Chrysopogon plumulosus (RF = 0.79), *Bothrichloa inssculpata* (RF = 0.72), *Hetropogon contortus, Sehima nervosum, Loudetia flavida* were the abundant and frequently distributed grass species occurring on fertile soils on hillsides. *Themeda triandra* is almost localized to the hillside of Degabule, near Lake Chamo, west of the plain.

5.2. Disturbance, environmental variables and patterns of vegetation distribution

The abundance of *Abutilon anglosomaliae, Pupalia lappacea, Commelina diffusa, Barleria acanthoides, Dyschoriste multicaulis, Bidens biternata* in *Abutilon anglosomaliae- Chrysopogon plumulosus* plant community type, indicated the current severe disturbances. These species are annuals or short-lived perennials colonizing the grass plain by displacing the perennial grasses in the area. They can successfully grown for short perod of time on nutrient poor clay soils when ample soil moisture is available on the plain. Grime (1979) clearly discussed that this kind of vegetation composition and vegetation strategies in certain area is an indicator of heavy disturbances.

In *Dichrostachys, cinerea- Achyranthes aspera Acacia mellifera* community type the abundant species, *Dicrostachys cinerea,* grows in a cluster on severely overgrazed, clay, and moist soils of the plain. On the other hand, A*. mellifera* has colonized the bottom of relatively fertile Degabule hillsides in the western part of the grass plain. The proliferation of *A. mellifera and A. nilotica* is associated with gradual soil fertility build up in the area over time due to the location that is at the foothills of mountainous terrain, the down slope movement of silt and clay particles from the hills creates marginally richer soil around the base of the hill. Discussion with key informants from the pastoralist community also showed that there were settlements in this specific area. Concurrently, their activities such as firewood collection and use, the practice of herding the cattle into a central pen (kraal) at a night for protection against predators, but allowing them to graze widely during the day, resulted in nutrient accumulation within the village site. It seems that the previous poor nutrient condition changed through nutrients enriched from livestock wastes and human interference in the area. Similar observations were reported by (Scholes and Walker 1993, Tinly 1981)after their study in the southern African savanna discussed that woody species for example, *Acacia tortilis, A. erubescens, A. mellifera, Dichrostachys cinerea, Grewia flava,* and *Terminalia sericea a*re increasing in cover and density around foci points (e.g. water points and kraals) at the expense of the grass cover. A number of factors have the effect of encouraging the germination and survival of woody encroaching species. The practice of cattle husbandry and continual shifting of foci points within grazing areas have resulted in the spread of the distribution of woody species across the country. This evidence might explain the proliferation and dominance of fine-leaved woody species vegetation of nutrient rich savanna (Scholes and Walker 1993) on the otherwise reported nutrient poor (Bolton 1970, Tamirat Andargie, 2001) grassland savanna of Nechsar Park. Therefore, in this community type, woody species are aggressively colonizing the field and the herbaceous species, particularly the grasses are decreasing at an alarming rate. Actually, the herbaceous associate composition and cover varies with woody species.

In *Bothriochloa insculpata - Loudetia flavida* -community type, disturbances were less and the herbaceous species were more diverse than other communities. This is Particularly true for the grass diversity. The diversity of invasive woody species was very low as compared to the other community types. This area is located at the southern plain and protected from livestock grazing under the current park management, African Parks Conservation. This area was also partly burned and the invasive bush species were partly removed a year before this study was undertaken. It seems that all these grassland management activities contribute to the improvement of grassland diversity in the grass plain. The community is characterized by diverse altitude to some extent also stone cover (Tamirat Andargie 2001), The species composition also varies based on altitudinal variation, and for example, *Themeda triandra* is localized to relatively higher altitude.

In *Sehima nervosum - Loudetia flavida* community type *Sehima nervosum, Loudetia flavida, Heteropogon contortus, Panicum coloratum, Pennisetum cladestinum,* and *Digitaria abyssinica* are the dominant grass species. The community is also co-dominated by *Acacia nilotica, Acacia mellifera, Acacia senegal, Balanites aegyptiaca, Maerua oblongifolia* and *Rhus natalensis*. The community is located in the ecolines of grassland and woodland vegetation. The over all plant diversity in this community is high (Tamirat Andargie 2001) which indicates the disturbances are relatively low in the area.

In the *Acacia oerfota* community type, the dominant bush species, *A. oerfata* was common in the lowest eastern portion of the grass plain at the foothill and surroundings of Harre mountain where there are still human settlements. The domination of *A. oerfata* seems to be explained by highly sandy nature of the soils, highly disturbed but progressive improvement of the soil fertility associated with cattle wastes. Key informants from the pastoralists reported that A*. oerfota species* is very weak and short lived as compared to other bush species and cannot tolerate strong solar radiation and fire as a result it can be easily destroyed.

5.3 Population structure and spatial distribution pattern of bush species

The nearly J-shaped distribution, exhibited by overall woody species in the grass plain suggested clearly hampered regeneration of these species during one or several phases of their life cycles (Tamirat Bekele 1993, Demel Teketay 1997). It also implies that the woody species seed germination, regeneration, and seedling recrutement are of driven by stochastic events such as disturbances and suitable rainfall occurrences during certain period of time in the area. Archer (1994) showed that the hampered regeneration indicated that the woody species seed dispersal and germination, regeneration, seedling recruitment are highly determined by moisture, nutrients, fire and grazing pressure. (In savannas, herbivory, fire and water availability play important roles in the dynamics and structure of the system (Scholes & Archer 1997, van Langevelde *et al.* 2003). Herbivory and fire are typically spatial processes, as their occurrence and impact on plants largely varies over different locations in the same landscape.

On the grass plain of Nechsar National Park, variability among the encroacher woody species was observed on their spatial distribution pattern, *Acacia nilotica, A. mellifera, A Senegal and A oerfota* that covers the hillsides and fertile areas of the plain, while the cluster of *Dichrostachys cinerea* colonized the alluvial and clay soils of the flat plain. Each woody species in the grass plain occurred in a cluster fashion. Similar results were reported by (Barot *et al.* 1999, Caylor *et al.* 2003, Kennedy and Potgieter 2003, Skarpe 1991). Because many processes interact in savannas, it is difficult to disentangle the importance of the different processes that play a role in the origin and maintenance of this clustered pattern. Mechanisms that can induce clustering of plants are the limited dispersion distances of seeds, clonal growth, or local nutrient concentration, for example by termites (Barot *et al.* 1999, Konat´e *et al.* 1999, Pacala &Levin 1997). Competition between plants is expected to disaggregate plants as plants nearby compete more strongly with each other than plants further apart for underground resources like water and nutrients (Pacala and Levin 1997, Skarpe 1991, Smith and Goodman 1986). In savannas, the most likely resource that plants are competing for is water (Scholes and Archer 1997, Walker and Noy-Meir1982), and therefore factors that influence soil water availability are likely to affect the clustering of trees as well. Clay soils retain water better than sandy soils, and have therefore a positive effect on the water availability for trees and grasses in the upper soil layers (de Ridder and van Keulen 1995). This reduces competition for water, and therefore might positively affect the clustering of trees. In addition, herbivores can play a role in the spatial organisation of plants. Accumulation of seeds in herbivore droppings might cause a clustering of trees. Apart from the above-mentioned processes, fire could also affect the spatial patterning of trees in savannas (Gignoux *et al.* 1998, Jeltsch *et al.*

1998). Modeling studies suggest that when fires occur frequently this increases clustering among trees (Gignoux *et al*. 1998, Jeltsch *et al.* 1998), because clustered trees are less affected by fire through their combined suppressing effect on grass biomass, and thus fuel load, than evenly spaced trees (Figure 17)

Figure 17 A cluster of *Dicrostachys cinerea* taken from the grass plain of Nechsar National Park

Particularly *D. cinerea* occurred in exclusive clusters on the clay soil of the grass plain. This observation was in agreement with the work of Thomas *et al*. (2008) that presented the determinant role that clay content of the soil and the fire frequency play in explaining the clustering of *D. cinerea* and other similar species. He also discussed that the positive effect of clay content on the clustering of trees could be due to the higher water retention capacity of such soils. Sufficient amount of rainfall and higher clay content results in higher water availability in the top layer of the soil. With high water availability at the surface, tree seedlings will establish more easily near mother trees that are at the same time competing for water.

5.4 woody density and cover

Overall, mean percentage cover and density of woody plants per hectare was estimated to be 31% and 1995 h^{-1} respectively. Coppock (1994) reported that woody plants cover exceeds 40% in about 40% of Borana rangelands. Gemedo Dalle *et al., (*2006) also reported 52% and 3014 woody plant cover and density respectively from Borana Rangelands. In general, these studies indicated that woody plants encroachment has been increasing over time. In Nechsar grass plain as compared to the previous work in Borana rangelands, percentage cover and density of woody species were lower.The variation of the finding from the previous work could be explained in terms of complex and dynamic interactions of climate, edaphic, land use pattern, herbivory and fire. As Nechsar Grass plain is relatively protected area, the disturbances associated with human pressure and livestock on the grassland is expected to be lower. Gamado Dalle *et al.* (2006) and Ayana Angassa *et al*. (2006) reported variability among Borana rangelands in bush encroachment even though it was not significantly different.

Bush cover of 40% and or 2400 woody plants ha^{-1} was considered as borderline between non encroached and encroached condition (Roques *et al*., 2001) and 2500 tree equivalent ha^{-1} is considered as a highly encroached condition (Richter *et al.,*2001). On the bases of these results it is difficult to conclude that in the grass plain of Nechsar Park both bush cover and density is below the threshold level and has not entered the encroached condition because, the African Parks Foundation annual report showed that, in 2006 a total area of 17 hectares were cleared of invasive plant species (mainly *Dichrostachys cinerea, Acacia mellifera and Acacia oerfota*) that had encroached a substantial portion of the Nechisar Plain and surrounding woodland (APC report, 2005). Therefore, had it not been for the burning of the invasive species by APC prior to the present study, the cover and density of the invasive woody species would have exceeded the current recorded figure.

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Cover and density of bushes were positively correlated and agree with the previous findings (Roques *et al*., 2001: Gamado Dalle, 2006) and allows density to be inferred from cover measurements. The bush percentage cover and density result of this study slightly deviated from the approximation of 40% cover for 2400 woody plants per hectare (Roquses et al., 2001). By extrapolating from this figure, 31 % cover found here would correspond to 1860 woody plants ha^{-1}. However, the result of this study showed ca. 1995 woody species per hectare. The deviation of extrapolation of density from percent cover can be explained based on the variation in canopy structure of woody species under investigation, For similar woody species, the extrapolation of density from cover is more pragmatic than a group of woody plant species having different canopy structure and growth stages. For instance, ca 500 *Dicrostachys cinerea* that can be found in 400 m^2 can have equal percentage cover with ca 20-30 of *A. mellifera* ocupaying the same area. Therefore, as the dominant woody species in the study area is *D. cinerea,* the slightly higher density recorded from study area is more realistic.

5.5 Impacts of encroachment of woody species on ecosystem

Increase in encroachment of woody species and herbaceous cover was negatively correlated. Similar results were reported from previous studies (Asefa Eshete *et al*.

2006, Gemado Dalle *et al*. 2006, Scholes and Archer 1997, Oba *et al*. 2001, Oba and Kotile 2001). Key informants from the Park also perceived the negative impacts of woody species encroachment on the grass diversity. The result clearly showed that bush cover and density has strong, negative correlation with grass cover. This finding also concurs with that of (Scholes and Archer 1997). Richter *et al.* (2001*)* also discussed that bush encroachment had an adverse influence on grass biomass production and consequently decreased potential grazing capacity. This study also supported the notion that grass biodiversity is strongly correlated with bush cover and density, in savanna system however, overall herbaceous cover is negatively correlated but not significantly. This might be because of the understory of some woody tree species have very good non-grass species composition and abundance as compared unencroached land. For example, the herbaceous diversity and cover under *Acacia oerfata* are better than the area that is unencroached with woody species (Figure .4) The result also indicated that positive correlation between overall species diversity and bush cover. Tamirat Andargie (2001) also reported that woodland savanna has better species diversity than grasslands.

Archer *et al.* (1997) suggested that the presence of woody plants can alter the composition, spatial distribution, and productivity of grasses in savannas. He also discussed that the effects of trees on grass ranges from positive to neutral to negative, and these may depend on (a) the ecophysiology or the specific characteristics of the tree and grass growth forms (canopy architecture, rooting patterns), photosynthetic pathway (C 3, C4, CAM) photosynthetic habit (evergreen, deciduous), and resource requirement (light, water, nutrients); availability of resource as influenced by interannual variability in the amount and seasonality of precipitation and topoedaphic properties; (c) extent of selective grazing, browsing, or grainovery; (d) frequency, intensity, and extent of disturbances such as fire(Figure 5.4).

a. *Acacia oerfota* b. *Dicrostachys cinerea*

Figure 18 The Variability in understory of herbaceous species composition of two invassive species

Discussion with elders from the pastoralist communities in the area have indicated that about 50 years ago, there was only few *Acacia mellifera* in the grass plain and the shepherds used this woody species in the area as an umbrella to protect themselves from strong solar radiation. Bolton (1972) also reported that many parts of the Nechisar plain area was mainly savanna grass land with scattered *Acacia-Commiphora* trees and bushes. However, the current study showed that there are scattered trees and cluster of bushes that are invading the open grass plain. The changes might be attributed to different factors. According to Archer (1997) the causes for bush encroachment include overgrazing of herbaceous cover that reduces competition for woody seedlings, fire suppression that enhances woody plat survival, atmospheric CO_2 enrichment that favors C3 woody plant growth, and nitrogen pollution that favors woody encroachment.

Jacob (1999) also showed that grazing, fire and rainfall regimes are factors that play important roles on plant species dynamics in Ethiopian savanna ecosystem. The present data from the grass plain also indicate the symptoms of ecological deteriorations in the northern and eastern central part of the grass plain. These parts had long settlement history and even currently are being heavily used for livestock grazing (Figure 18).

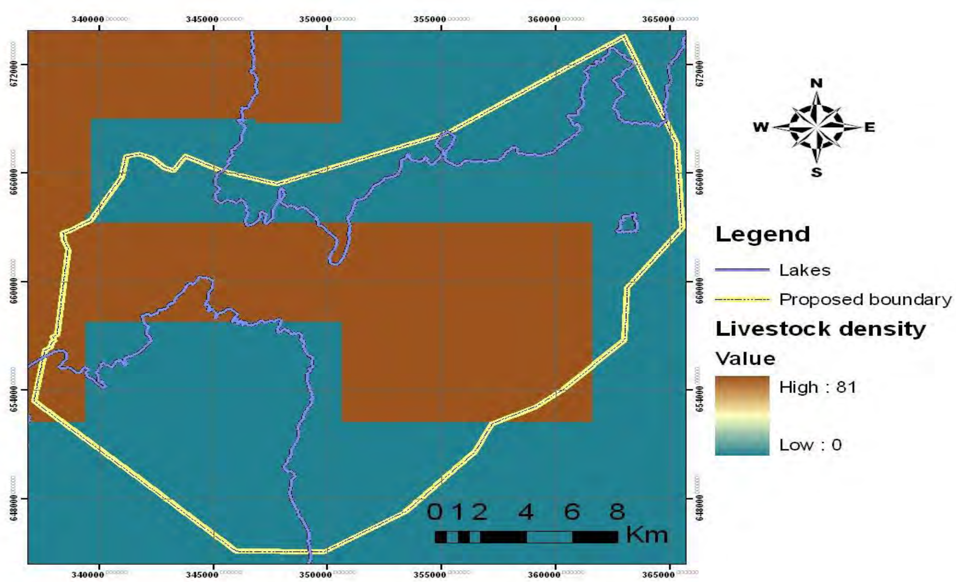

Figure 19 Livestock density around Necessary Park (PGIS PROJECT, 2007)

In this part of the plain there is a significant deterioration of the herbaceous vegetation, bush encroachment, unpalatable forbs cover, incidence of increasing gully erosion was recorded when compared with the other parts of the plain (Figure 21).

Figure 20 Indecencies of gully erosion in the Northern part of the grass plain of Necessary National Park

According to Yisehak Doku (2003) during the last thirty years, from the Nechisar plain 33.6% of suitable grassland for Burchell.s zebra has been reduced. He also showed that the major components of habitat destruction at Nechisar plain includes bush encroachment, fire, cattle trampling, overgrazing and catchment floods. He also put the severity of those factors to degrade the Enchase plain grass quality as 69.2% was bush encroachment, 21.2% was forest fire, and 9.5% was overgrazing and trampling. Although grazing effects can be difficult to disentangle from the effects of climate, those that have attempted to do so show that livestock grazing can drive grassland systems into bush land (Archer 1995, Scimel and Holland 1995). Heavy livestock grazing can convert grassland to bushland in eastern Africa, analogous to that observed in southern Africa (Ringrose *et al*. 1990). Sometimes this conversion forms a monospecific stand of persistent woody species, which greatly reduces biodiversity (de Queiroz, 1993).

Asner *et al.* (2004) indicated some basic trends in vegetation-grazing interaction associated with woody encroachment in a global drylands in terms of five vegetation properties ; woody vegetation cover, herbaceous cover, surface litter cover, dominance by perennial herbaceous plants and dominance by annual herbaceous plants. Under heavy grazing scenario, many studies indicated that dramatic increase in a woody cover or biomass if woody plant is already present or introduced to the region (Archer, 1994). Both herbaceous and surface litter (cover and biomass) are found to decrease under condition of heavy grazing (Asner *et al*. 2003). Shifts from perennial to annual grass are more obvious in heavy grazing regimes. Maria *et al. (1999*) showed that in the steppe rangeland, forbs biomass, grass, forbs, unpalatable forbs and weedy annual cover, and diversity varied along grazing pressure gradients. Grass biomass and total vegetative cover responded interactively to rainfall and grazing. Forbs biomass, grass, forbs and weedy annual cover and richness varied between years. Grasses decreased and forbs and weedy annuals increased with increasing grazing pressure.

6 CONCLUSION

One hundred and thirty one plant species belonging to 45 different families were recorded. *Dicrostachys cinerea, Acacia nilotica, Acacia mellifera,* and *Acacia oerfota* were the major invasive woody species in the area. *Abutilon anglosomaliae Bothriochloa insculpata*, *Rhynchosia malacophylla*, *Endostemon tereticaulis, Commelina diffusa*, *Digitaria abyssinica* were the most frequent species in the area. *Abutilon anglosomaliae, Dicrostachys cinerea, Chrysopogon plumulosus, Bothrichloa insculpata, Pupalia lappacea, Loudetia flavida* are species with higher cover abundance in the Grass plain of Nechsar National Park. The hierarchical aglomeratve cluster analysis using average linkage strategy provides six major plant communities and one solitary releve. The low average specie richness resulted in low over all average species diversity. ANOVA showed no variability among plant communities with the respect to species diversity, richness, and evenneness at $p \leq 0.05$. Results also showed that woody species density was 1995 woody plants ha^{-1}. Mean cover of woody, grass, unpalatable forbs, and total herbaceous species was 31%, 58%, 68% and 121% respectively. The bare land cover was 12%. The high woody and unpalatable forbs cover indicated the progressively increasing grass species diversity deterioration in the grass plain of the Park. Relatively high bare land cover observed resulted in high incidence of gully erosion in the area. Analysis of variance showed significant variability among the plant community at $P \leq 0.05$ for woody species, grasses, forbs, and bare land cover. Pearson correlation coefficient matrix indicated that woody species cover was negatively correlated with total herbaceous cover (grass and forbs) and bare land cover. Grass cover was negatively correlated with forbs, bare land cover, and woody species density. Total herbaceous cover was negatively correlated with bare land cover, bush density. The relationship between bush cover, woody species density, grass cover, herbaceous cover, and bare land cover and related soil erosion is complex and related to climate, land escape geology and anthropogenic disturbances.

Main threats to the grassland ecology of Nechsar National Park are progressive bush cover increase, loss of grass cover, and increase in unpalatable forbs. Currently greater than 50% of the landscape of the grass plain is in a poor to fair grassland conditions. Decline in the grassland condition, unless reversed, will jeopardize the biological diversity as well as aesthetic value of the Nechsar National Park.

Even though the response of ecosystem to disturbance may vary depending on the nature, intensity, site and species relationships, the prevailing livestock pressure, and the progressive increases in invasive bushes seems to inflict irreversible damage unless appropriate intervention are planned and executed in the shortest possible time. Indeed, this unsustainable utilization will not only affect the biodiversity and ecological condition of the grass plain of Nechsar Park but also disrupt socio-economic anticipation of the local communities. Therefore, the sole dependency of the livelihood of the pastoralist community to the grass plain resource of the park should be addressed to bring win-win solution. Strict preservation without any significant use may not seem feasible for even high biodiversity conservation sites like Nechsar Park. A compromise is, therefore, necessary to allow an acceptable level of protection to many parts of the grass plain by taking into consideration the local people as an integral part of grassland ecosystem. Many conservationists and policy makers have now recognized the feeling of the local communities and seemingly found out that the conservation of protected area systems could not be successful without considering the communities that had historically occupied these areas. The ecological and botanical knowledge that have been developed over the years within the communities in the management of natural resources enables conservation agencies to demonstrate the benefits of biodiversity conservation more effectively for promoting sustainable grassland resources. In this line, the participation of different stakeholder who can play a key role in providing meaningfull support to lessen the livelihood dependence of the pastoralist community on the grass plain of the park is crucial for the conservation and sustainable utilization of the resource.

The overall situation of the park assumed improved since African Parks Foundation (APF Plc) has taken the management of the Park. However, currently APF has decided to stop working for the management of Nechisar Park. Thus, there should be a quick response before the remaining park resource is aggressively devastated

Future Research recommendation

Several research issues that need to be addressed as part of a long term monitoring plan and also that would help to promote better understanding of the mechanisms of bush encroachment specific to the grass plain of Nechsar National Park include:

- The effect of human settlements on the proliferation of woody species in the grass plain

- Soil seed bank analysis for the invasive woody species
- Soil nutrient and soil moisture dynamics in a relation to vegetation dynamics
- Seed dispersal, seed germination, and seedling recruitment for selected invasive species
- Ecologically sound methods of woody species and perennial forbs control e.g. *Dicrostachys cinerea, Acacia nilotica, Acacia mellifera, A. senegal* and *Acacia oerfota* on the one hand and *Abutilon anglosomalie* on the other hand.

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APPENDICES

Appendix 1 list and full names of 131 plant species recorded in the survey

Species Scientific name	Family name	Sum of % cover	Frequency
Abutilon anglosomaliae Cufod.	Malvaceae	758.75	71
Abutilon bidentatum (Hochst.) A .Rich.	Malvaceae	92.25	22
Acacia mellifera (Vahl) Benth.	Fabaceae	283.75	24
Acacia nilotica(.L) Willd.	Fabaceae	375.5	23
Acacia oerfota (Forssk) Schweinf	Fabaceae	190.25	4
Acacia senegal (L.) Willd.	Fabaceae	152.5	7
Acacia seyal Del.	Fabaceae	179.75	14
*Acacia tortilis (*Forssk.) Hayne	Fabaceae	1	1
Acalypha fruticosa Forssk.	Euphrbiaceae	11.25	5
Achyranthes aspera L.	Amaranthaceae	329	34
Adenium obesum (Forssk.) Rome & Schult.	Apocynaceae	16	1
Aerva javanica (Burm.f.) Schultes	Amaranthaceae	2	2
Aerva lanta (L.)Juss.ex. J. A Schultes	Amaranthaceae	65	28
Aeschynomene schimperi Hochst. ex.A.Rich.	Fabaceae	116.75	45
Alectra parasitica Hochst. ex. A.Rich.	Scrophularceae	1	1
Alysicarpus rogosus Willd Subspp. Rugosus	Fabaceae	1	1
Arstida kenyiensis Henr.	Poaceae	52.25	12
Balanites aegyptiaca (L.) Del.	Balanitaceae	3.5	2
Balanites rotundifolia (Van Tieghem) Blat.	Balanitaceae	3	3
Barleria acanthoides Vahl.	Acanthaceae	159.5	3
Barleria eranthemoides R.Br.ex C.B.Clarke	Acanthaceae	4	2
Bidens biternata (Lour.) Merr.& Sherff.	Asteraceae	71.25	8
Boerhavia diffusa L.	Nyctaginaceae	6	2
Bothriochloa insculpta Hochst.ex A.Rich.	Poaceae	528.5	61
Brachiaria lachnantha (Hochst.) Stapf.	Poaceae	3.5	1
Capparis fascicularis D.C.	Capparidaceae	22	11
Cardiospermum halicacabum	Sapindaceae	1	1
Cenchrus ciliaris L.	Menispermaceae	23.5	5
Cenchrus pennisetiformis Hochst.	Poaceae	117.25	10
Ceratostigma abyssinicam (Hochst.) Schweinf & Ascher.	Plumbaginaceae	1	1
Chasmanthera dependens Hochst.	Menispermaceae	1	1
Chenopodium opulifolium Koch. & Ziz.	Chenopodiaceae	1	1
Chloris roxburghiana Schult.	Poaceae	87	12
Chrysopogon plumulosus Hochst.	Poaceae	616.5	31
Cissus quadrangularis L.	Vitaceae	19.5	5
Corchorus trilocularis L.	Tiliaceae	77.5	27
Commiphora africana (A. Rich.) Engl.	Burseraceae	4	3
Commelina diffusa Burm.f.	Commelinaceae	330.85	53
*Commicarpus plumbagineus (*Cav.) Standl.	Nyctaginaceae	13	11

Conyza bonariensis (L.) Cronq.	Asteraceae	16.5	6
Crotalaria pycnostachya Benth.	Fabaceae	79	15
Cucumis dipsaceus Ehrenb. ex Spach	Cucurbitaceae	5	5
Cucumis prophetarum L.	Cucurbitaceae	2	2
Cycnium erectum Rendle	Scrophularaceae	4	3
Cynodon dactylon (L.) Peres.	Poaceae	116.75	25
Cyperus obtusiflorus Vahl.	Cyperaceae	252.5	40
Dalechampia pavoniifolia (Chiov.) M. Gilbert	Euphorbiaceae	5.5	2
Dichrostachys cinerea Wight & Arn.	Fabaceae	702.75	24
Digitaria abyssinica (Hochst. Ex. A.Rich) Stapf.	Poaceae	441.5	50
Dobera glabra (Forssk.) Poir.	Salvadoraceae	9	8
Dyschoriste multicaulis (A.Rich.) O. Kuntze	Acanthaceae	29.28125	24
Endostemon tereticaulis (Poir.) M. Ashby	Lamiaceae	157.75	54
Enneapogon cenchroides C.E Hubb.	Poaceae	384	25
Eragrostis schweinfurthii	Poaceae	7	5
Euphorbia acalyphoides Boiss.	Euphorbiaceae	1	1
Flueggea virosa (Willd.) Voigt.	Euphorbiaceae	3	3
Gomphocarpus phillipsiae (N.E.Br.) Goyder	Asclepiadaceae	1	1
Grewia erythracea Schweinfurth	Tiliaceae	2	2
Grewia velutina (Forssk.) Vahal.	Tiliaceae	11.5	5
Grewia villosa Willd.	Tiliaceae	4.25	3
Harisonia abyssinica Oliv.	Simaroubaceae	1	1
Heliotropium rariflorum Stocks	Boraginaceae	12	11
Heteropogon contortus (L.) Roem. & Schult	Poaceae	146.25	19
Hibiscus canabinus L.	Malvaceae	1	1
Hibiscus dongolensis .Del.	Malvaceae	26.5	15
Hibiscus micranthes L.f.	Malvaceae	27.25	14
Indigofera ambelacensis Schweinf.	Fabaceae	21	15
Indigofera schimperi Jaub.& Spach.	Fabaceae	108.5	36
Ipommoea aquatica Forssk.	Convulvulaceae	39	22
Kalanchoe lanceolata (Forssk.) Pers.	Crassulaceae	3.25	2
Leucas glabrata (Vahl.) Sm.in Rees	Lamiaceae	142.25	26
Leptochloa rupestris C.E Hubb.	Poaceae	9.5	2
Leucas martinicenisis (Jacq.) R.Br.	Lamiaceae	14.5	2
Lintonia nutans Stapf.	Poaceae	213	41
Loudetia flavida (Stapf.) C.E Hubb.	Poaceae	472.25	26
Maerua crassifolia (Forssk.) A.Rich.	Capparidaceae	40.5	9
Maerua oblongifolia (Forssk.) A.Rich	Capparidaceae	13.75	4
Maerua triphylla Gilg.	Capparidaceae	10.5	3
Mattiola rivae Engl.	Crucifereae	1	1
Maytenus senegalensis (Lam.) Exell.	Celastraceae	3.5	1
Mukia maderasepatana (L.) M.j.Roem.	Cucurbitaceae	2	2
Mollugo nudicaulis Lam.	Acanthaceae	2	2
Monechma debile (Forssk.) Nees.	Molluginaceae	180.25	24
Ocimum americanum L.	Lamiaceae	8.25	5
Oxygonium sinatum (Mmeisn.) Dammer.	Polygalaceae	29.75	16
Ozoroa insignis Del.	Anacardiaceae	1	1
Panicum atrosanguiunem A.Rich.	Poaceae	3	2
Panicum coloratum L.	Poaceae	54.5	6
*Pavonia burchellii (*D.C.) Byer.	Malvaceae	1	1

Pavonia melhanioides Thulin.	Malvaceae	9.25	3
*Pavonia procumbens (*Wight &Arn.) Walp.	Malvaceae	1	1
Pennisetum clandestinum cheiov.	Poaceae	85.5	18
Pentanisia ouranogyne S. Moore	Rubiaceae	20.75	8
Pentarrihum somalense N.E. Br.	Asclepiadaceae	39.5	20
Phyllantus maderasepantensis L.	Euphorbiaceae	32	15
Plectranthus barbatus Andrews	Lamiaceae	178	23
Plectranthus punctatus (L.F.) L` H`er	Lamiaceae	178	23
Polygala erioptera D.C.	Pedaliaceae	24	2
Portulaca quadrifida L.	Polygalaceae	52.75	22
Priva adhaerens (Forssk.) Chiov.	Portulacaceae	1	1
Priva tenax Verde.	Verbenaceae	1	1
Pterodiscus saccatus S.Moore	Verbenaceae	5	5
Pupalia lappacea (L.) A.Juss.	Amaranthaceae	483.25	46
Rhus natalensis Krauss.	Anacardiaceae	35.5	8
Rhynchosia malacophylla Spreng. & Boj.	Fabaceae	380.5	59
Ruellia patula Jacq.	Acanthaceae	65.5	21
Salvadora persica L.	Salvadoraceae	2.25	1
Sarcostemma viminale (L.) R.Br.	Convulvulaceae	3	3
Sclerocarya birrea A.Rich.	Anacardiaceae	3	2
Seddera bagshawei Rendle.	Convulvulaceae	1	1
Sehima nervosum (Rutt.)Stapf.	Poaceae	181.5	11
Sericocomopsis hidebrandtii Scinz.	Amaranthaceae	39	11
Setaria verticillata (L.) P. Beauv.	Poaceae	80.5	27
Sida alba L.	Malvaceae	13	7
Solanium incanum L.	Solonaceae	34.25	9
Solanium lonzae J.P Lebrum	Solonaceae	25	10
Solanium nigrum L.	Solonaceae	16.25	5
Sporobolus pyramidalis P.Beauv.	Poaceae	5.5	3
Tephrosia uniflora Pers.	Fabaceae	73.05	21
Tephrosia villosa (L.) Pers.	Fabaceae	18	9
Tetropogon villosus Desf.	Poaceae	108.75	18
Themeda triandra Forssk.	Poaceae	267.25	14
Tribulus terrestris L.	Zygophylaceae	1	1
Tricliceras pilosum (Willd.) R.Fernand	Turneraceae	6.25	5
Triumfetta flavescens Hochst.	Tiliaceae	434.5	43
Ximenia caffra Sond.	Olacaceae	7.75	4
Zaleya pentandra (L.) Jeffrey	Alzoaceae	4.5	1
Ziziphus Spina-christi (L.)Desf.	Rahamnaceae	8	2

Appendix 2.Pearson's Product moment correlations coefficient matrix for some of the ecosystem structure variables in the grass plain of Nechsar National Park at P< 0.05 and P< 0.01

Basal grass cover	-.283(*)							
Forbs cover	-.022	-.267(*)						
Herbaceous cover	-.212	.443(**)	.412(**)					
Bare land cover	-.004	-.316(**)	.107	-.070				
Stone cover	-.153	.171	-.016	-.028	-.222			
Altitude	-.071	.056	-.143	-.039	.025	-.016		
Bush density	-.340(**)	-.005	-.103	-.047	.051	.013	-.058	
Diversity	.006	.037	.019	.044	.137	-.154	.024	-.472(**)
	Bush cover	Basal grass cover	Forbs cover	Herbaceous cover	Bare land cover	Stone cover	Altitude	Bush density

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Appendix.3 GPS data for each releve from the grass plain of Nechsar National Park

RELEVES	LAT	LONG	ALTITUDE
1	6.00639956	37.66076703	1295.00
2	6.00575063	37.66512344	1268.00
3	6.00466006	37.66957532	1236.00
4	5.95421785	37.64739286	1381.00
5	6.00320530	37.67373936	1229.00
6	6.00218162	37.67856969	1228.00
7	6.00034146	37.68263784	1220.00
8	5.99781926	37.68630794	1230.00
9	5.99106126	37.68722484	1227.00
10	5.99060571	37.68277950	1223.00
11	5.99130878	37.67943763	1217.00
12	5.99132781	37.67484737	1225.00
13	5.99236230	37.67029214	1242.00
14	5.99421118	37.66635641	1264.00
15	5.99771381	37.65486357	1263.00
16	5.98256721	37.66415952	1286.00
17	5.97975768	37.66789508	1274.00
18	5.97698604	37.67419894	1238.00
19	5.97612253	37.67838713	1219.00
20	5.97479610	37.68243483	1221.00
21	5.97563202	37.68271361	1227.00
22	5.97419964	37.68656988	1231.00
23	5.97407844	37.69141437	1241.00
24	5.96734232	37.69651576	1262.00
25	5.96800785	37.69273401	1260.00
26	5.96890396	37.68827367	1235.00
27	5.96999176	37.68365532	1219.00
28	5.97068880	37.67995228	1223.00
29	5.97213644	37.67567206	1237.00
30	5.97334016	37.67182091	1249.00
31	5.97461672	37.66747682	1258.00
32	5.97792272	37.65967445	1305.00
33	5.97196938	37.65747654	1304.00
34	5.97049383	37.66179004	1272.00
35	5.96906740	37.66602223	1260.00
36	5.96911090	37.66597940	1262.00
37	5.96618981	37.67355437	1236.00
38	5.96512355	37.67791623	1225.00
39	5.96363316	37.68396352	1211.00

40	5.96119638	37.69147438	1229.00
41	5.95841442	37.69077064	1234.00
42	5.95998310	37.68712484	1208.00
43	5.96101742	37.68276759	1211.00
44	5.96242726	37.67765866	1225.00
45	5.96332328	37.67346385	1247.00
46	5.96422501	37.66700291	1258.00
47	5.96534844	37.66119375	1277.00
48	5.96640447	37.65597241	1315.00
49	5.96103452	37.64658426	1358.00
50	5.95959568	37.65168004	1351.00
51	5.95874257	37.65769062	1305.00
52	5.95787278	37.66216865	1281.00
53	5.95731933	37.66693460	1263.00
54	5.95764530	37.67156954	1246.00
55	5.95669890	37.67865619	1231.00
56	5.95238943	37.69016370	1197.00
57	5.93123912	37.68845145	1179.00
58	5.93137776	37.68384886	1178.00
59	5.93200388	37.67820809	1183.00
60	5.93221511	37.67100141	1212.00
61	5.93353802	37.66757095	1227.00
62	5.93470545	37.66127195	1274.00
63	5.93690520	37.65353034	1335.00
64	5.93873220	37.64534466	1392.00
65	5.91715191	37.64386928	1306.00
66	5.91320864	37.64700553	1311.00
67	5.91319372	37.64701190	0.00
68	5.91174608	37.65078971	1289.00
69	5.90979410	37.65536036	1269.00
70	5.90756435	37.65950010	1235.00
71	5.90590222	37.66407469	1215.00
72	5.90510133	37.66811435	1222.00