AN ASSESSMENT OF WOODY VEGETATION STRUCTURE IN MAASAI MARA CONSERVANCIES OF NAROK COUNTY, KENYA

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ABSTRACT

Vegetation structure is a result of adaptation of plants to the environment. It is important because it can be used as indications of measuring changes in habitats. Vegetation structure mapping and monitoring is however not adequately done in most habitats of East Africa mainly because of cost reasons. Furthermore, protection of habitats especially national parks and reserve prioritize on animal conservation and not woody plants. It has been observed that the woody vegetation formations of the Maasai Mara have been deteriorating hence affecting negatively habitat quality. This has prompted management interventions such as reforestation programmes by the conservancies. These interventions are however done without much scientific information on the woody vegetation structure of the study area which can provide focused solutions. This study examined the woody vegetation vertical, composition, horizontal and temporal structure of six conservancies (Ol Chorro, Lemek, Mara North, Olare Orok, Motorogi and Naboisho) of the Maasai Mara ecosystem. Primary data was collected from 108 sample variable transects and 250 sample car transects. In addition, 9 focus group discussions were held with local groups to get their views on the subject.

The study observed that the conservancies' landscape could be delineated by use of the woody vegetation physiognomy into *Acacia* bushland, bushed grassland, evergreen bushland, evergreen woodland, grassland, impeded drainage grassland, riverine vegetation, shrubland and *Tarchonanthus* bushland vegetation formations using canopy height, cover and indicator species. An analysis of similarities showed the different vegetation formation as statistically different in terms of species composition though some overlap exists in the species composition. Mapping procedures using GIS software Quantum GIS and Google Earth images were used to develop a vegetation map of the Maasai Mara Conservancies. A total of 7094 woody tree species were sampled using the variable transects. The results were as follows: *Croton dichogamus* was the most dominant species while diversity indices showed riverine vegetation and *Tarchonanthus* bushland formations as the most diverse with impeded drainage grassland being least diverse in respect to woody vegetation. The effect of browsing was evident in 54% of the sampled woody plants while breakages and human use evidence were 13% and 1% respectively. The disturbances were height specific; browsing was prevalent in lower height classes of regeneration while knock over and human use were more prevalent in higher height classes of recruitment and mature trees. Analysis using Chi-square test showed the occurrence of browsing to be statistically different at different height classes. The disturbances were also species specific, for instance, breakages were more pronounced in *Acacia* species while browsing was prevalent in *Grewia, Maytenus* and *Phyllanthus* species. The population structure of some species such as *Diospyros abyssinica* showed decline while others such as *Olea africana* and *Warburgia ugandensis* showed flat structures indicating unhealthy populations.

Although comparisons of the current vegetation map and a map done 40 years ago showed the general trend of vegetation formation in the study area has not changed, results from focus group discussions and the absence and/or low frequency of key indicator species show changes in vegetation composition and some woody vegetation formations especially evergreen woodlands as generally decreasing in the study area. The study concluded that browsers and breakages prevent the study area to be woodier and the big tree natured species of the study area as reducing. It is recommended that more efforts be done to conserve the big trees especially those of evergreen woodland vegetation formation in areas with lesser extent of browse, human and breakages disturbances.

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LIST OF ABBREVIATION AND ACRONYMS

Anosim- Analysis of similarities

Dbh- Diameter at breast height

GIS- Geographical Information Systems

GPS- Global Positioning System

H- Symbol for Shannon index

IVI- Importance Value Index

m- Meters

MMNR- Maasai Mara National Reserve

MNC- Mara North Conservancy

QGIS- Quantum GIS

SME- Serengeti Mara Ecosystem

CHAPTER ONE

1.0: INTRODUCTION

This chapter introduces the study topic. The relevant background information in the vegetation structure and the concept of conservancies are described. The research problem is also defined and the objectives stated.

1.1: Study Background

Vegetation structure is a result of the adaptation of plants to the environment including both biotic and abiotic factors (Sala, 1988). Its measurements involve focus on aspects like density, canopy cover and standing crop of different species (Schulz and Leininger, 1990). The data obtained from these measurements is useful to resource managers in order to understand the responses of vegetation to different management interventions (Schulz and Leininger, 1990).

Savannas cover around 40% of the terrestrial landmass and any changes within this ecosystem can have impacts on human livelihood globally (Holdo *et al.,* 2009). Savanna vegetation ecosystems are generally composed of a combination of open grasslands, woodlands of dispersed trees and closed thickets of dense or closed thickets of broad leaved shrubs and trees (Sharam *et al.*, 2006). The Serengeti Mara Ecosystem (SME) is an example of Savanna and it covers an area of over 25000 km^2 from Northern Tanzania to Southern Kenya. The vegetation formation in the SME is mainly made up of grasslands and savannas (Trump, 1972).

The Kenyan part of the SME is commonly referred to as Maasai Mara and includes the famous Maasai Mara National Reserve (MMNR) managed by Narok County Government. There are also important wildlife dispersal areas around MMNR that provide habitat and forage for wildlife. The dispersal areas are owned by the community in group ranches and conservancies. While the reserve is not inhabited permanently by people, patches of areas around conservancies are inhabited by people who undertake various economic activities. As such, the natural resources of the dispersal areas are under intense pressure to sustain both the communities and wildlife.

Conservancy's management is also mainly private while parks and reserves are managed by public institutions.

Group ranches have been in existence around MMNR since the gazettement of the reserve. However since 2005, there have been increased efforts to form community based conservation areas (conservancies) that pay fixed amounts to land owners in the dispersal areas of Maasai Mara. So far, eight such conservancies have been formed around Maasai Mara former group ranches, in southern Kenya wildlife dispersal areas, with noticeable positive changes in wildlife numbers and vegetation structure (Aboud *et al.,* 2012). It is the vegetation of these conservancies the study focused at. The study area is in and around six conservancies in the Maasai Mara namely Ol Chorro, Lemek, Mara North Conservancy, Motorogi, Olare Orok and Naboisho. The area is part of the greater Serengeti Mara Ecosystem (SME) whose vegetation and habitats have been studied extensively since the 1950s (Darling 1960; Glover and Trump, 1970; Norton Griffith, 1979; Pellew 1983; Dublin *et al*, 1990; Walpole *et al.,* 2004; Sinclair *et al.,* 2007; Holdo *et al.,* 2009), thus substantial comparative information is available.

1.2: Statement of the research problem

A number of descriptions of vegetation are available in maps and images globally. Density and distribution of vegetation types can be derived from available maps and images but species specific attributes such as species height, use, frequency and composition (vegetation structure) are harder to derive. Remote sensing and GIS technology has made it possible to obtain detailed information of the earth surface to the extent that it can identify species, although this is an expensive technology that is out of reach of most management units more so in Sub Sahara Africa. This is also the case for the Maasai Mara conservancies where research resources often cannot afford precise remote sensing studies. Furthermore the data from these kinds of sources (remote sensing and GIS) will still require ground-truthing. Banda *et al.,* (2006) noted that plant stand structure, composition and species diversity can only be obtained by field measurements using classical ecological approach.

The vegetation types of savannas and indeed of the Maasai Mara conservancies have undergone changes overtime as they are dynamically influenced by herbivores, fire, topography and climate. There has been concern on decline of some woody species such as *Balanites aegyptiaca* L. (Del), *Olea europea* L. *Spp africana* (Mill.) P. Green (synonym *Olea africana* Mill) and *Diospyros abyssinica* (Hiern) F. White within the Maasai Mara conservancies. It is has also been shown that elephants are causing a decline of Acacia species by hindering regeneration, recruitment and mature phases in Maasai Mara (Dublin *et al.,* 1990). There has been concern that woodlands are generally decreasing in the Maasai Mara ecosystem (Dublin, 1995: Sharam *et al*., 2006) including the Maasai Mara conservancies, as in most of African Savannas (Western and Maitomo, 2004).

With the apparent vegetation changes in the conservancies, the concerned decision makers such as conservancy managers and hoteliers are turning to management interventions such as reforestation and reduced livestock pressures (Western and Maitomo, 2004), as strategies in attempts to maintain the quality of woodlands and grasslands in the area. Camps and lodges desire tall and closed woody vegetation formation around their property and pure grasslands on plains to support game. The interventions to these ends are done without adequate scientific information meaning that they are ad hoc interventions. Questions loom over the relevance of the interventions as some studies conclude the vegetation changes in Maasai Mara conservancies are part of the natural process.

Much investment has been put in conservation as conservation areas prioritize themselves with conserving animal populations. As such there is limited data on the status of woodlands in the SME in terms of their current and possible future structures. Despite vegetation importance in influencing animal populations, the study of the vegetation structure and ethno-botanical knowledge of the Maasai Mara woody plants, more so in the Maasai Mara conservancies is still poor.

The study attempted to define the landscape of the study area by delineating vegetation formations and structures and compared them with previous studies. It also described the population structure and local uses of key woody species. The findings can assist decision makers on essential management interventions of woody vegetation in the area which is crucial for habitat preservation and wildlife conservation.

1.3: Research Questions

The study is based on the following questions:

(a) What is the composition of woody plant species in the study area?
(b) What is the distribution of vegetation formations in the study area?
(c) Is there a difference in landscape vegetation formations in terms of woody species and structure?
(d) What factors affect the woody vegetation structure in the study area?
(e) Is the occurrence of browsing the same at different height classes?
(f) What are the perceptions of the community on abundance trends of woody vegetation in the study area?
(g) What can be concluded from regeneration and recruitment trends of woody species in terms of sustainability?

1.4: Research Objectives

1.4.1: General objective

To investigate the status of woody vegetation in the Maasai Mara Conservancies.

1.4.2: Specific objectives

(a) To investigate the diversity and abundance of woody plant species in the Maasai Mara Conservancies
(b) To demarcate the landscape of the study area on the basis of vegetation formations
(c) To describe the disturbances that affect woody vegetation
(d) To describe the spatial and temporal woody vegetation structure in the study area.

1.5: Hypotheses

a) There is no difference in woody species composition among vegetation formations.
b) The occurrence of browsing is uniform at different height classes of woody species

1.6: Justification

This study looked at the vertical, horizontal, composition and temporal vegetation structures of Maasai Mara Conservancies in relation to apparent use and possible future trends. The topic is relevant as vegetation data is dynamic and constant assessment is important. Humans use vegetation of Maasai Mara conservancies for various purposes. The population of human beings is increasing, more so in Africa and Narok County, which has a higher population growth rate (3.3%) than the national average (2.6%) for Kenya (Ministry for Planning, 2011). This will inevitably mean more human induced pressures are expected to affect the vegetation of Maasai Mara. The study will enhance the knowledge of the structure and the impacts of human activities on vegetation and thus habitats and primary productivity. The findings can assist decision makers to come up with solutions that will enhance the interaction of human and vegetation and thus, wildlife and tourism, and as such foster sustainable development in these areas.

Furthermore quantification of the woody vegetation can also be useful in the application of contemporary environment management and protection strategies such as Payment for Ecosystem Services (PES). Vegetation monitoring is important to document changes that occur and assessing the efficacy of interventions employed. The greater Serengeti Mara is recognised by United Nations Educational, Scientific and Cultural Organization (UNESCO) as word heritage site because of its faunal diversity and prehistoric sites.

Conservancies are chosen as the study areas because they incorporate human settlement and wildlife conservation on the same or adjacent areas of land to a greater degree compared to national parks and reserves. Studying conservancies can enhance the knowledge in management of wildlife habitats outside public protected areas as significant quantities of wild flora and fauna are found in less protected areas.

1.7: Operational definitions

Breakages: Any visible damage on woody vegetation that is neither caused by human use nor browsing. It is also referred to as knock over in the study.

Conservancy: An area of land protected for wildlife conservation, and wildlife compatible uses. They are managed privately and land owners are paid fixed incomes at specified periods.

Disturbance: Perturbations to woody vegetation. The disturbances identified in the study include human use, herbivore (domestic and wild) browsing and breakages.

Population structure: Graphical representation of woody species on the basis of their height classes to assess the health of the species.

R Statistic: Statistical software for statistical computing and graphic by use of codes. R statistic allows for extensions in their program

Savanna: Complex landscape in the tropics characterized by grassland matrix and patches of woody vegetation in variable proportions.

Transect: a path in which counts and records of woody vegetation phenomena are taken.

Vegetation formation: groupings of vegetation communities based on their physiognomy especially height and cover.

Vegetation structure: the compositional, temporal, vertical and horizontal distribution of vegetation formation

Woody vegetation: type of plant that produces wood as its structural tissue. It includes shrubs and trees

CHAPTER TWO

2.0: LITERATURE REVIEW

The review of literature looks at various studies undertaken in the field of vegetation structure all over the world. The themes in the field of plant community, land use in conservation areas and landscape ecology. Major findings and gaps in these fields are identified and described in the last paragraph of each sub-topic. The conceptual framework is also described under the literature review; it looks at the systems of concepts, assumptions, expectations and beliefs that informed this research.

2.1: Plant community

2.1.1: Vegetation structure

Vegetation structure refers to three-dimensional spatial and angular distribution of plant biomass. Structure usually refers to vertical distribution though the horizontal structure can also be defined with techniques such as cover, density or distribution (Sala, 1988). Structure can also be described by species composition and temporal changes. Wessels *et al.,* (2011) lists geologic substrate, topography, human activity, fire and large herbivores (notably elephants) as the determinants of woody vegetation structure in savannas.

Tripathi and Singh (2009) observed the species diversity and vegetation structure in natural and plantation forests in Katerniaghat Wildlife Sanctuary, North India. They measured species richness, diversity and evenness and vegetation structure in terms of density, basal area and concentration of dominance. They concluded riverine forests had the highest species diversity and richness followed by miscellaneous forests. It was found that natural forests had higher density of plants at ground layer but species richness was higher at ground layer in plantation forests.

Wessel *et al*. (2010) studied the woody vegetation structure along a land use gradient in the South Africa's rangelands using airborne light detection and ranging (LiDAR). They compared canopy cover and height distributions and canopy cover on areas with different management strategies. It was found out that large trees (>7m) were clearly valued and conserved in communal rangelands and low prevalence of trees under 5m. This raises concern on the long-term sustainability of the tree resources. This is significant since the average heights for trees in the study area were between 2-5 meters. This analysis was possible by comparison of tree (>3m height) and shrub (<3m height) where it was seen the ratio of tree to shrub was almost equal in conservation areas, the same ratio varied widely in communal lands and was significantly high in cultivated areas where big trees are conserved for fruit/shade. The study made use of LiDAR technology and SPOT images which are expensive and could not capture the structure of woody vegetation less than 1m as it cannot differentiate between herbs and woody vegetation at that height (Wessels *et al*, 2010). This indicates regeneration trends were not adequately covered in the study.

In their study of vegetation structure and composition along a protection gradient of the Miombo woodlands in western Tanzania, Banda *et al*. (2006) looked at species richness, basal area, stem density and unique species in totally protected area in national park, game controlled area, forest reserve and open area where people have unrestricted access to forest resources. Their results showed basal area to be highest in game controlled areas; unique species was high in all areas except national parks; stem density was high in game controlled area and forest reserve; and species richness was high in game controlled area and forest reserves. Their result contradicts the assumption by conservation managers on the total protection of areas to protect biodiversity including plants. They also observed that protection in East Africa is geared towards animals thus the protected areas are usually 'floral-poor'.

Van Essen *et al.,* (2002) assessed woody vegetation at Ol Choro Oiroua Conservancy in Maasai Mara. They identified six plant communities in *Olea africana-Euclea divinorum* forest community, *Croton dichogamus-Acacia brevispica* low thicket, *Rhus natalensis-Themeda triandra* tall closed shrubland, *tarchonanthus camphorates-T. Triandra* low closed woodland, *Euclea racemosa- T triandra* tall closed shrubland and *T triandra-Cynodon* dactylon short closed grassland. The study acknowledged changes in the woodland communities of the Mara in the past quarter century. For example, the woody vegetation in Ol Choro Oiroua is under pressure from agricultural development, intensive livestock grazing and fuel wood source for both tourist facilities and the community. These activities are changing the vegetation structure of the conservancy and limit the access of game of their former dry season dispersal area. Growth potential of woody plants can indicate the degree to which woody vegetation structure is changing due to various pressures.

The study by van Essen *et al.* (2002) however did not look into the growth potential or regeneration of woody plants. Research by Walpole *et al.,* (2004) identified thirteen woody habitats in Maasai Mara National Reserve based on species. They analyzed the densities, browse availability and species richness of different habitats in the reserve. Like Van Essen *et al.,* (2002) they also failed to assess the population structure of the woody species in their study area.

The horizontal, vertical, composition and temporal structure of woody vegetation were looked at in this study. The population trends of key woody species in the Maasai Mara were also observed. The population structure enabled deduction of the sustainability status of woody species by observing regeneration and recruitment trends.

2.1.2: Vegetation classification, formations and mapping

It is common in vegetation ecology to classify plant communities into vegetation types or formations. The criteria of this classification have been problematic in both the nomenclature and relative importance of factors to warrant comparisons between different studies (Gruttblatt *et al.,* 1989). Among the commonly used classification criteria is to assign a vegetation type according to the physiognomic characteristics such as canopy height and cover (Kindt *et al.*, 2011). This criterion classifies primarily a given area as a woodland, shrubland, bushland, thicket or grassland using the dominant life form.

It is also possible to classify species by various desktop methods including ordination, analysis of similarities/dissimilarities or cluster analysis among other methods (Kindt & Coe, 2005). These methods aim at grouping communities of similar organisms (species) together. These analyses can only be done once the data is collected. Classification based on physiognomic characteristics can be done in the field.

Trump (1972) recognizes 18 vegetation types of ecological significance in the former Narok District, Kenya. The major climax vegetation types in the district as recognized by him include Bamboo, forests, evergreen and semi deciduous bushlands, acacia woodland on recent alluvium, *Acacia-Commiphora* bushed and wooded grassland and montane grasslands. Nine other vegetation types are derived from these six primary vegetation types. He mapped vegetation of soils with impeded drainage separately and described three more vegetation types from these.

In his work, Trump mentions the floristic composition of Narok district's vegetation but does not quantitatively describe the frequency or size classes of the species. This is also the case with Glover and Trump (1970) who identified three major ecological units in forests, evergreen bushland and *Acacia-commipora* shrub in Narok district. Riverine vegetation, according to them, cuts across the three ecological units. The frequency and size classes are useful in determining the distribution of woody against herbaceous vegetation, density, cover and height which are vital in the understanding of the general functions of the ecosystem (Sankaran *et al.*, 2004). The spatial distribution of vegetation types is key to understanding ecological processes, animal behaviour (Reid *et al.*, 2003) and human impacts on the ecosystem (Serneel & Lambin 2001; Lamprey & Reid 2004).

The early maps and cartographic description of SME come from intensive scientific exploration during the 1970s. These early maps such as of Glover & Trump (1970) and Trump (1972) were mapped using aerial photographs and benefitted from extensive ground-truthing. However, the maps were drawn by hand and this limited the detail and accuracy with which complex land cover boundaries were described (Reed *et al.,* 2008). Further development in technology according to Reed *et al.,* (2008) such as Geographical Information Systems (GIS) and remote sensing resulted to various commercial land-cover classifications but the maps are sometimes produced without supervision of the satellite imagery, furthermore extensive ground-truthing is often lacking in these maps. They claim the vegetation map presented in their paper was the first detailed map of the SME on the basis of extensive ground-truthing and application of spatial and spectral position afforded by remote sensing. Thus vegetation mapping is inadequately undertaken in the SME.

The map produced by Reed *et al.,* (2008) for the SME vegetation is detailed as it had 859 ground-truthing points that were verified from 1998 to 2002, the sample points for the Masai Mara conservancy areas appear to be following the road and thus the vegetation formations delineated for the Maasai Mara area might not be represented accurately from the map. Additionally, the work does not explicitly describe floristic composition and interactions in the SME. Floristic descriptions are important in detecting degradation (Serneel & Lambin, 2001) and thus management interventions.

Reid *et al.,* (2003) describe the floristics of the Masai Mara. They state that *Acacia gerrardii* Benth*, A. drepanolobium* Sjostedt and *Euclea divinorum* Hiern make the bulk of woody vegetation in the Mara. They also claim that the average tree heights did reduce from 5.1m in 1999 to 4.5m tall in 2002 and there is more tree and shrub cover in the group ranches than the reserve; the tree cover was 4% in the reserve and 12% in the ranches respectively in 2002. Additionally, moderate grazed areas have high quality grass compared with areas grazed less frequently or overgrazed for example; the grass cover was 70% in the reserve and 61% in the group ranches in 2002. The grass in the reserve was also taller than the grass at the ranches (Reid *et al.*, 2003). However like Reed *et al.* (2008), they also fail to represent the floristics of Mara Group ranches spatially and the population structure of key woody species.

This study classified and mapped vegetation formation based on physiognomy. The vegetation formations were analysed to assess the difference in species composition between the formations. The study not only developed a vegetation map but also described floristics, species distribution, frequencies and population structure.

2.1.3: Factors affecting vegetation in savannas

Sankaran *et al.,* (2004) state that various methods have been put across in attempts to explain the vegetation patterns of savannas. They posit the methods revolve on either competition based mechanisms where limiting resources e.g. water determine tree-grass population or demographic-bottleneck mechanisms where the vegetation is controlled by factors 'bottlenecks' such as herbivory and fire.

Reed *et al.,* (2008) support the idea that savannas vegetation types and structure is influenced by competition based mechanisms in particular niche separation mechanism where vegetation types occupy distinct niches of resource use. They show areas receiving more than 650mm of rainfall per annum as mainly composed of woodlands while areas with lesser rainfall dominated by grassland vegetation type except where the moisture is altered by a landscape factor such as topography. Low lying areas in grasslands because of topographic influence of moisture availability thus had woody vegetation type.

Pellew (1983) and Holdo *et al.,* (2009) on the other hand view vegetation in the savannas as a result of demographic factors. Pellew (1983) posits that three factors in elephants, giraffes and fire directly influence the woodland structure of Senerora in the Serengeti. He states the factors that affect woody vegetation structure as height specific; for instance, he views trees exceeding 6m as ecologically mature as they escape influence of fire (whose threshold is 3m) and giraffe browsing (whose threshold is 5.75m). According to him, fires affects regeneration of trees while elephants cause mortality to trees in all size classes of regeneration (< 1m), recruitment (1-5.75m) and mature phases (>5.75m). He determined the mortality of mature trees to be 6% per annum from the time period of 1968-1977. He assumed 5 of the 6% to arise from elephant damage and the remaining 1% to non elephant mortality such as lightening, senescence and wind. He estimated that 60-85% of all *Acacia tortilis* shoots below 5.75m were consumed by giraffes. He concluded that the retarding effect of giraffe was significant; it takes *Acacia tortilis* 36 years for a browsed tree to exceed the height out of reach by a bull giraffe (5.75m) while without browsing it takes just 13 years to reach that height.

Holdo *et al.*, (2009) identifies the key variables in fire, browsing and grazers determine vegetation structure across rainfall and fertility gradient in the Serengeti savannas. They identify their keystone browsing species as elephants though they note that elephants are mixed feeders and key grazing species as wildebeests. While the current elephant population do not control the woody vegetation by themselves, Holdo *et al.*, (2009) posit that the population affects tree-size class distribution of woody vegetation because increase in their population density causes shift in tree size distribution from mature to small height classes and woodland may shift to grasslands. Like Norton Griffith (1979) and Pellew (1983), Holdo *et al.*, (2009) see fire having an overall pernicious effect on woody vegetation type and structure. Grazers influence the woody vegetation by controlling the amount of fuel available for fire and grasses compete with woody plants especially regeneration for nutrients and water. Sharam *et al.*, (2006) identify browsers as having the greatest impact on regeneration of woody species, using *Euclea divinorum* seedlings; they note that seedling survival is reduced by 50% due to fire, 70% through browsers and elephants having no effect.

Homewood *et al.*, (2001) state the transition between woodlands and grasslands are driven by edaphic factors and disturbance although many of the processes have underlying human drivers. For instance, Sinclair *et al.*, (2007) report in Serengeti, no lightening fire has ever been reported and fires are started by humans. Another example of human influence in vegetation dynamics in the savanna is given by Norton-Griffith (1979) who mentions the 'elephant problem' in many savanna areas is a product of agricultural settlements in elephants range confining them to smaller areas. The same sentiments are echoed by Naveh (2000), a landscape ecologist, who claims the current ecologic theories should include humans as the highest organization hierarchy in any ecological framework. Most frameworks studying vegetation dynamism in savannas view humans as 'external' drivers and not the main drivers of the vegetation changes and types. It is therefore important to include the human factor as a variable that determine vegetation type and structure; which is not included in most studies explaining savanna's vegetation structure.

2.1.3: Plant population characteristics

Sahu *et al.*, (2012) view the analysis of tree diversity and population structure as vital in provision of baseline information of managing and conserving forests. In their analysis of a tropical deciduous forest in Malyagiri hill ranges of Eastern Ghats, Odisha, India. They used important value index (IVI) to describe *Shorea robusta* (IVI=45) as the most dominant tree. They recorded 57 species, five of which were randomly distributed and fifty two contiguously distributed. The diversity was also high with a Shannon index value of 3.38. Species richness was smaller among the trees in big size classes compared to smaller trees.

Tripathi *et al.,* (2010) studied the population structure and regeneration status of important tree species in the sacred forests of Meghalaya, India. They categorized the regeneration status of the species as '(i) good, if seedlings>saplings>adult (ii) fair, if seedling>sapling</= adult (iii) poor, if species survives in only saplings stage but not as seedlings (though saplings may be less or equal to adult), (iv) none, if a species was absent both in seedling and sapling stage but present as adult, and (v) new, if a species was present only in seedling/sapling stage but not as adult trees.' They found the population structure to be pyramidal and the presence of all regeneration status. It was also observed that most species did not show regeneration in closed forests and new species were abundant in smaller forest patches.

In her analysis of woody plant distribution in West Africa's savannas, Lykke (1998) established that most large and preferred trees have flat size class distribution while the less preferred shrubby woody species having the inverse J distribution. She concluded that for population to maintain a relatively constant population; more individuals are required in the smaller classes than in the larger ones.

Lekoyiet (2006) compared the woody species population structure between conserved and communal sites in Kimana and Elesenekei group ranches in Kajiado, South Kenya. She recorded more seedlings in conserved compared to communal areas though the difference was not significant. *Acacia xanthophloea* and *Acacia tortilis* tree species showed an inverted J distribution in her study at the conserved and communal sites but she notes a general decline of the same species in the higher diameter classes due to various human uses such as charcoal burning and clearance for agriculture, and elephant influence.

This study observed the population structure of key woody species by using height classes. Populations with healthy and sustainable populations were expected to have more individuals in the lower height classes of regeneration as compared to higher size classes. A major gap in woody vegetation studies has been the failure to analyse the population structure of species.

2.2: Land use in conservation areas

2.2.1: Factors affecting land use

The degree to which conservation areas can coexist with human activities is hotly contested as the implications of this coexistence to the sustainability of the socio-economy and environmental aspects (Homewood *et al.*, 2001). There is an attempt to integrate human land use and conservation through establishment of community based conservation areas (conservancies). Community based conservation areas make direct payments to land owners for availing their land to tourism operators. However, land use change in and around conservation areas threatens the persistence of biodiversity through loss of wildlife grazing and dispersal area to agriculture, and increased disturbance of wildlife around human inhabitation (Aboud *et al.,* 2012).

The Maasai community in the SME has traditionally adhered to pastoral land use system that is more or less compatible with wildlife. However, more recently they have diversified their land use systems and agriculture and tourism provide a considerable portion of their income (Thomson *et al.*, 2002). In their analysis of land use strategies among the pastoralists, Thomson *et al.*, (2002) found out that small scale cultivation, mechanized cultivation, tourism and a mixture of small scale cultivation and tourism as the distinguishable emergent land use strategies among the SME pastoralists. They however note that livestock keeping still remains a major component whatever the land use strategy chosen.

The Kenyan side of the SME is faced with land use changes and subsequent wildlife decline as compared to the Tanzanian side and is can be attributed to land tenure policy and spread of mechanized agriculture rather than agropastoral population growth and agropastoral land use (Homewood *et al.*, 2001). Their findings conclude that private ownership of land policy in the Kenyan side of the buffer zones of SME is the major cause of vegetation and habitat change as owners seek for land use option with maximum economic return which in most cases is mechanized agriculture. This is consistent with Thomson *et al.*, (2002) conclusion that the distance to Masai Mara National Reserve is the most powerful variable influencing land use strategy in the Masai Mara area followed by landscape attributes more so elevation and slope as the two variables influence the economic returns from the land use strategy chosen. Socio-economic variables in education, leadership and wealth were also important in determining land use though the variables were measured on lesser samples where the information was available.

Serengeti National park and MMNR are protected areas in which wildlife conservation land use is the dominant land use strategy. Around these areas are buffer zones (referred also as conservancies in this paper). The policy around these buffer zones differ significantly; while the Tanzanian buffer zones are mainly state owned with general wildlife conservation and licensed game hunting (except Loliondo Game Controlled Area and Ngorongoro Conservation Area)[1] as the major land use practices, the Kenyan buffer zone are privately owned and the land use policy is multiple land use (Homewood *et al.* 2001).

2.2.2: Woody plant use in arid areas

Shackelton *et al.*, (2007) identify woody resources as providing the function of supplying basic needs, savings for cash resources and providing safety-net during hard times. Basic needs include goods such as fuel wood, medicine and construction materials among others. The function of woody plants use in the provision of energy, food, medicine and shelter to the rural poor reduces some of the costs that the government would have incurred in providing these services and hence cash savings. It has also been recorded (e.g. by Shackelton in South Africa) that woody and forest resources are useful in the times of adversity such as loss of employment, death, disasters to provide a buffer or safety-net before things resume to normal.

Maundu *et al.,* (2001) note *Olea europea spp africana* as the most common tree used in ceremonies among the Loita Maasai. *Ficus thonginii, Ficus cordata, Olea capensis* and *Cordia ovalis* are also commonly used for ceremonies. The ceremonies range from circumcision to fertility to welcoming animals from far grazing lands. Bussman *et al.*, (2006) conducted research

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[1] Loliondo Game Controlled Area (LGCA) land use is a mixed land use policy that includes herding, small scale agriculture, wildlife tourism, hunting leases and commercial mechanized farming. The land use policy significantly differs from the other game controlled areas around Serengeti in Tanzania that only allow for wildlife conservation and licensed hunting.

in the Sekenani Valley region of Maasai Mara and concurred with Maundu *et al.,* (2001) on *Olea europea* as the most important ceremonial tree.

Plant use for timber is a recent woody plant use by the Loita Maasai. The most common species for this purpose are *Juniperus procera* and *Podocarpus falcatus*. The timber is used to make frames for roofing modern houses (Maundu *et al.*, 2001). Strong poles used for main structure of the house are derived from *Juniperus procera, Olea europea, Acacia nilotica* and *Olea capensis*. These are supported by thinner but strong stems of *Tarchonanthus camphoratus*, *Croton dichogamus*, *Ochna ovata* and *Mystroxylon aethiopicum*. Species for dead fences include *Tarchonanthus camphoratus*, *Rhus natalensis*, *Maytenus heterophylla* and *Mystroxylon aethiopicum*. Posts for making fences in Loita are mainly from *Juniperus procera* and *Olea europea*. *Juniperus procera* is preferred for fencing because it is termite resistant and durability as it can last to over 100 years. Live fence are made from plants that can grow from cutting such as *Commiphora* species, the gate is usually made from *Gardenia volkensii* and it is the women who close it.

Woody plants are also used as food plants in Loita. Maundu *et al.*, (2001) report inner bark of *Acacia* species is chewed for its water and sweetness. Gums and resins from *Acacia* and *Commiphora* are sometimes chewed to exercise the mouth and to pass time. Plants are also used to make alcoholic drinks e.g. roots from *Aloe spp.* in fermentation process of alcohol. Fruits are a major part of foods consumed by children and women. The five most preferred fruits by Loita Maasai include *Carissa edulis, Vangueria appiculata, Pappea capensis, Syzygium cordatium* and *Floucortia indica*. Other common fruits include *Rhus natalensis, Grewia similis, Cordia monoica* and *Scutia myrtina.* Common species used to make soup are *Acacia nilotica, Pappea capensis, Carissa edulis* and *Scutia myrtina.* Some soft stems e.g. of *Rhus natalensis* and *Rhoicissus tridentate* are also chewed while others like *Warburgia ugandensis, Olea europea*, are used as toothbrush.

Production of wood fuel is another major use of woody species in many parts of the world. In Loita, Maundu *et al.,* (2001) report the preferred firewood species as *Olea europea, Tarchonanthus camphoratus, Zanthoxylum usambarensis* and *Sherbera alata;* with *Olea europea* as the most preferred firewood species. Bussman *et al.*, (2006) observe the Maasai of Sekenani consider the smell of wood and prefer hardwoods for wood fuel.

Plants play a major role of medicine among many communities of the world. Among the Maasai, this is underpinned by the fact the name *olchani*, which is used both as a general name for all plants as well as for medicine. Maundu *et al.*, (2001) observe over 90 plant species used by the Loita Masai for a range of ailments such as gastro-intestinal infections to chest, to body aches among others. *Warburgia salutaris, Zanthoxylum usambarensis, Olea europea and Withania somnifera* are the top four medicinal plants in Loita.

Woody species are also useful in making wood products such as arrow shafts, kitchen utensils, walking sticks, fire sticks, snuff containers, arrow poison and clubs. Woody plants also contribute to fodder and veterinary uses among the Loita Maasai but Maundu *et al.*, (2001) study did not cover this as they considered the field too vast and does not pose a serious threat to plant diversity.

Other forms of minor plant use also exist in Loita. These include cleaning gourds, containers, detergent, glue, insecticide, mattress, ornament and decorations, perfume and deodorant, sandpaper, sieve, smoking gourds, string and rope, tanning leather, thatching, tobacco substitute, toilet tissue, towel, toys, stinging nettles, bee-food, bee-habitat and poisonous plants. The study of plants in Sekenani by Bussman *et al.,* (2006) was consistent with that of Loita's ethnobotany by Maundu *et al.,* (2001) in most part.

While the ethnobotany of Loita and Sekenani area is available, there is inadequate documentation of other areas of Masai Mara e.g. Koiyaki/Aitong area. Furthermore, the studies of ethnobotany by Bussman *et al.*, (2006) and Maundu *et al.*, (2001) do not describe the population structure, relative density, frequency or dominance of the mentioned floral species. This information is important in assigning importance values to the species and can be indicators of the population trend. This study looked at plant use in Koiyaki area of Maasai Mara and analysed the population structure of key woody species.

2.3: Landscape ecology

Landscape ecology involves the study of spatial variation in landscapes at different scales. The structure of the landscape, its function and changes within the landscape are the focus of this relatively new field. Structure influences the diversity, distribution and abundance of organisms. The structure is described by patch/matrix/corridor model. Function deals with the movement of materials and energy within and between landscapes components while changes refer to alterations of landscape structure and functions in space and time (Coulson and Tchakerian, 2011). It includes the natural and anthropogenic causes and consequences of landscape heterogeneity. A major feature of the field is its broadly interdisciplinary nature. The overall practical application of the discipline is the integrated approach in management of natural areas as ecological phenomena rarely occur in isolation. Kent (2011) notes all vegetation studies should have a strong background in the field of ecology. He views landscape ecology as a discipline concerned with the description, analysis and explanation of spatial pattern of a plant community within a given area. After all, plants give a good description of other biotic and abiotic components of a system.

Opdam *et al.*, (2001) state landscapes are studied by patterns in the geographical approach and processes in the ecological approach. They claim the future of landscape ecology depends on whether these two approaches can be integrated. In decision making of future functions of landscape, a cyclic process starting with problem definition is established. After problem definition and assessment, there is need to identify a set of possible solutions. From the set, the most cost-effective measures are chosen from which a new landscape plan is constructed and implemented. The last step is monitoring and evaluation that measures the extent of which the objectives are achieved during implementation. It is uncommon for all these stages to be undertaken in the decision making process on landscapes.

Opdam *et al.*, (2001) conclude landscape ecology as a field has a lot of literature in two areas of 1) empirical case studies on different scales, organisms and processes and; 2) modelling studies to extrapolate empirical studies in space and time. On the other hand, there are major gaps in two other areas of 1) producing guidelines and general rules from models and; 2) provision of tools for integration at the landscape level. It is these research gaps that this study, to some extent, attempted to fill by providing reforestation guidelines.

Stohlgrel *et al.*, (1997) posit studies done to identify gaps in habitat protection have been inapplicable mainly because of single-scale or poor multi-scale sampling methods, large minimum mapping units, subjective field measurements and poor ecological methods. They provide a methodology that enhances the measurement of plant diversity at a local level and provide a quantitative link between field ecology, resource mapping and landscape analyses. Stohlgrel *et al.*, (1997) thus attempts to address the issues in landscape ecology as identified by Opdam *et al.*, (2001) by describing a hypothesis driven approach to the design and implementation of landscape databases for general resource monitoring and ecosystems management.

A cornerstone concept in Stohlgrel *et al*. (1997) idea is 'keystone ecosystems'. This is a term that refers to areas characterized by indigenous species diversity, unique, critical or temporary habitats or habitats of great aesthetic value. These keystone ecosystems are important for a given ecological or management question. Quantification of the contribution of keystone ecosystems to landscape diversity and understanding the functional and structural differences between the ecosystems and their adjacent environments were the objectives of their study in Rocky Mountain National Park, Colorado, United States of America.

Their study (Stohlgrel *et al*., 1997) on landscape analysis of plant diversity showed the estimate of plant diversity decreased in a weak linear relation to increase in minimum mapping unit (MMU). For instance at 2 hectare mapping unit six vegetation types were observed 552 species in the 754 hectare study in Rocky Mountain National Park. This contrasted significantly with 100 Ha mapping unit where three vegetation types were recognized and 341 species estimated. This illustrates how important habitat types can be lost in the mapping process. Empirical models of biodiversity that use plant density as indices can be used to link the processes to ecosystem models. Diversity described by use of vegetation structure, plant species composition and richness can be modelled to an empirical function of landscape, climate and biotic variables

(Stohlgrel *et al*., 1997). Effects of changing spatial scale on landscape pattern are also described by Turner *et al.*, (1989).

Wiens (2009) view landscape ecology and sustainable conservation as sharing an interest in ‘places’. However, he states that they differ in their perspectives of the places and thus, the integration of landscape ecology to conservation is not complete. He reckons humans have influenced the nature and the need of conserving biodiversity is increasingly urgent. A preserve should not be considered in isolation from the surrounding landscape but the landscape mosaic should include not only the protected area but also other areas with different land cover, human uses and conservation value. Landscape ecology provides a framework to develop the shared sustainability between biodiversity and sustainability of cities, villages and culture (Wiens, 2009). He illustrates these concepts by studying prairie dog conservation in North America Great plains where he predicts the population of prairie dogs extending their habitats beyond the boundaries of the preserve areas and thus are a potential cause of conflict with adjacent land owners because the establishment of the preserve, like many conservation efforts, did not consider the landscape context in its setup. The study linked landscape ecology theories to vegetation structure phenomenon.

2.4: Conceptual framework

2.4.1: Theoretical background

Various models have been put forth to explain the tree-grass relationships and the vegetation structure of Savannas. Each model has its merit but none can explain in totality the persistence of tree-grass systems (House *et al*., 2003). An ideal model would incorporate elements of all and help in prioritizing the conditions under which each factor is important. This is however complicated as most studies look at woody and herbaceous cover in isolation (House *et al*., 2003) and different studies are undertaken at different scales (Sankaran *et al*., 2005). House *et al*., (2003) indicate the vegetation structure of savannas with precipitation of over 650mm per annum as determined by disturbances while it is widely accepted that ecological relationships are not linear but multivariate (Wiens, 1993; Wu and Loucks, 1995). Thus this study conceptual framework (Figure 1) is mainly influenced by the hierarchy theory of landscape ecology that takes into account multivariate nature of ecological problems and demographic bottleneck models of savannas vegetation.

Hierarchy Theory postulates the study of a relationship between a certain identity and its surroundings can be simplified by studying the signals and constraints imposed by its upper hierarchical levels and the buffered signals it receives from all the lower hierarchical levels. On the hierarchy, higher level force constraints upon lower levels and therefore can be regarded as constants. Lower level dynamics can be fast such that their signals are smoothed out at higher levels and thus can be regarded as averages (Wu and Loucks, 1995). Other theories in studying landscape ecology include holism and mechanistic theory.

It has been established by ecologists that four key variables in water, nutrients, fire and herbivory as the determinants of savannas vegetation structure and functions. In competition based theories, water and nutrients takes precedence as key determinants while fire and herbivory act as modifiers. Sankaran *et al*. (2004) further report most of the existing competition-based models have focussed on Plant Available Moisture (PAM) rather than Plant Available Nutrients (PAN).
Demographic bottleneck theories have the basic premise that impacts of climate variability and disturbances differ at different stages of a tree. The disturbances such as fire and herbivores are not only modifiers but also maintainers of the system in disequilibrium. The demographic-bottleneck has gained momentum because the root- niche separation, a cornerstone concept in competition based models has proven to be equivocal through evidence presented by empirical studies (Sankaran *et al*., 2004) and resource competition alone has been inadequate to explain long term tree-grass coexistence in spatially explicit model of savannas simulated by field data. This is the reason demographic bottleneck theory is adapted in the conceptual framework (Figure 2.1) for this study.

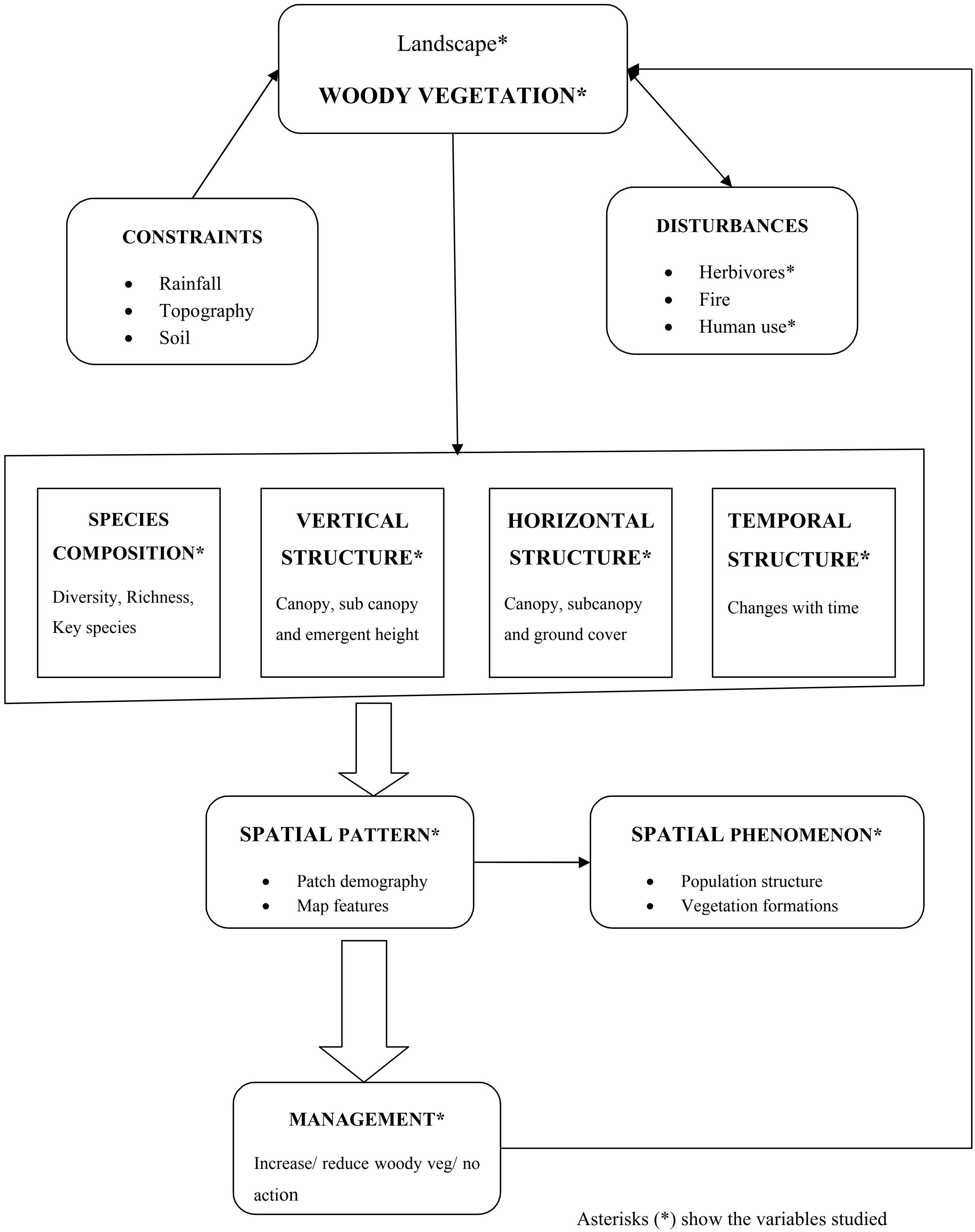


Figure 2.1: Conceptual framework for the study (Source Researcher, 2014)

2.4.2: Explanation of the framework

From the conceptual framework (Figure 2.1), woody vegetation can be used to define landscape. The woody vegetation structure can be divided into composition structure, vertical structure, horizontal structure and temporal structure. The composition structure looks at the species characteristics, vertical structure looks at the height characteristics, horizontal looks at cover characteristics while temporal observes the vegetation structure in relation to time.

The woody vegetation structure is affected by constraints and disturbances. The spatial constraints are limiting factors in determining vegetation structure such that it is impossible to have given vegetation formations under some constraining conditions. The disturbances are not the primary cause of given vegetation structure but can maintain the vegetation in a given state once a disturbance has taken place. The extant woody vegetation structure also determines the occurrence of spatial disturbances. For instance, fire will only occur if there is sufficient fuel.

The spatial constraints in the study area include topography, soil and rainfall. Woody vegetation needs water, and the main source of water in savannas is precipitation in rainfall. Topography influences the amount of water available for woody plants as valley areas will have more water available compared to steep areas. Thus existence of vegetation patches is expected to have a strong relationship with topography. Soil and nutrition levels influence the occurrences of woody species. The spatial constraints are assumed to be uniform in the study area.

The vegetation structure is determined by demographic bottlenecks (disturbances) in the study area as constraints are uniform. It has been hypothesized that in mesic areas, bottlenecks are more important determinants of vegetation structure than climatic conditions (Sankaran *et al*., 2004). The bottlenecks include herbivores, fire and human use. Herbivores, both wild and domestic, influence the vegetation through feeding (browsing and grazing) and breakages (also referred to as knock-overs in the study). Browsers retard the growth of woody vegetation and regeneration while grazers facilitate for woody vegetation dominance by reducing competition from grasses. The vegetation structure will also influence the herbivores presence in a particular patch. Knock over results mainly from elephant damage, though other animals and humans can also cause knock-overs. Human use is also viewed as a demographic bottleneck because as communities use woody vegetation for various purposes it has an effect on the vegetation structure and the type of use is again influenced by the vegetation structure. Occurrences of fire have a great influence on woody plants in the regeneration and recruitment phase to grow into mature phase by causing senescence or retarding growth. The disturbances have a fast temporal scale and are considered as averages as individual measurements can be cumbersome.

The outcomes of vegetation structure as influenced by spatial constraints and disturbances results to spatial pattern dynamics such as patch demography and map features. The spatial patterns dynamics can represent spatial phenomenon such that patch demography represents population characteristics and map features used to represent vegetation formations. The occurrence of spatial pattern dynamic and spatial phenomenon will determine if, when and where management interventions are necessary. The interventions can be strategies to increase, decrease or maintain the woody vegetation structure represented by spatial patterns dynamics. Strategies to increase woody cover can include reforestation or protection while reducing the woody cover includes activities that will decrease the woody cover at composition, vertical or horizontal structure.

Human factors cannot be ignored in the conceptual framework. This emerges from the dominance of the human organisms in natural systems. It is apparent humans affect ecosystems in both positive and negative ways. The human influence in the study is by using vegetation for various purpose and management interventions. In woody vegetation structure, fragmentation and development may cause the decline of woody vegetation. Conversely, restoration efforts (e.g. reforestation) and conservation will enhance the development of woody vegetation. Overgrazing by grazers tend to foster the development of bush encroachment. Unintended consequences of reforestation might include introduction of exotic woody species, decline of indigenous species and general ecological effects of the two. In a nutshell, management decision on a particular land use has a direct impact on the vegetation structure.

CHAPTER THREE

3.0: STUDY AREA

This section describes the study area. It includes its location, general topography, policies, climate, flora, fauna, population and geology. The woody vegetation is affected in different magnitudes by these aspects.

3.1: Location

The Maasai Mara conservancies are located in Narok County, south western Kenya and North of Masai Mara National Reserve. The area of interest is in and around six conservancies of Ol Chorro, Lemek, Mara North, Motorogi, Olare Orok and Naboisho (Figure 3.1). These conservancies are part of the Serengeti-Mara ecosystem from northern Tanzania to southern Kenya. The study area is located between the latitudes 1°13'40"S, - 1°18'11"S and longitudes 35°01'59"E -35°25'41"E.

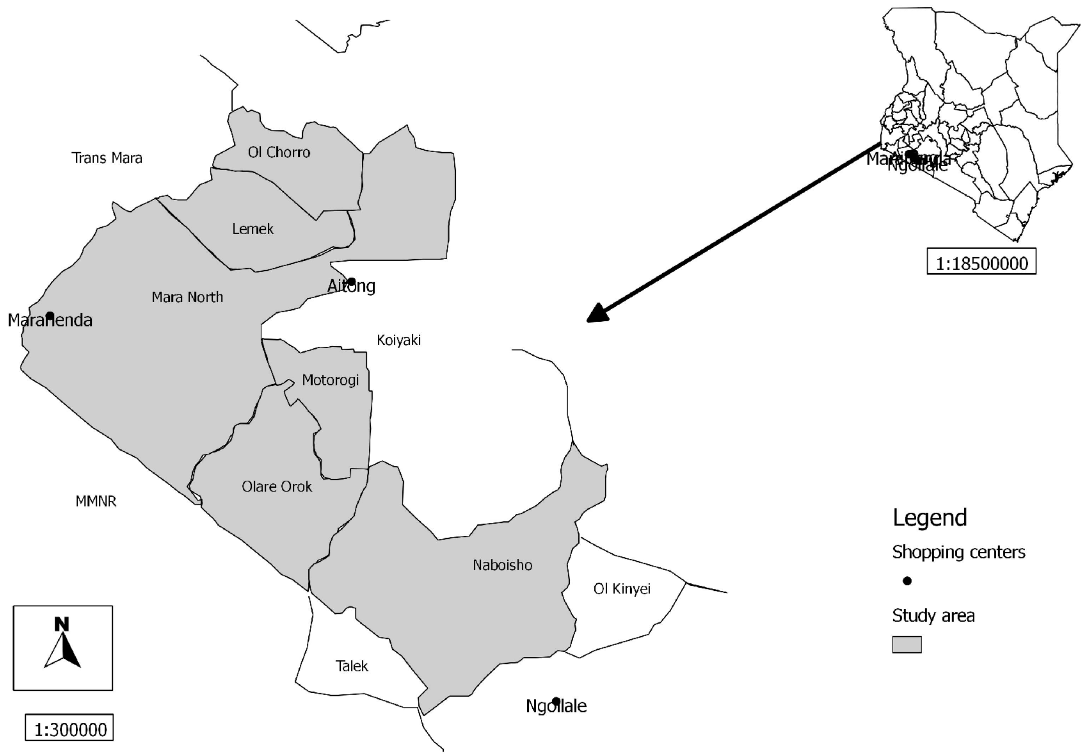


Figure 3.1: The study area and its location in Kenya (Source Mara North Conservancy, 2012)

The general Maasai Mara ecosystem area is a product of previous earth movements including tectonics, uplifts, and volcanic activities, warping and tilting. It is generally an upland system with the following topographical units;

(i) Ngamaa Hills to the east of Keekorok and the Sekenani gate,

(ii) Siria Escarpment (Isuria or Ololοlo Escarpment) forming the western boundary, forming a prominent fault line scarp (escarpment which has been associated with faulting,

(iii) Mara Triangle between the Mara river, the Siria Escarpment and extending far southwards towards the Tanzanian boundary,

(iv) Central plains between the Mara River and the Ngamaa Hills

The topography of Narok County includes highlands rising to 2300 metres above sea level (asl) to lowlands of around 1000m asl. Highlands occur mainly in the north of the County in Suswa, Mau and Mulot while lowlands are prevalent in Lower Mau, Olulunga, Maasai Mara and Loita areas, south of the County. It is therefore apparent the slope is towards the south. The study area is within the Maasai Mara area and is thus generally lowland though hills such as Lemek Hills and Aitong Hills are also occurring. The topography of the area determines the drainage patterns.

3.3: Drainage and Climate

The main river in the study area is the Mara River (Figure 3.2) that is 290km long draining into Lake Victoria through Tanzania. The other rivers in the area include Talek River, Olare Orok River and various tributaries and seasonal streams that drain into the river. The Mara River flows through Mara triangle and central plains causing flooding and swampy conditions in these areas during the rainy season with obvious faunal and floral significance (Darling, 1960). There are indications of soil erosion in some areas suspected to be caused by deforestation and overgrazing. The rivers seasonal stream and ponds form the bulk of water sources for the residents of the study area as rainwater harvesting is limited and piped water non-existence. There are also a few permanent springs emanating from the foot of escarpment.

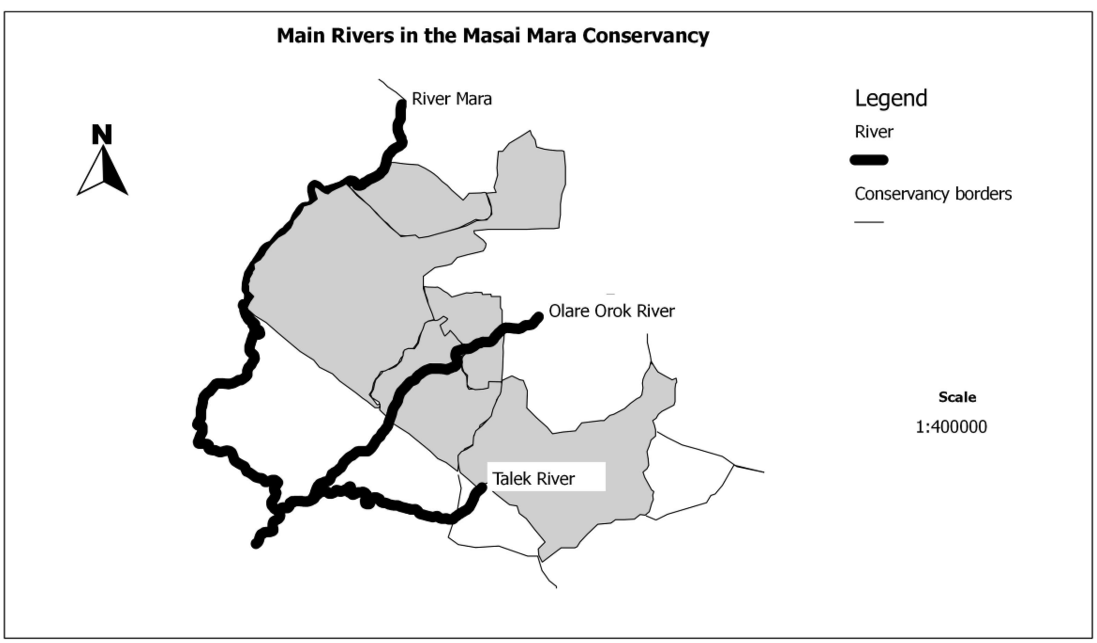


Figure 1.2: Map showing major rivers in the study area

The mean monthly temperature for the Maasai Mara area is fairly constant at 27 degrees centigrade. Darling (1960) reports daily temperatures cannot surpass 30˚ C but the night temperatures are usually lower and can be as low as 10˚C during winter months. It has been observed that mean temperatures of the Mara are continuously rising leading to progressive habitat desiccation (Ogutu *et al.,* 2007). Drought is also not uncommon in the Mara region, the most noteworthy occurring in recent times being in 1984, 1993, 1999–2000, 2005–2006 and 2008–2009 (Ogutu *et al.,* 2007).

The rainfall in Narok area is influenced by low pressure of Intertropical Convergence Zones (ICTZ) though topography can also cause local variation. Broten and Said (1995) note there is a general increase of rainfall from east to west and northward in the Serengeti-Mara ecosystem. They claim the area gets bimodal type of rainfall with the wet season between November and May and dry season between June and October. Long rain periods occur from March to May while short rain is between November and December. The main dry period is between June and October while a lesser dry period occurs between January and February. The mean annual rainfall for Aitong area was 900mm in Aitong and 600 mm in Lemek areas. Loita and Siana plains receive a mean rainfall of 750mm while the Mara plains between 500-700 mm per annum. Some parts of Mara plains, Aitong and Lemek are in the study area while Siana is in the south east of the study area.

3.4: Geology and soils

The geology of the Maasai Mara is underlined by Precambrian rocks of the basement systems. Younger volcanic deposits, then recent alluvial deposits now cover the original crystalline rock of Mozambican belt. This deposition was followed by metamorphosis and folding of sediments that led to the formation of granites and gneiss in the west with hills formed from schists and quartz. The hills were then eroded resulting to a peneplain in some areas while areas such as Siria escarpment remained. Phonolites originating from tertiary volcanoes subsequently covered these peneplains. A few rocky outcrops originating from the basement rocks are common in open grassland area.

The soils are generally categorized by shallow sandy, well-drained soils at the hills, transforming to deep, silt poorly drained soils at the plains. Siria Escarpment and Ngamaa Hills consists of shallow, porous sandy soils. Recent deposits occur along river Mara bands of alluvium and alluvial soils. These soils are not well drained lateritic clays to dark black cotton soils. The soils of the plains are also poorly drained black cotton soils and are subjected to seasonal waterlogging. The soils of the Mara have been described in detail by Sombroek (1982).

3.5: Vegetation

The vegetation type of the study area can be described as a savanna. Woody vegetatation seems to be determined by altitude with the high areas having tall woody vegetation of *Olea africana, Rhus natalensis, Tarchonanthus camphoratus and Ozoroa insignis*. The plains areas are dominated by acacia species with emergent's of *Elaeodendron buchananni*. Grasslands have scattered species such as *Balanites aegyptiaca* and *Boscia angustifolia*. Riverine woody vegetation is dominated by *Warburgia ugandensis, Diospyros abyssinica, Acacia kirki , Ficus species* and *Euclea divinorum. Croton dichogamus* appears to cut through all these topographic areas. Some areas are dominated by almost pure stands of *Acacia drepanolobium.* Darling (1960) notes virtually every hill and ant hill is covered by dense assemblage of thick and shrubby and forest trees. This vegetation assemblage is sometimes called 'lion bush community' and is dominated by *Croton dichogamus*.

The grass species in the area is dominated by the palatable *Themeda triandra* and the relatively palatable *Pennisetum mezianum*. Suspected overgrazed areas are dominated by the relatively unpalatable wire grass and false star grass. The sodom apple (*Solonum incanum*) is also present in areas suspected of overgrazing. The areas where livestock grazing occur often is characterized by short grass and patches of bare land while areas where the grass is exclusively for wildlife has tall grass more so during the wet season.

3.6: Wildlife

Various wildlife species in mammals' reptiles and birds are known to occur in the Maasai Mara ecosystem. The world-renowned wildebeest migration takes place within this ecosystem where a remarkable two million herbivores migrate from Serengeti to Maasai Mara annually. Wildebeests make 1.5 million of these, the rest being zebras and other antelopes. The Maasai Mara Ecosystem also supports the big five that is, lions, elephant, rhinoceros, leopard and buffalo. Other animals common in the Mara ecosystem include topi, Thomson gazelles, eland, kongoni, giraffe and flocks of impala which are found frequently on lion bush community (Darling, 1960). Grant gazelle, packs of wild dogs, reedbuck and jackals also occur. Darling (1960) also noted rare faunal species such as oribi, chanler reedbuck, greater kudu and roan antelope.

Six out of the seven species of Kenyan vultures are present in Maasai Mara Ecosystem with only Lammergeier missing with Egyptian, Hooded, Nubian, Griffon, White-backed and White-headed vultures being present. The bird list does not only include carrion eaters but over 450 bird species have been recorded in the ecosystem. These range from the big highly conspicuous ostrich to the small but still conspicuous Cardinal Quelea. Other common birds include White-bellied Go-away-bird, Secretary birds, Kori bustards and weaver birds. Uncommon birds such as wood peckers (Golden-tailed, Little Spotted and Fine-banded), bare face Go away bird and Eastern Grey Plantain-eater also occur. Rare birds such as African Finfoot and Blue Quail also occur within the Mara ecosystem.

Woody vegetation provides important habitats for wildlife in the Mara. The link between vegetation loss and decline of wildlife in Mara has inadequate studies (Ottichilo *et al.,* 2000) though Dublin (1990) notes the decline in giraffe population can be attributed to reduction of woody cover in the Mara. Otichillo *et al.,* (2000) argues no single factor has caused a greater decline in wildlife population than loss of habitat. They mention the case documented loss of habitats in wildlife dispersal areas of the Mara in particular dwarf shrubby grassland and wooded grasslands have contributed to wildlife population through reduced reproductive rates, increased mortality and competition for food. They note that apart from ostrich and elephants, all the other resident herbivore species especially buffalo and warthogs have significantly reduced in number in 20 year period (1977-1997) in the Masai Mara Ecosystem. Similarly Walpole *et al.,* (2003) showed a decline of woody vegetation in the Mara is correlated to the decline of rhino population based on the rhino's diet.

3.7: Land use and policy

Narok County has a total land area of 17933.05 Km^2 (Commission of Revenue Allocation, 2011). The study area has a total land area of around 800 Km^2 (Osano *et al.,* 2012) with origins from group ranches. Group ranches were established from Land (Group Representative) Act Cap. 287 (1968). The Act Cap. 284 provided for incorporation of group representatives who were recorded as owners. Reduction of overgrazing in communal land and the landlessness situation among the Maasai community were among the main objectives of the act (Richmond-Coggan, 2006). Under the Act, group members can chose to subdivide the land to own individual titles. Most of the group ranch members have opted to subdivide their lands to own individual titles and some of the individual land owners are re-pooling their land parcel together to lease to tour operators forming wildlife conservancies.

3.7.1: The concept of conservancies

The concept of a conservancy is relatively new to the Mara though Ol Choro Ourua conservancy was established in 1992. Olare Orok Conservancy was established in 2006. The conservancies differed from previous land conservation model in that land owners are offered fixed monthly lease payment based on their land size by tour operators. This payment is guaranteed regardless of visitor numbers. The land owners are also required in many cases to move off their land and agreeing to some restrictions on land use activities such as grazing and collection of natural resources (Bedelian, 2012). Other operators followed this model and pooled land owners together to form conservancies such as Mara North Conservancy, Motorogi Conservancy, Naboisho Conservancy, Lemek and Ol Chorro Ourua conservancy (Table 3.1). Conservancies are usually marketed as high end, low-impact safari destinations.

Table 3.1: Study area conservancies in Masai Mara Ecosystem

Conservancy name	Group Ranch	Year formed	Area (Ha)
Olare Orok [a]	Koiyaki	2006	9720
Mara North [a]	Koiyaki/lemek	2009	30000
Motorogi [a]	Koiyaki	2007	5466
Naboisho [a]	Koiyaki	2010	20628
Lemek [b]	Lemek	-	6860
Ol Chorro [b]	Lemek	1992	6879
Total			**79553**

Sources (Bedelian [a], 2012 and Osano *et al* [b], 2012)

In the study area, the conservancies' land is mainly used for livestock keeping/grazing, building, tourism, wildlife/grazing, infrastructure (roads and water) and social sites. The study area main land use is conservation with the establishment of different conservancies. These are community based conservation areas covering a total of 92, 248 hectares around the Maasai Mara National Reserve and the study area included 80,000 hectares (800 km^2) of these.

3.8: Settlement patterns and housing

The population of Narok South Constituency is at 317,844 people with 67365 people in the Mara region (Kenya National Bureau of Statistics, 2009). Settlement patterns in the study area are influenced by land use, land potential, land tenure and urbanization. The main land uses which influence settlement patterns, are livestock keeping and small scale crop farming. In the project area, human settlement takes places in various forms including permanent urban settlements, temporary or semi-permanent houses, tourism camps, 'research' centres and permanent wildlife rangers' camps.

CHAPTER FOUR

4.0: RESEARCH METHODOLOGY

The methodological approach involved both primary and secondary data sources. Primary data collection included transects surveys recording species characteristics in the field (transect surveys) and interviewing stakeholders on the use of tree/woody resources. Secondary data sources used included documents, maps and images. The materials used included hand held GPS device, camera, and tree measurement devices. The methodology used is consistent, in many aspects, with Stohlgren *et al.* (1997) and Ogutu (1996).

4.1: Study design

The study was carried out in the Maasai Mara Conservancies between May 2012 and July 2013. Pilot surveys were carried out in May 2012 and quantitative data through sampling was collected on June and July 2012. Focus group discussions were held on 17th-22nd July 2013 to complement the quantitative data. The summary of data used is shown in table 4.1.

Table 4.1: Summary of data types and sources for the research (Source: researcher, 2012)

Data variables	Data type	Level of measurement	Source
Species characteristics			
Species name	Primary	Nominal	Field work (Variable transect)
Species height	Primary	Ratio	Field work (Variable transect)
Disturbances			Field work (Variable transect)
• Browse	Primary	Ordinal	Field work (Variable transect)
• Human use	Primary	Ordinal	Field work (Variable transect)
• Breakages	Primary	Ordinal	Field work (Variable transect)
Site characteristics			
Vegetation formation	Primary	Nominal	Field work (Car transect)
Cover	Primary	Interval	Field work (Car transect)
Indicator species	Primary	Nominal	Field work (Car transect)
GPS coordinates	Primary	Interval	Field work (Car transect)
Maps	Secondary		Trump (1970), Mara North (2012)
Satellite images	Secondary		Google Earth (2014)
Community perceptions	Primary	Nominal	Field work (Focus Group Discussions)

4.2: Data collection

4.2.1: Pilot survey

The purpose of the pilot survey done in the Maasai Mara conservancies was to evaluate the vegetation formations and explore on most efficient data collection methods. Nine vegetation formations were described from the pilot survey in the study area (Table 4.2). It was also observed that new woody species rarely occur after recording 60-75 individuals in the vegetation formations, therefore samples of 80 species per site were seen as representative of a site.

The vegetation formation in each site was determined by observing the indicator species, canopy height and canopy cover. The method of classification used in determining vegetation formation/type is summarized in table 4.2. The classification method is based on Glover and Trump (1970), Trump (1972), White (1983), Gruntblatt (1989) and Kindt *et al.* (2011).

Table 4.1: Methods of identifying vegetation formations

Vegetation formation	Derived from(strata)	Indicator species	Canopy height(m)	Canopy cover
Grassland		*Balanites aegyptiaca*	0	0-10%
Bushed grassland		Varied	>3	10-30%
Impeded drainage grassland	Grassland	*Acacia drepanolobium*	0	2-10%
Evergreen bushland		*Euclea divinorum*	3-7	>40%
Evergreen woodland		*Diospyros abyssinica*	>8	>40%
Tarconanthus bushland		*Tarconanthus camphorates*	3-7	>40%
Acacia bushland		*Acacia gerrardii*	3-7	>30%
Shrubland	Inland woodland	*Croton dichogamus*	<3	>30%
Riverine	Riverine woodland	Varied	Varied	>30%

Source (Fieldwork, 2012)

The photographs of some of the vegetation formations in the study are shown in plate 4.1.

A 1: Evergreen woodland vegetation formation

A 2: Acacia bushland vegetation formation

A 3: Shrubland vegetation formation

A 4: Tarconanthus bushland (back ground)

A 5: Riverine vegetation with evergreen bushland characteristics

A 6: Grassland vegetation formation

Plate 4.1: Photographs of some selected vegetation formations. Source (researcher, 2012)

4.2.2: Sampling

The areas within the study area were mapped in Google Earth to design a map. The areas of interest were in and around the six conservancies. The boundaries for the study area were obtained from a Keyhole Markup Language (kml) file of the conservancies obtained from Mara North Conservancy offices. Polygons were drawn around each distinctive vegetation type and were marked as grassland, inland wooded areas and riverine wooded areas. The texture of the image on Google Earth was the main basis of designating the different vegetation type. Wooded areas are darker and coarser compared to grassy vegetation types which were lighter and smoother. The riverine woody vegetation was identified as woody vegetation in permanent water courses. Ogutu (1996) notes different plant communities register different tone because of the differences in plant density and or composition on satellite imagery. Google Earth has been used to show land use changes (Dittrich *et al.,* 2010), show locations (Bridi *et al.,* 2013) and digitizing areas to create maps (Laszlo and Tothmeresz, 2012). The map produced from this procedure presented the sampling frame.

The sampling approach employed stratified sampling. The strata were selected on the basis of the vegetation formation and three strata were selected. These strata included riverine woody vegetation, grassland woody vegetation and inland woodland vegetation. This is in accordance with Stohlgren *et al.* (1997) in identification of homogeneous, heterogeneous and keystone ecosystems as it is important to understand the functional and structural differences between keystone ecosystems and their surroundings in light of conservation issues. More importantly, this stratification is fundamental as simple random sampling would generally miss areas rich in species because wooded areas commonly occur in patches in the study area. Similar approach has been used by Walpole *et al.,* (2004).

The stratified random sampling employed was *Disproportionate Stratified Random sampling*; more specifically *Optimum Allocation Stratified Random Sampling* focusing on costs and precision of the data. The sampling method was chosen because vegetation formations are heterogeneous and irregular. Optimum allocation stratified sampling was the preferred sampling procedure as it allows for the use of different sampling procedures for different strata and are more representative of the elements in the population. This is because in terms of woody species composition, grassland areas are more homogeneous compared to riverine and inland woodlands. The total number of variable transects sampled were 108 with 63 transects in inland woodlands, 30 transects on grasslands and 15 transects on riverine woodlands. A total of 250 sample car transects were also taken and 9 focus group discussions conducted to complement data from variable transects.

4.2.2.1: Variable Transects

Quantitative data was collected primarily by the use of variable transects. Variable transect is chosen ahead of plot method because it saves time and has proven to have accuracies for quantitative analysis (Foster *et al.,* 1998; Nath *et al.,* 2009). This also leads to collection of more complete parameters e.g. herb composition and regeneration, and have time to do more transects. The idea of variable transects is to sample a standard number of plants in a given location rather than a standard area. The method can be variable more in width, length, shape of transects, number of plants per sample and so on.

The study used variable transects of 60×10 meters or the 80th recorded woody species in a sample site. The variability of the transects were more pronounced between strata than within strata for the purposes of consistency. For riverine vegetation plots, the transects were variable in both length and width (Druce *et al.,* 2008), as only 80 species were recorded in each transect. Grassland transects were fixed at 60×10 meters regardless of the number of woody tree species recorded. Inland transects were variable in length but not width (10 meters). The length was the point at which 80th species was recorded but the transects did not exceed 60 meters even if the site had less than 80 recorded species.

The start point of each transect was selected at random and the coordinates marked by a hand held Garmin Oregon 550x Global Positioning System (GPS) device. A bright and conspicuous object was placed at this point to assist in maintaining a straight line and a ten meter rope was placed to mark the width (Figure 4.1). The 5 meter point of the rope was at the centre of the bright object. Another 10 meter rope was placed perpendicularly from the object to mark the length, subsequent delineation of length and width were aligned using this initial 10×10 quadrant. At the end of the transect (80th species or 60 meters) 'the end point' coordinates were marked on the handheld GPS. Figure 4.1 illustrates the typical set up of transects. All transects, except for riverine vegetation were set in this manner. The transects for sampling riverine vegetation involved marking the coordinates of the start point on the GPS and marking the endpoint at the point of recording the 80th species.

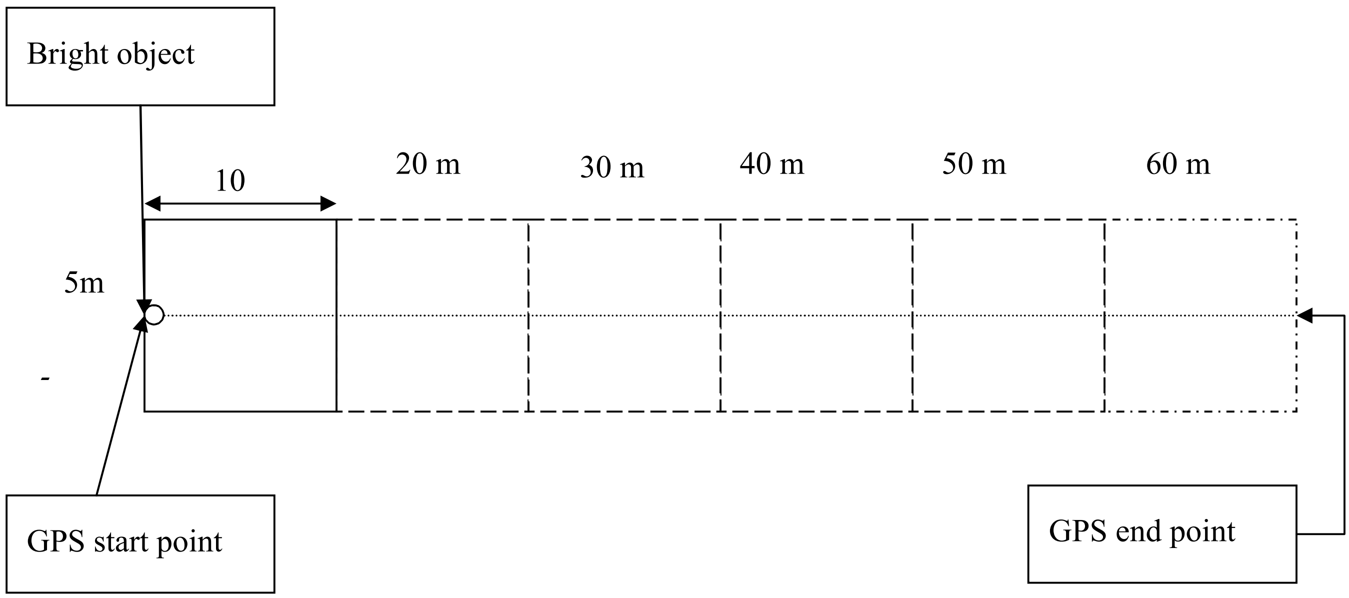


Figure 2.1: Illustration of typical transect layout

The data recorded on each transect included the plant species whether alive or dead, height, visible use of the plant and furcation. At each 10 meter interval, the canopy and ground cover were estimated (Appendix 1A). For riverine transects however, the canopy and ground cover were estimated after recording the 80th species. The species identification and authority was done according to Beenjie (1994).

The heights of individual woody species were estimated by use of similar triangles for large trees (>5 meters) and field estimates using researcher's 1.8m height as scale (Druce *et al.,* 2008), for smaller trees a meter rule was used. The height was recorded to the nearest 0.1m for small trees and nearest 0.5 meter for large trees. Visible use on the plant species included the evidence of browsing which were categorized on the scales of intense (3), moderate (2), less (1) or none (0). Walpole *et al.,* (2004) also recorded the evidence of browsing in MMNR as did Van de Vijver

(1999) in Tangarine National Park Tanzania using similar method of four levels of browsing. This was done by assessing the branches and leaves. Human use was recorded by observing signs of cutting on the trees by use of axes or machetes (*pangas)*, while breakages/ knock-over were recorded for trees with evident consumptive uses which could not be attributed to browsing or human use. Both human use and knock over were expressed as percentages. The methodology of using percentage to describe use is consistent with Druce *et al.,* (2008) who estimated the use of trees as percentages in Kruger National Park, South Africa. At the end of each 10 meter interval, the canopy and ground cover were calculated by the use of line intercept method where the percentage cover was determined by the following formula;

$$\%\,\mathrm{cover} = \frac{total\ distance\ on\ cover\,line}{total\ distance\ on\,line} \times 100$$

4.2.2.2: Car transects

The car transects were used to describe site characteristics (Appendix 1B) which included noting the major canopy, sub canopy and emergent woody species. The canopy, sub canopy and emergent species height were also estimated by the use of similar triangles. The major ground species were named and cover estimated. If management regime and the use of location are apparent, they were noted. The general terrain of the location including the soil and topography was also indicated. The major purpose of car transects was to have a general view of the site characteristics that could not be captured by the sample transects and to complement the variable transect data. All areas where variable transects were laid for species characteristics had a site characteristic description, but site characteristics were also used to describe some sites independently such as sites with unique features and inaccessible sites.

Geo-referenced photographs were also taken on areas where data is collected to complement the data. The photographs were also taken at points where data was not collected to enhance vegetation description of the area. Using the site characteristics, the vegetation formation/ type of the sample site was determined.

4.2.2.3: Focus group discussions

Focus group discussions of women, elderly people (male) and youth in Mararienda, Aitong and Ngoilale shopping centres around the conservancies were conducted to get shared understanding on the nature of uses and history of woody vegetation. Focus groups were of distinct gender and age because of cultural issues; women cannot speak openly in a forum with men in Maasai culture. Focus group discussions have been used by Hoehanou *et al.,* (2011) to determine the use of key species, their decline and exploitation methods in four ethnic groups of Benin. Wezel and Lykke (2004) also used focus group discussion in three countries of West Africa (Burkina Faso, Niger and Senegal) to assess the status of woody species in similar ecological studies.

Each focus group consisted of at least six individuals and at most ten individuals. Plate 4.2 shows a photograph of the discussion with women in Ngoilale area. The questions were administered with the help of a translator in Maasai language. The questions asked were in the thematic areas of woody plant use in the community, visible vegetation change and perceptions to reforestation (Appendix 1C).

Plate 4.2: Focus group discussion with women in Ngoilale. Source (Researcher, 2013)

4.3: Data analysis

Data was collected from the field was collated in Microsoft Excel 2007. The data was saved as text (tab delimited) files so that it is compatible with R Statistic software that was the main analysis software.

4.3.1: Species diversity

Importance Value Index (IVI) was used to compare ecological significance of woody species in the study area. It refers to the sum of relative density, relative frequency and relative basal area (ha^{-1}). It represents the relative dominance of a tree species. Relative importance of woody species was calculated using the Importance Value Index (IVI) of Curtis and McIntosh (1951). Ratio and summation commands were used to compute IVI in R Statistic.

IVI = Relative density + Relative frequency + Relative dominance

Relative density = Number of stems per ha of the i_{th} species / Total number of stems per Ha of all species x 100

Relative frequency = Frequency of i^{th} species / Total frequency of all species x 100

Relative dominance = Sum basal area of i^{th} species / total basal area of all species x 100

The basal area was computed by the formulae;

Basal Area in $m^2 = dbh^2$ (cm) × 0.00007854

It is common practice in forestry to only record diameter at breast height (DBH) and obtain data of the height using conversion tables (Niklas 1994; Hanus *et al*., 1999). However, woody vegetation in savannas is short and multi stemmed and it is easier to measure the height than diameter. The field data collected from transects did not include diameter at breast height. Diameter was determined by sampling a sub set of a species where both the diameter and height were measured and obtaining a constant from this sample that was multiplied with the height to get the diameter.

Indices of species diversity Simpson and Shannon indices were calculated for each vegetation type by using the package Biodiversity R that has function "diversity" in R Statistic. Species accumulation curve for the study area was illustrated by use of Vegan package in R. Shannon equation is shown below;

$$\text{Shannon index } (H') = -\sum_{i=1} p_i \log_e p_i$$

where: H' = the value of the Shannon-Wiener diversity index

P_i = the proportion of the i^{th} species

$\log_e$ = the natural logarithm of P_i

s = the number of species in the community

4.3.2: Demarcation of vegetation formation

The geo-referenced vegetation formation data collected from variable and car transects were transferred to Google Earth © as points. Google Earth images (© 2014 Digital Globe, © Cnes/Spot) were then used to demarcate boundaries of the vegetation formations. Extrapolation was done for areas where data was not collected based on the tone and texture of the areas where the vegetation formation is known. The digitized polygons were sent to Quantum GIS to create a vegetation map.

A statistical analysis for the vegetation formation was undertaken by use of Analysis of Similarity (ANOSIM) test was used where sites are classified by a categorical environmental variable, it assesses whether sites within categories are more similar than sites between categories. ANOSIM was calculated from Vegan package in R statistic. A significance level for a test of no difference between categories is calculated. The statistic calculated R, can be interpreted as correlation coefficient with values approaching 0 suggesting little correlation with the groups and values approaching 1 or -1 suggesting strong correlation. Negative values are unlikely because they would indicate similarities between categories are higher than similarities within category (Kindt and Coe, 2005).

The analysis considered the vegetation formation in each variable transect site as the environmental variable for the ANOSIM analysis. Vegetation formation was determined by considering canopy height, cover and indicator species. Analysis of species similarities were used to evaluate the accuracy of field methods of vegetation classification. The test was done by using the 'anosim' function in R package Vegan and the ecological distance used was Bray Curtis because it allows sites that do not share any species to be given the same maximum distance (Kindt and Coe, 2005). Nine hundred and ninety nine permutations were used for ANOSIM analysis. The null hypothesis was to be rejected if anosim value obtained was > or = 0.5, and fail to reject null if anosim value was < 0.49.

4.3.3: Factors influencing woody vegetation

The factors that affect woody vegetation are determined by height of the woody species in savannas. Four height classes of < 1m (regeneration), 1.1-2.9 m (lower recruitment), 3-5.4 (upper recruitment) and > 5m (mature) were selected based mainly on feeding reach of various herbivores and fire. Different herbivores feed at different levels of a tree (Pellew, 1983) and most woody species above 3 meters escape the impact of fire (Holdo *et al.,* 2009).

The rates of browse, knock over (breakage), density and human influence in the woody species were calculated by relative frequency counts. These rates were analyzed in respect to height and species in by the use of *tapply, with* and *cut* functions in R Statistic. The vegetation structure was analyzed by examining the frequency of selected woody species at different size classes. Data from focus group discussion were use to enrich the findings on the evident use of the woody species. The statistical significance of browsing was analyzed using chi square test in R statistic. Chi square (χ^2) compares the values of theoretical data against the actual data. If the occurrence of browsing was not dependent on height, then the browse occurrence recorded at different height classes was not to be significant and vice versa. The null hypothesis was to be rejected if calculated χ^2 was greater than tabulated χ^2

4.4.4: Temporal and spatial vegetation structure

Graphs of the population structure of key woody species were drawn on R Statistic package Vegan. Species showing normal population structure were expected to show a pyramid shaped graph. Comparisons of the developed vegetation map and Trump map were done in Quantum GIS to assess the temporal structures. Data from focus group discussion were used to complement the analysis of vegetation structure.

4.4: Scope and limitation

The research covered the vegetation formations of conservancies around Maasai Mara established by 2011. However the study area did not include Enonkishu conservancy and Ol Kinyei conservancy. Enonkishu Conservancy was excluded because widespread commercial agriculture and silviculture is evident unlike the other conservancies that have mainly natural vegetation formations. Ol Kinyei Conservancy was inaccessible in that the research party was unable to get permission in time.

The research made use of Google Earth images, more specifically SPOT and GeoEye. The vegetation formations were however in some instances not clear because of clouds caused obstructions.

Edaphic factors are known to cause occurrence of species in savannas. However it was beyond this study's resources to study edaphic factors. It was assumed that the soil type was not the primary determinant of woody vegetation species.

CHAPTER FIVE

5.0: RESULTS AND DISCUSSIONS

This section presents the results of the study in line with the study objectives, hypotheses and questions. The results are presented under the thematic areas of woody vegetations' species diversity, vegetation formation, factors influencing vegetation and temporal and spatial structure in the study area. These results are discussed in the light of similar previous studies.

5.1: Species diversity

5.1.1: Species richness

BiodiversityR, an R statistic package, gave a species richness value of 86 woody species in the study area. Species richness score was highest in riverine and evergreen bushland which had 54 and 45 respectively. Impeded drainage grassland had the least with a score of 5 (Table 5.1). R Statistic was also used to calculate the number of species per transect. Table 5.1 shows species diversity including the species richness per sampled transect.

Table 5.1: Species diversity of vegetation formations

Vegetation formation	Observations per transect	Species richness	Shannon index(H)	Simpson index(D)	Total transects
Acacia Bushland	5-18	41	2.3736084	0.82954769	23
Bushed Grassland	8-15	34	2.607035	0.89781601	6
Evergreen Bushland	7-15	45	2.1812583	0.77404262	15
Evergreen Woodland	4-16	25	1.8537139	0.71247776	8
Grassland	1-7	15	1.3919606	0.60118437	20
Impeded Drainage Grassland	1-4	5	0.2227088	0.08850256	4
Riverine	9-17	54	2.9776372	0.9187509	15
Shrubland	6-12	25	2.1349537	0.78549319	6
Tarconanthus Bushland	6-16	36	2.6007322	0.87334309	11
Study area			3.0462904	0.91704927	108

Source (Fieldwork, 2013)

Similarly Tripathi & Singh (2009) observed that riverine vegetation had the highest species richness in his study area in India. They explain that this is possibly because of higher moisture and nutrients coupled with greater micro-topographical variations. Walpole *et al.,* (2004) identified 62 woody species from 333 plots and 16,789 sampled plants in the Maasai Mara National Reserve. This study identifies 86 woody species from 108 transects and 7094 sampled plants. Walpole *et al.,*(2004) notes the species richness in the MMNR is lower compared to the communal rangelands because of greater animal densities in the reserve and the faster decline of woody vegetation habitats in the reserve as compared to communal rangelands/conservancies. The results from this study support their conclusions of greater woody vegetation richness in the conservancies compared to the national reserve. This implies total protection of areas for wildlife conservation has negative effect on woody vegetation as it was also observed by Banda *et al.,* (2006) in Western Tanzania.

5.1.2: Species diversity indices

Diversity indices present more information on the community composition than richness indices and are important in understanding the community structure (Bognounou *et al.,* 2009; Kindt & Coe, 2005). Shannon and Simpson indices are among the commonly used methods for measuring diversity. The package vegan in R statistic was used to calculate the Shannon and Simpson's indices for different vegetation formations and the study area (Table 5.1).

Legrende *et al.,* (2005) explain the concepts of alpha, beta and gamma diversity. They mention alpha diversity as variations of species in individual sites and beta diversity as the variation of species among sites. Gamma diversity is the variation of the whole region of interest and the indices used are similar to those of measuring alpha diversity. Shannon and Simpson indices measure alpha and gamma diversity.

Both the Simpson and Shannon diversity indices rate riverine (D= 0.91, H=2.98) and *Tarchonanthus* bushlands (D=0.87, H=2.60) as most diverse and rich in terms of woody species. Grassland (D=0.60, H=1.39) and impeded drainage grasslands (D=0.08, H=0.22) are the least diverse. These data are concordant, for most part, with species richness data as illustrated in table 5.1. However, *Tarchonanthus* bushland and bushed grassland have higher diversity indices compared to *Acacia* bushland which has a higher species richness score. Barrantes and Sandoval (2009) explain diversity indices as being factors of sample size. *Acacia* bushland had more transects (n=23) compared to *Tarchonanthus* bushland (n=11) and bushed grasslands (n=15). More importantly, diversity indices are a function of evenness, while *Acacia* bushland were dominated by one species i.e. *Acacia gerrardii*, *Tarchonanthus* bushland and Bushed grasslands were co-dominated by a number of species. *Tarchonanthus camporatus, Croton dichogamus* and *Rhus natalensis* are co-dominants in *Tarchonanthus* bushland formation while *Acacia gerrardii, Grewia bicolor* and *Croton dichogamus* were co-dominants in bushed grassland formation.

In interpreting diversity using Shannon index, (Lima, 2006) notes values less than 2 indicate low diversity while values above 2 indicating high diversity. Giliba *et al.,* (2011) agrees that an ecosystem with H' value greater than 2 as having medium to high diverse in terms of species. The Shannon and Simpson indices shows that woody species as present in all the habitat types. As expected, grasslands (H=1.39) and impeded drainage grassland (H=0.22) had very low woody diversity indices. Evergreen woodland (H=1.85) had a low index too. The woody vegetation in grassland and impeded drainage grassland were mainly in the regeneration phase. Impeded drainage grasslands was dominated by one species i.e. *Acacia drepanolobium*. Evergreen woodland was a near stable/ climax state and this explains the lower diversity indices. Shannon indices value normally fall between 1.5 and 3.5 (Lima, 2006; Bognounou *et al*., 2009) and the values for grassland and impeded drainage grassland could be interpreted to mean that they have insignificant woody species diversity. Savadago et al (2007) observed species diversity of Bukina Faso forests and observed dense woodland as most diverse with Shannon Index of 4.34 with gallery forest least diverse (H=1.33). Tripathi and Singh (2009) explain that high species diversity of vegetation can imply provision of habitat for diverse herbivores and other fauna as well.

Since diversity indices are influenced by sample size and vegetation studies designs rarely have uniform samples, accumulation curves are used. The curves are generated to analyze the effectiveness of the sampling. That is, if there are adequate samples to have a representative community? Classical ecological communities' species accumulation curves begin to plateau with adequate sample. The assumption in this study is all the vegetation types are classical. Figure 5.1 shows the species accumulation curves for the study area. The curve suggests adequate samples were taken in the study area as the curve plateaus.

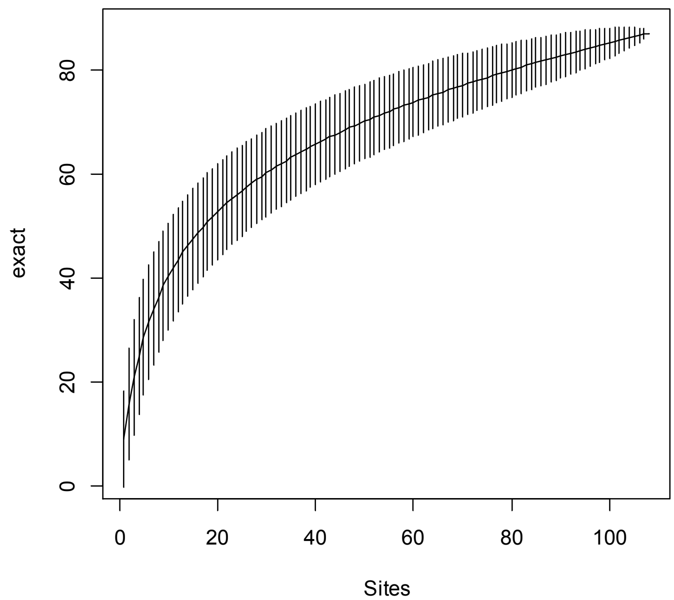


Figure 3.1: Species accumulation curve for the study area

5.1.3: Importance value index (IVI)

The importance value index was obtained by summing the relative frequency, density and dominance. The index showed the most abundant species, i.e. *Croton dichogamus,* was also the most important species of woody vegetation in the study area. Table 5.2 shows the IVI for the first 30 species.

The most common 20 species in the sample accounted for 89.2% of all the individuals encountered. This compares well with 85.8% for top 20 species by Walpole *et al.,* (2004) in a woody vegetation study in MMNR. The common species were more widespread and rare species more localized for example in riverine areas. The common most species include *Croton dichogamus, Acacia gerrardii, Acacia brevispica, Euclea divinorum, Grewia bicolor, Maytenus senegalensis* and *Erythrococca bongensis.* The common species compare with Walpole *et al.,* (2004) observations though they do not rank *Euclea divinorum, E. bongensis* and *M. senegalensis* as common.

Table 2.2: IVI for top 30 species

Species	Number Sampled	Relative Frequency	Relative Density	Relative Dominance	IVI
Croton dichogamus Pax.	1485	6.30	20.95	14.32	41.57
Grewia bicolor Juss.	313	6.09	4.42	22.85	33.35
Acacia gerrardii Benth.	653	4.72	9.21	12.59	26.52
Euclea divinorum Hiern.	589	4.20	8.31	13.16	25.66
Diospyros abyssinica Hiern.	61	1.26	0.86	12.72	14.84
Ormocarpum trichocarpum Taub.	589	3.15	8.31	0.06	11.52
Acacia drepanolobium Sjøstedt.	607	2.41	8.56	0.33	11.31
Maytenus senegalensis Lam.	238	5.04	3.36	0.07	8.47
Erythrococca bongensis Pax	212	5.04	2.99	0.37	8.40
Tarchonanthus camphoratus L.	176	1.36	2.48	4.49	8.34
Phyllanthus ovalis Forssk.	288	3.04	4.06	0.67	7.78
Elaeodendron buchananii Loes.	128	3.36	1.81	1.53	6.69
Acacia brevispica Harms	202	3.46	2.85	0.28	6.60
Acacia kirkii Oliv.	144	1.15	2.03	3.41	6.59
Rhus natalensis Krauss	116	3.78	1.64	0.71	6.12
Olea africana Mills.	90	2.83	1.27	1.81	5.92
Warburgia ugandensis Sprague	61	2.20	0.86	2.48	5.54
Dichrostachys cinerea L.	182	2.20	2.57	0.34	5.11
Grewia similis K, Schum	120	2.83	1.69	0.15	4.67
Cordia ovalis Roxb	74	2.94	1.04	0.66	4.64
Lannea spp	62	1.89	0.87	0.35	3.12
Capparis tomentosa Lam.	48	2.10	0.68	0.04	2.82
Teclea nobilis Del.	52	1.78	0.73	0.15	2.67
Commiphora Africana A. Rich.	64	1.26	0.90	0.15	2.31
Scutia myrtina Kurz.	28	1.36	0.40	0.20	1.96
Strychnos usambarensis Gilg	34	1.36	0.48	0.08	1.92
Vangueria madagascariensis Gmel	21	1.36	0.30	0.22	1.88
Balanites aegyptiaca Del.	27	1.05	0.38	0.34	1.77
Gardenia volkensii K. Shumm	15	1.26	0.21	0.27	1.74
Others	415	18.99	5.86	5.20	30.05
Total	**7094**	**100**	**100**	**100**	**300**

Source (Fieldwork, 2013)

Bigger trees had higher relative dominance which results in the increase of IVI. *Grewia bicolor species* had the highest relative dominance because most of the samples are heavily browsed such that they are short and wide. For instance, one *Grewia* sample was about 0.2 meters high but with a diameter of 3 meters. Additionally, the species had a high relative frequency because it was found in all vegetation types except impeded drainage grassland. The IVI recognizes the top species as the most significant ecologically in the study area. The number of *Diospyros abyssinicca* sampled (n=61) were not numerous but because of the size (diameter and height) of the trees sampled, the species recorded a high relative dominance and thus IVI value. Giliba *et al.,* (2011) used IVI to describe the vegetation structure of Miombo woodlads in Tanzania where they found *Brachystegia mycrophylla* and *Brachystegia speciformis* as the top two important species in the vegetation formation.

Analysis of IVI values for species per vegetation formation showed the dominance of different species per vegetation type. *Acacia gerrardii* dominated the acacia bushland with around 80% dominance. It was also the species that co-dominated bushed grassland with 36%, the other species was *Grewia bicolor* with 30%. Evergreen bushland was dominated by *Croton dichogamus* while evergreen woodland dominated by *Diospyros abyssinica.* Acacia dreponolobium dominated impeded drainage grasslands with 95% dominance while sparse *Elaeodendron buchannanni, Boscia angustifolia* and *Balanites aegyptiaca* were the woody species dominating grasslands. *Euclea divinorum, Acacia kirkii, Grewia* and *Croton dichogamous* were dominant in riverine vegetation. *Croton dichogamus* was again the dominant species in shrubland while Tarchonanthus camphorates was the dominant species in Tarchonanthus bushland. Table 5.3 shows the IVI for different vegetation formations computed from relative dominance and relative density. Savadogo *et al.,* (2007) also showed IVI for different vegetation formations in Bukina Faso where they observed that *Mitragyna inermis, Detarium microcarpum, Acacia dudgeon* and *Piliostigma thonningii* as dominant species in gallery forest, dense woodland, open woodland and fallow vegetation formations respectively.

Table 5.3: IVI for different vegetation formations

Vegetation type	Species	Number Sampled	Relative dominance	Relative Density	IVI -200
Acacia bushland	*Acacia gerrardii*	533	87.08	36.38	123.46
	Grewia bicolour	120	5.25	8.19	13.45
	Ormocarpum trichocarpum	150	0.24	10.24	10.48
	Acacia drepanolobium	150	0.01	10.24	10.25
Bushed grassland	*Acacia gerrardii*	49	36.85	12.6	49.44
	Grewia bicolour	51	30.46	13.11	43.57
	Croton dichogamus	68	9.84	17.48	27.32
	Dichrostachys cinerea	50	6.57	12.85	19.42
Evergreen bushland	*Croton dichogamus*	457	50.96	39.26	90.22
	Euclea divinorum	291	28.01	25	53.01
	Phyllanthus spp	84	0.66	7.22	7.87
Evergreen woodland	*Croton dichogamus*	308	18.08	48.66	66.74
	Diospyros abyssinica	44	48.37	6.95	55.32
	Euclea divinorum	127	24.63	20.06	44.69
Grassland	*Ormocarpum trichocarpum*	368	0.35	66.31	66.66
	Elaeodendron buchananni	6	43.3	1.08	44.38
	Balanites aegyptiaca	23	26.64	4.14	30.78
Impeded drainage grassland	*Acacia drepanolobium*	353	93.53	95.41	188.93
	Ormocarpum trichocarpum	13	2.02	3.51	5.53
	Acacia Senegal	2	2.32	0.54	2.86
Riverine	*Acacia kirkii*	143	16.65	11.88	28.53
	Euclea divinorum	102	19.91	8.47	28.38
	Croton dichogamus	181	10.55	15.03	25.58
	Grewia bicolour	53	13.91	4.4	18.32
	Phyllanthus spp	188	1.63	15.61	17.25
Shrubland	*Croton dichogamus*	179	74.52	41.53	116.05
	Acacia brevispica	68	2.34	15.78	18.12
	Grewia bicolour	27	10.36	6.26	16.63
	Cordia ovalis	15	7.08	3.48	10.56
Tarconanthus bushland	*Tarconanthus camphorates*	166	49.83	18.8	68.63
	Croton dichogamus	233	22.63	26.39	49.02
	Rhus natalensis	64	5.11	7.25	12.36
	Euclea divinorum	58	1.15	6.57	7.72
	Combretum molle	4	6.4	0.45	6.85

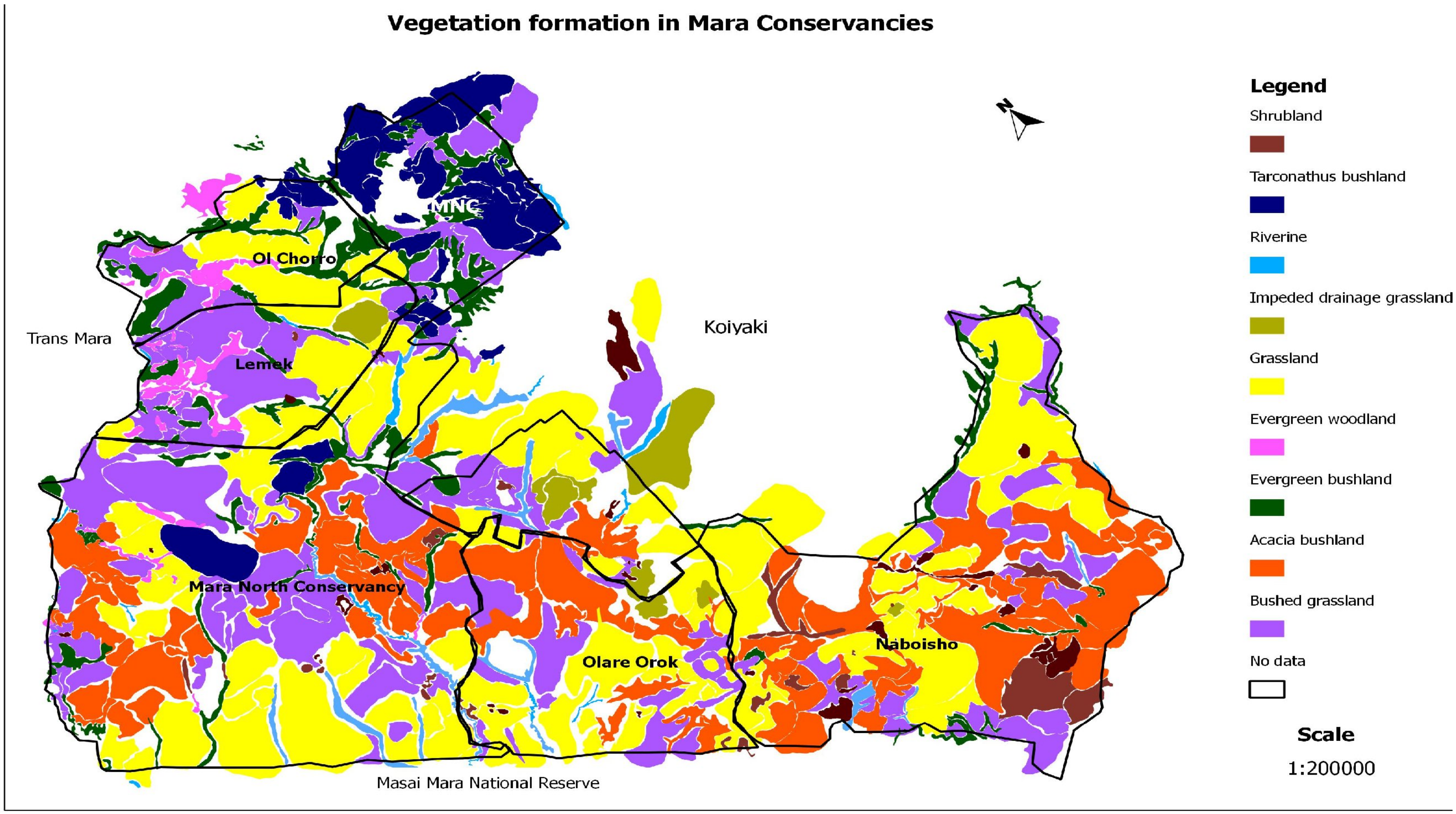
Source (Fieldwork, 2013)

The IVI especially the relative dominance can be used to determine indicator species. The indicator species of a vegetation formation is likely to be the species with high relative dominance. These results affirm that having numerous individuals for a particular species does not make the species an indicator species. For instance, 166 *Tarchonanthus camphoratus* species were sampled in the *Tarchonanthus* bushland vegetation formation while 233 *Croton dichogamus* were sampled in the same formation. However, *Tarchonanthus camphoratus* was the indicator species of this vegetation formation because most of the *Croton* occured as regeneration and tarchonanthus is conspicuous in this vegetation formation. This is attested by the fact *Tarchonanthus camphoratus* has a higher relative dominance value compared to *Croton dichogamus*. Devi and Yadava (2006) also used IVI as proxy for dominant species in ecosystems. They concluded that *Dipterocarpus tuberculatus* was the most dominant tree in tropical evergreen forests of Manipul, India with an IVI score of 272.6.

The use of dominant species as indicator species is implicit in the works of Glover and Trump (1970) and Trump (1972) in their vegetation studies of former Narok district in the 70s. They classified vegetation types based on indicator species and physiognomy. The results of IVI especially relative dominance values show the indicator species for the different vegetation types as consistent with those in table 4.2 that outlined the field methods of determining the vegetation formations.

5.2: Vegetation formation

Areas with woody vegetation were observed on hilly topography, valleys and areas with modified micro-topography that facilitate water holding capacity. Observations by Darling (1960) and Glover & Trump (1970) also suggest woody vegetation as occurring in hilly and riverine areas in the Maasai Mara ecosystem. Figure 5.2 shows a map of the different vegetation formations in the study area from field observations and observations from Google Earth (2014).



Sources (Researcher 2014, Mara North Conservancy 2012 & Google Earth images (© 2014 Digital Globe, © Cnes/Spot)

Figure 5.2: Map showing vegetation formations in study area

5.2.1 Vegetation formation distribution in the study area

The grassland vegetation types (grassland, bushed grassland and impeded drainage grassland) are the most common hence they form the matrix in the landscape. Grasslands were also the main vegetation formation in the study area by Trump (1972) and Walpole (2004) in the neighbouring MMNR. Bushed grassland appear to be the transition between grasslands and woodlands. The most common woody vegetation type is *Acacia* bushland. Though the vegetation formation (*Acacia* bushland) had significant proportions of grass cover as well. The vegetation formation in some areas of the study is not presented. This is because the vegetation formation could not be identified with certainty on Google Earth.

The vegetation formation tended to be less woody as one move to the south and east. *Acacia* bushland vegetation formation is predominately in the south while evergreen bushland, *Tarchonanthus* bushland and evergreen woodland mainly occur in the northern part. This distribution also affects the characteristic of bushed grassland formation in the study area. Bushed grassland is a transitional vegetation type and was characterized by *Acacia gerrardii* and *Grewia* species in the south while *Euclea* spp and *Croton* were the dominant species of the vegetation formation in the north. Trump (1972) also observed that evergreen bushland and semi evergreen thicket to be prevalent in the north and bushed grassland prevalent in the south. Grasslands occur through out the study area.

Mara North Conservancy showed significant distribution of all the nine vegetation types described in the study. This was not surprising as it is the biggest conservancy with 32,000 of around 80,000 Ha in the study area. It also stretches from north to south along the entire study area. The conservancies with huge proportions woody vegetation formation were Lemek and Ol Chorro that were dominated by evergreen woodland, evergreen bushland and bushed grasslands derived from these two. Motorogi Conservancy appeared to be least woody because it was dominated by grassland, impeded drainage grassland and bushed grasslands derived from acacia bushlands. Van essen *et al*. (2002) identified seven plant formations in Ol Chorro conservancy. Their classification was mainly based on species composition and not physiognomy.

Evergreen bushland, bushed grassland and grassland vegetation formation appeared to be distributed across all the conservancies. *Tarconathus* bushland and evergreen woodland tends to be concentrated in the north of Mara North, Lemek and Ol Chorro Conservancy. *Acacia* bushland was dominant in the south of Mara North, Naboisho, Olare Orok and Motorogi conservancies. This differs slightly with Trump (1972) observation in which evergreen bushland was not distributed in the south of the study area.

5.2.2: Characteristics of the vegetation formations

Evergreen woodland, evergreen bushland, and shrublands occurred in patches sometimes covering an area of less than a hectare. Grassland vegetation types and sometimes *Acacia* bushland were usually extensive covering incessant tens and sometimes hundreds of hectares. Shrublands often occured in hilly areas and were dominated by *Croton dichogamus, Acacia brevispica, Cordia ovalis* and *Grewia bicolor.* Darling (1960) note that virtually every small hill in Maasai Mara is covered by *Croton dichogamus*. Evergreen woodland, riverine and evergreen bushland occurred mainly along drainage lines (though evergreen bushland also occurred in hilly areas) and have numerous overlapping species with a canopy of *Euclea/ Diosopyros* and a sub canopy of *Croton* is not uncommon.

Glover and Trump (1970) note riverine vegetation formation cuts across other vegetation formations. They mention that this vegetation type falls largely between Acacia watercourse (dominated by *Acacia kirkii* and *Acacia xanthophlea)* and relic forests and bushland. In the study area, the riverine formation had mainly the characteristics of evergreen woodland and evergreen bushland and in a few cases shrubland and bushed grasslands. This is consistent with observations of Glover and Trump (1970) who described the understory of riverine vegetation formation to be similar to those of evergreen bushlands.

Tarchonanthus camphoratus, the dominant species of *Tarchonanthus* bushland vegetation formation is documented to be a problematic species in pasture lands and cultivation areas (Glover & Trump, 1970). It is reported to grow after a disturbance (fire/human) to an *Olea* or *Juniperus* forest and grows in eroded soil. Glover and Trump (1970), report that it can act as a nursery to vulnerable species of evergreen bushland communities. They also claim that areas colonized by *Tarchonanthus* bushland are not conducive for pastoral or cultivation not because of the plant but rather because of the shallowness and erosion of soil where the bushlands occur. The high species richness and diversity index (Table 5.1) in the *Tarchonanthus* bushland formation support the view that the vegetation formation acts as a nursery for evergreen bushland and woodland species. Tarchonanthus bushland has been mapped as a natural vegetation type from the 60s (Trump & Glover, 1970) to 2000 (van Essen, 2002). It therefore means the evergreen bushland vegetation formation is under constant disturbances or has a slow recovery.

Bushed grassland are the formations with woody species not exceeding 30% canopy cover. The areas with this vegetation formation were, or could be, woodier if disturbances were to be reduced. Like riverine vegetation, bushed grassland is derived from all other formations and thus have overlapping indicator species. Grasslands and impeded drainage grasslands have very little woody vegetation cover though impeded drainage grasslands is usually dominated by *Acacia drepanolobium*.

5.2.3: Evaluation of vegetation formations

Analysis of similarities

Analysis of similarities (Anosim) measures the similarities between different sites/ vegetation formation in terms of species composition. Anosim values range from -1 to 1 with 1 indicating complete difference and 0 complete similarities with other groups. Values much smaller than zero have been regarded as unlikely in Anosim analysis because they would indicate greater dissimilarity among replicate units within samples than occurs between samples. Clarke and Gorely (2001) provide a guideline of interpreting Anosim values and suggest R values > 0.75 show distinct groups, R>0.5 as overlapping but clearly different, R> 0.25 as overlapping strongly and R< 0.25 as barely indistinguishable. The results for the ANOSIM tests are shown in figure 5.3.

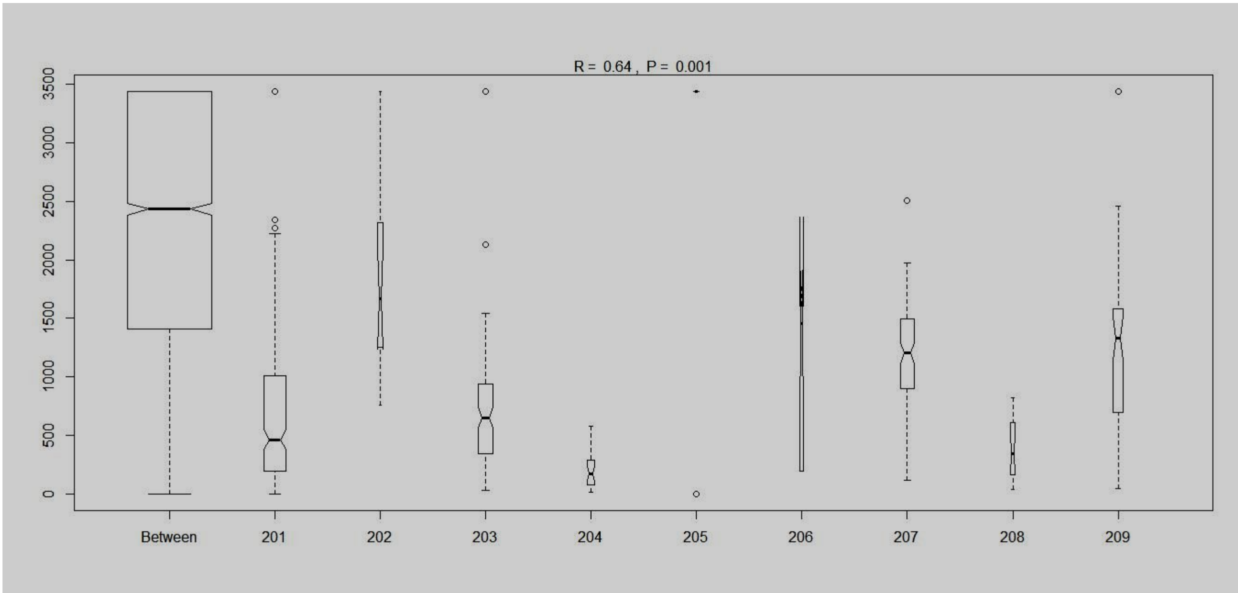


Figure 5.3: Anosim values for different vegetation formations

Legend

201: Acacia bushland, 202: Bushed grassland, 203: Evergreen bushland, 204: Evergreen woodland, 205: grassland, 206: impeded drainage grassland, 207: riverine, 208: shrubland, 209: Tarconathus bushland

Figure 5.3 shows the ANOSIM values for the different vegetation formations. The R value of 0.64 was obtained at 0.001 significance in the analysis of species composition among vegetation formations. The species selected for analysis were the ones greater than 1 meter in height because regeneration is not characteristic of vegetation formation. From these Anosim values therefore, the null hypothesis that there is no difference among the vegetation formations is rejected because it exceeds 0.5 which shows the different vegetation formations have discernable difference but there is some overlap in species. Sandiford & Barrett, (2010) used Anosim tests to differentiate species composition among vegetation type in Albany region, Australia. They found obtained R values ranging from 0.15-0.35 implying most of their vegetation formations had similar plant species composition.

The analyses of similarities of woody plants of less than 1 m and 0.5m yielded an R value of 0.41 and 0.2 respectively at 0.001 significance level. This shows that there no significant difference in the regeneration of species in the different vegetation types. This further supports the notion that if all the disturbances were to be removed in the study area, it would revert to a more homogenous woody state.

5.3: Factors influencing woody vegetation

The factors influencing woody vegetation are disturbances and constraints. The disturbances described are browse, breakages, also referred to as knock over in the study, and human-use. The analysis of disturbance allows the study to discuss its contribution to the vegetation structure and the importance of species in terms of utilization by fauna and humans.

5.3.1: Browse

Browsing is known to shape the woody vegetation structure of savanna ecosystems. Table 5.4 shows the browsing prevalence of key species in the study area. The index is an aggregated value of the measure of indices used from 0 meaning no evidence of browse to 3 implying intense browse.

Table 5.4: Key browse species

Species	Browse Index	Species	Browse index
Balanites aegyptiaca	2.81	*Commiphora africana*	1.9
Ormocarpum trichocarpum	2.74	*Capparis tomentosa*	1.8
Erythrococca bongensis	2.15	*Acacia brevispica*	1.7
Maytenus senegalensis	2.1	*Dicrostachys cinerea*	1.5
Grewia bicolour	2.1	*Acacia gerrardii*	1.1
Phyllanthus spp	2	*Acacia kirkii*	1
Lannea spp	2		

Source (Fieldwork, 2013)

Grewia bicolor and *Phyllanthus species* are among the most important browse species in the study area. Although *Balanites aegyptiaca* showed the highest browsing index, the number of sampled individuals (n=27) make it a less important browse species compared to *Grewia bicolor, Acacia brevispica* and *Phyllanthus spp.* which had over 200 samples each. *Ormocarpum* has a high browse index of 2.4 and 589 observations but most of the observations were between 0.1 and 0.3 meters high. The relative contribution of the species to browsing animals is not as significant as the woody plants that have a mean of 2 meters in height.

Croton dichogamus is the most abundant species (n=1485) in the study area and is among the least browse species with an index of 0.05. This can explain its dominance in the study area. Walpole *et al.,* (2004) showed dominant species such as *C. dichogamus* and *E. divinorum* as having less browse pressure in the Mara with understory species such as *Erythrococca* and *Grewia* showing intense browse pressure. The shrubby nature of some woody plants for example *Grewia bicolor, Commiphora africana* and *Gardenia volkensii* can be attributed to browsing. It is not uncommon to find aged bushes of these species less than a meter tall but with radii of between 1-2 meters (Plate 5.1).

Source (Researcher, 2012)

Plate 5.1: *Grewia bicolor* kept in the ground level due to browsing

Augustine and McNaughton (2004) observed broad leaved genera such as *Rhus* and *Grewia* lacked defensive mechanisms (spines and thorns) unlike *Acacias*. They note most of the savanna would be dominated by broad leaved species with the exclusion of browsing. The occurrence of browsing is dependant on height in Africa's savannas (Pellew, 1983; van Essen *et al*.,2002; Augustine & McNaughton 2004). Woody species at lower heights are generally browsed more; tall trees escape the effects of browsing. Table 5.5 shows the levels of browsing at different height classes.

Table 5.5: Browse extent at different heights

	BROWSING EXTENT								
	NONE		LESS		MODERATE		EXTENSIVE		Total
Height(m)	Freq	Perc.(%)	Freq	Perc.(%)	Freq	Perc.(%)	Freq	Perc.(%)	
0-0.9	1342	31.40	768	17.97	760	17.78	1404	32.85	4274
1-2.9	1196	63.92	237	12.67	222	11.87	216	11.54	1871
3-5.4	378	80.25	52	11.04	36	7.64	5	1.06	471
>5.5	324	78.45	57	13.80	22	5.33	10	2.42	413
	3240	**46.09**	**1114**	**15.85**	**1040**	**14.80**	**1635**	**23.26**	**7029**

Source (Fieldwork, 2013)

Over 50% of the sampled woody vegetation showed some evidence of browsing as shown in table 5.5. At the regeneration height (i.e. less than a meter high), the effect of browsing was highest with around 70% frequency of browsing, 30% of which was extensive. The data supports the notion that the effects of browsing on woody plants are height specific and browsing pressure tends to be less intense as a plant moves to higher height class. This observation is consistent with Pellew, (1983) who noted that woody plants in lower height classes were under higher pressure of browsing but differs with Walpole (2004) who showed 77% of woody plants less than 1 meter and 85% of woody plants > 1m with some evidence of browsing. The type of species and height influences the occurrence of browsing in a tree. Table 5.6 shows the prevalence of browse for different species at different height classes.

Table 5.6: Species browse extent at different heights

Species	Height class	Browse rate								Total
		None	perc(%)	less	perc(%)	moderate	perc(%)	Intense	perc(%)	
Balanites aegyptiaca	0-0.9	0	0.00	0	0.00	2	8.33	22	91.67	24
	1-2.9	1	33.33	0	0.00	1	33.33	1	33.33	3
	3-5.4	0	0.00	0	0.00	0	0.00	0	0.00	0
	>5.5	0	0.00	0	0.00	0	0.00	1	100.00	1
Phyllanthus species	0-0.9	30	14.35	33	15.79	42	20.10	104	49.76	209
	1-2.9	10	13.16	14	18.42	21	27.63	31	40.79	76
	3-5.4	1	50.00	0	0.00	1	50.00	0	0.00	2
	>5.5	1	100.00	0	0.00	0	0.00	0	0.00	1
Grewia bicolour	0-0.9	30	11.72	41	16.02	46	17.97	139	54.30	256
	1-2.9	9	18.00	11	22.00	11	22.00	19	38.00	50
	3-5.4	2	50.00	1	25.00	1	25.00	0	0.00	4
	>5.5	0	0.00	1	33.33	1	33.33	1	33.33	3
Acacia kirkii	0-0.9	26	36.11	16	22.22	22	30.56	8	11.11	72
	1-2.9	19	46.34	7	17.07	11	26.83	4	9.76	41
	3-5.4	4	50.00	3	37.50	1	12.50	0	0.00	8
	>5.5	13	68.42	5	26.32	1	5.26	0	0.00	19
Ormocapum trichocarpum	0-0.9	12	2.05	32	5.47	49	8.38	492	84.10	585
	1-2.9	0	0.00	1	25.00	1	25.00	2	50.00	4
	3-5.4	0	0.00	0	0.00	0	0.00	0	0.00	0
	>5.5	0	0.00	0	0.00	0	0.00	0	0.00	0
Acacia gerrardii	0-0.9	55	19.78	114	41.01	73	26.26	36	12.95	278
	1-2.9	45	29.61	45	29.61	53	34.87	9	5.92	152
	3-5.4	39	41.49	32	34.04	21	22.34	2	2.13	94
	>5.5	50	46.73	41	38.32	14	13.08	2	1.87	107
Croton dichogamous	0-0.9	437	94.38	11	2.38	11	2.38	4	0.86	463
	1-2.9	765	97.45	9	1.15	6	0.76	5	0.64	785
	3-5.4	192	99.48	0	0.00	1	0.52	0	0.00	193
	>5.5	28	100.00	0	0.00	0	0.00	0	0.00	28
Olea Africana	0-0.9	22	44.90	7	14.29	7	14.29	13	26.53	49
	1-2.9	7	23.33	4	13.33	8	26.67	11	36.67	30
	3-5.4	0	0.00	0	0.00	1	100.00	0	0.00	1
	>5.5	6	75	1	12.50	1	12.50	0	0.00	8

Source (Fieldwork, 2013)

Trees in higher height classes show lesser extent of browsing. In fact apart from *Acacia gerrardii, Acacia kirkii, Grewia bicolor* and *Olea africana*, woody plants greater than 3 meters rarely showed evidence of browsing. Coincidentally, the mentioned species are the ones preferred by elephants (*Loxodonta africana*) and giraffes (*Giraffa camelopardis*) that have the capability of browsing at heights above 3 meters (Pellew, 1983).

5.3.2: Breakages

Breakages/Knock-overs were recorded as estimated percentage of the whole plant. A knock over index of 100 indicates the whole plant has breakages while a 0 index indicate no visible breakage. The indices in table 10 are aggregated values of the percentages. The causes of knock over are diverse but the study assumes the knock over in the study area is caused by animals in particular the elephant.

Table 5.7: Breakages for different species

Species	Knock over index
Acacia gerrardii	16.45
Vangueria madagascariensis	13.33
Acacia kirkii	11.53
Euclea divinorum	11.34
Warburgia ugandensis	11.15
Dovyalis abyssinica	10
Tarchonanthus camphorates	9.09
Croton dichogamus	7.64
Diospyros abyssinica	6.89

Source (Fieldwork, 2013)

Prevalence of breakages (knock overs) is highest in *Acacia species*. Other common and big woody plants such as *Croton dichogamus*, *Euclea divinorum*, *Warburgia ugandensis* and

Diospyros abbysinica also show significant knock over levels. It was also observed the extent of knock over was evident at taller trees compared to shorter trees. Table 5.8 show the rates of knock over at different height classes.

Table 5.8: Knock over prevalence at different height class

Height(m)	Knock over rates										
	0	10	20	30	40	50	60	70	80	90	100
0-0.9	96.47	0.05	0.51	0.30	0.26	0.58	0.14	0.14	0.30	0.56	0.68
1-2.9	78.09	2.51	5.13	3.15	2.99	2.67	1.50	1.18	0.96	0.80	1.02
3-5.4	60.93	4.67	8.28	6.79	5.94	7.22	2.34	2.55	0.85	0.00	0.42
>5.5	51.82	3.63	11.14	11.14	7.51	8.96	1.45	2.42	0.97	0.97	0.00

Source (Fieldwork, 2013)

Mature trees (over 5.5 meters) have higher prevalence of knock over (48%) compared to trees in other height classes. The prevalence of knock over for regeneration is 4%, around 22% for 1-2.9 height class and 40% for 3-5.4 meter size class. Jansson (2011) showed that elephants in MMNR prefer grazing to browsing, when grass is available. Elephants caused damage to *Acacia* woodlands by breaking the trees compared to other woodland types such as *Balanites*.

More than 50% of mature acacia trees had evidence of knock overs. It is documented that elephants are the major natural causes of mature tree breakages in African savannas with them preferring the Acacia species (Dublin, 1986; Druce et al., 2008). Plate 5.2 shows a photograph of an *Acacia gerrardii* tree knocked over by an elephant. Other causes of tree breakages can include weather e.g. wind and rain, old age or senescence of the plant and human interference. *Tarchonanthus camphoratus* also showed significantly high rates of knock over (55%) for mature trees. Evidently, elephants also like to ring bark *Tarchonanthus camphoratus.* Mature *Warbugia ugandensis* also showed high breakages due to elephant damage (57%). In fact, focus group discussion revealed that most people would not prefer this species (*W. ugandensis*) near their homes as their ripe fruits attract elephants.

Source (researcher, 2012)

Plate 5.2: ***Acacia gerrardii*** **tree knocked over by elephants**

5.3.3: Human use

Evidence of human use was taken by observing and estimating machete/panga marks on sampled trees. Like knock over, the measurement of human use was also measures in percentage with total evidence of human use taken as 100% while no evident use as 0%. The human use indices presented in table 5.9 are the aggregate of these indices in the study area.

Table 5.9: Human use indices per species

Species	Human use index
Albizia gummifera	3.75
Warbugia ugandensis	1.9672131
Tarchonanthus camphorates	1.9318182
Strychnos usambarensis	1.7647059
Commiphora africana	1.09375
Croton dichogamus	1.023569
Euclea divinorum	0.9137056
Acacia gerrardii	0.5972435
Acacia kirkii	0.1388889
Rhus natalensis	0.0862069

Source (Fieldwork, 2013)

The evidence of human use of the woody species was not pronounced in the study area. The species with the highest index (3.75) had only 8 individuals sampled. *Warburgia ugandensis* with 60 sampled individuals and *Tarconanthus campharatus* with 160 observations had human use index of 2% each. In the analysis of human use against species height (Table 5.10), it is seen that humans make use of trees in bigger size classes compared to smaller trees in recruitment and regeneration. There was minimal evidence of human use in the study area with all the study species recording > 90% 'no human use' (table 5.10). The evidence of direct consumptive human use of woody plants in the conservancies can be regarded as insignificant as only *Croton dichogamus* had more than 5 individuals in a size class with evidence of human use.

Table 5.10: Evident human use on standing species

Species	**Height class**							
		0	perc(%)	10-50	perc(%)	51-100	perc(%)	Total
Croton dichogamous	0-0.9	458	98.92	3	0.65	2	0.43	463
	1-2.9	759	96.69	21	2.68	5	0.64	785
	3-5.4	188	97.41	5	2.59	0	0.00	193
	>5.5	28	100.00	0	0.00	0	0.00	28
Acacia gerrardii	0-0.9	277	99.64	1	0.36	0	0.00	278
	1-2.9	150	98.68	0	0.00	2	1.32	152
	3-5.4	93	98.94	1	1.06	0	0.00	94
	>5.5	104	97.20	3	2.80	0	0.00	107
Euclea divinorum	0-0.9	259	99.23	0	0.00	2	0.77	261
	1-2.9	135	97.83	1	0.72	2	1.45	138
	3-5.4	51	98.08	1	1.92	0	0.00	52
	>5.5	131	98.50	2	1.50	0	0.00	133
Tarconanthus camporatus	0-0.9	63	100.00	0	0.00	0	0.00	63
	1-2.9	35	97.22	1	2.78	0	0.00	36
	3-5.4	50	90.91	4	7.27	1	1.82	55
	>5.5	21	95.45	0	0.00	1	4.55	22
Warbugia ugandensis	0-0.9	18	100.00	0	0.00	0	0.00	18
	1-2.9	19	95.00	0	0.00	1	5.00	20
	3-5.4	12	100.00	0	0.00	0	0.00	12
	>5.5	10	90.91	1	9.09	0	0.00	11

Source (Fieldwork, 2013)

Focus group discussion in the Mara conservancy with elders, women and youth confirmed that firewood was the main source of fuel and women mainly collect dry firewood that is easy to light. The species that is most preferred for firewood is *Olea africana* but because of its rarity, the use of *Tarchonanthus camphoratus, Croton dichogamus, Euclea divinorum* and *Acacia gerrardii* is common. The community members claimed that they collect 'naturally' broken wood for fuel wood. *A. gerrardii* and *Tarconananthus camphoratus* showed high indices of knock over to support this claim. It appeared the breakages were sufficient to sustain communities for fuel wood as evidence of cutting is not much.

Olea africana was mentioned by all the focus groups as a very important and preferred species in the study area. This is consistent with the Sekenani Maasai (Bussmann *et al.,* 2001) and Loita Maasai (Maundu *et al.,* 2001) who identified it as the most preferred and useful species. The species (*O.africana*) among the most preferred species in a variety of uses such as fuel wood, fencing and construction, ceremonies and medicine. The number of this species with evident human use was small, in fact of the sampled species (n=90), none had evidence of human use. These results could be interpreted as the species is being well conserved in the conservancies. However, it has been established that humans make use of woody plants in higher height classes, and of the 90 recorded species only 9 were above 3 meters high. Additionally, stumps of *Olea africana* were not uncommon in the study area.

The species mentioned by focus groups as important for construction and fencing included *Acacia nilotica, Cordia ovalis, Acacia gerrardii, Albizia gummifera, Ziziphus mucronata, Olea africana, Diospyros abysinnica, Dicrostachys cinerea, Elaeodendron buchananni, Rhus natalensis, Balanites aegypgtiaca, Tarconathus camphoratus, Strychnos spp, Scutia myrtina* and *Warburgia ugandensis.* Medicinal woody species include *Ximenia americana, Rhus natalensis, Scutia myrtina, Carissa edulis, Acacia nilotica, Warburgia ugandensis, Toddalia asiatica, combretum molle, Teclea nobilis, Croton dichogamus, Commiphora eminii, Acacia gerrardii, Acacia drepanolobium* and *Balanites aegyptiaca.* All the species used as food additives were considered as medicinal. Firewood woody species include *Olea africana, Tarchonanthus camphoratus, Euclea divinorum, Croton dichogamus, Rhus natalensis, Combretum molle,* *Acacia gerrardii, Acacia xanthophlea, Acacia nilotica, Warburgia ugandensis, Elaeodendron buchananni* and *Cordia ovalis.*

The relative importance of the disturbances (Table 5.11) show browsing as the major disturbance in the study area with 54% of the woody species samples sampled showing some evidence of browsing, 13% showed some evidence of breakages and only 1 % showed some effects of human use.

Table 5.11: Summary of disturbances in the study area

Height class	Number sampled	Breakages		Browse		Human use	
		N	%	N	%	N	%
0.1-0.9	4274	151	3.53	2932	68.6	9	0.21
1.0-2.9	1871	410	21.91	675	36.08	35	1.87
3.0-5.4	471	184	39.07	93	19.75	14	2.97
>5.5	413	199	48.13	89	21.55	8	1.97
Average	7029		13%		54%		1%

Source (Fieldwork, 2013)

The number analyzed for the disturbances was 7029. This is because the count did not include dead trees without evident disturbances. If these were included, the effects of breakages/ knock over would be greater as most of the times dead trees show complete (100%) breakages.

The study areas' ecosystem behaves in a similar way as multiple stable state ecosystems as explained by Dublin *et al.,* (1990). They posit a multiple state ecosystem as that which changes to another state when disturbed and does not return to its original state once the disturbance returns to its original value. Instead, a second factor maintains the system in the new state. This theory was tested in MMNR where they showed fire to have caused woodland loss and when fires were reduced, the woodlands could not return to their previous state because of elephant's disturbance on regeneration and mature trees.

Similarly, fire, human use and breakages have caused the decline of woody vegetation types such as evergreen woodlands into less woody vegetation formations such as grasslands and bushed grasslands in the study area. Once these disturbance are removed (e.g. by establishing conservancies), the areas are unable to revert to previous woody state because of mainly browsing of the regeneration and recruitment size classes by herbivores. This study thus supports the multiple state theory as explained by Dublin *et al.,* (1990).

Chi square test showed browsing occurrence to be statistically significant at different height classes. The chi square calculated χ^2 (3, N=7029) =42.17 $p< 0.05$ was greater than the critical value of χ^2 at 3 degrees of freedom and 95% confidence interval. Thus the hypothesis that the occurrence of browsing is uniform at different height classes is rejected. On the contrary, the occurrence of browsing is greater at lower height classes in woody species and reduces as the woody species goes into higher height classes.

5.4: Temporal and spatial vegetation structure

5.4.1: Key species population structure

The key species height was plotted against the frequency to illustrate their population structure in R Statistic. Four height classes of < 1m (regeneration), 1.1-2.9 m (lower recruitment), 3-5.4 (upper recruitment) and > 5m (mature) were selected. Taller trees are assumed to be older. Woody plants generally fit within type 3 survivorship curve with high mortality at earlier growth. Normal population structure is illustrated by the general 'L' or 'inverse J' curve where the regeneration is greater than recruitment which is in turn greater than mature size classes. Figure 5.4 shows the distribution of height classes in the study area.

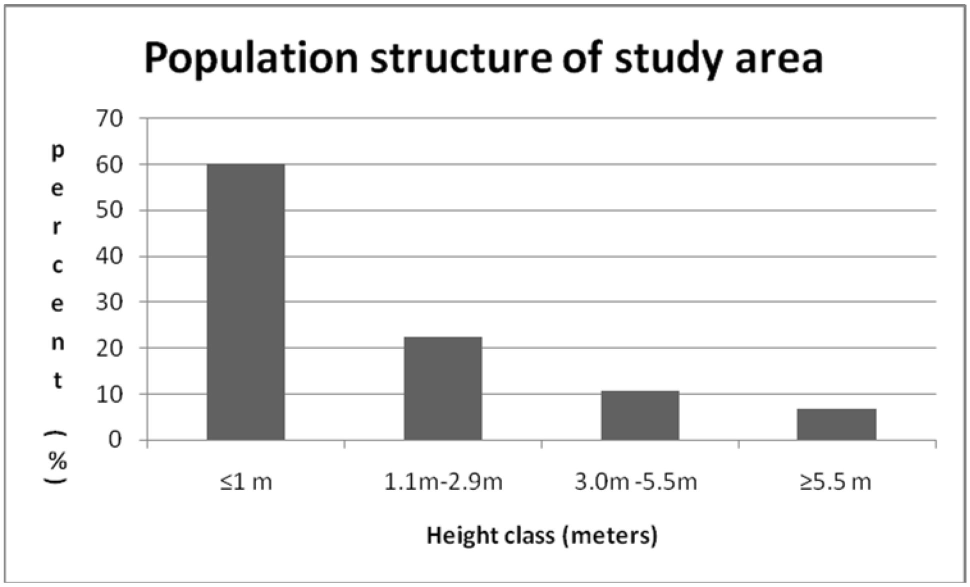


Figure 5.4: Distribution of height classes

The overall distribution shows an inverse J distribution where the regeneration> recruitment> mature size classes. This can be interpreted to mean the woody species in the study area is showing normal distribution. It is important to consider however that this distribution includes all the observed species in the study area and some species such as *Ormocarpum trichocarpum*, and *Acacia drepanolobium* only occurred as regeneration and lower recruitment while others such as *Diospyros abyssinica* mainly occurred as mature. Some species (e.g. *Grewia bicolor, Elaeodendron buchananni, Rhus natalensis and Cordia ovalis*) in the study area (figure 5.5) showed this classical inverse J population structure.

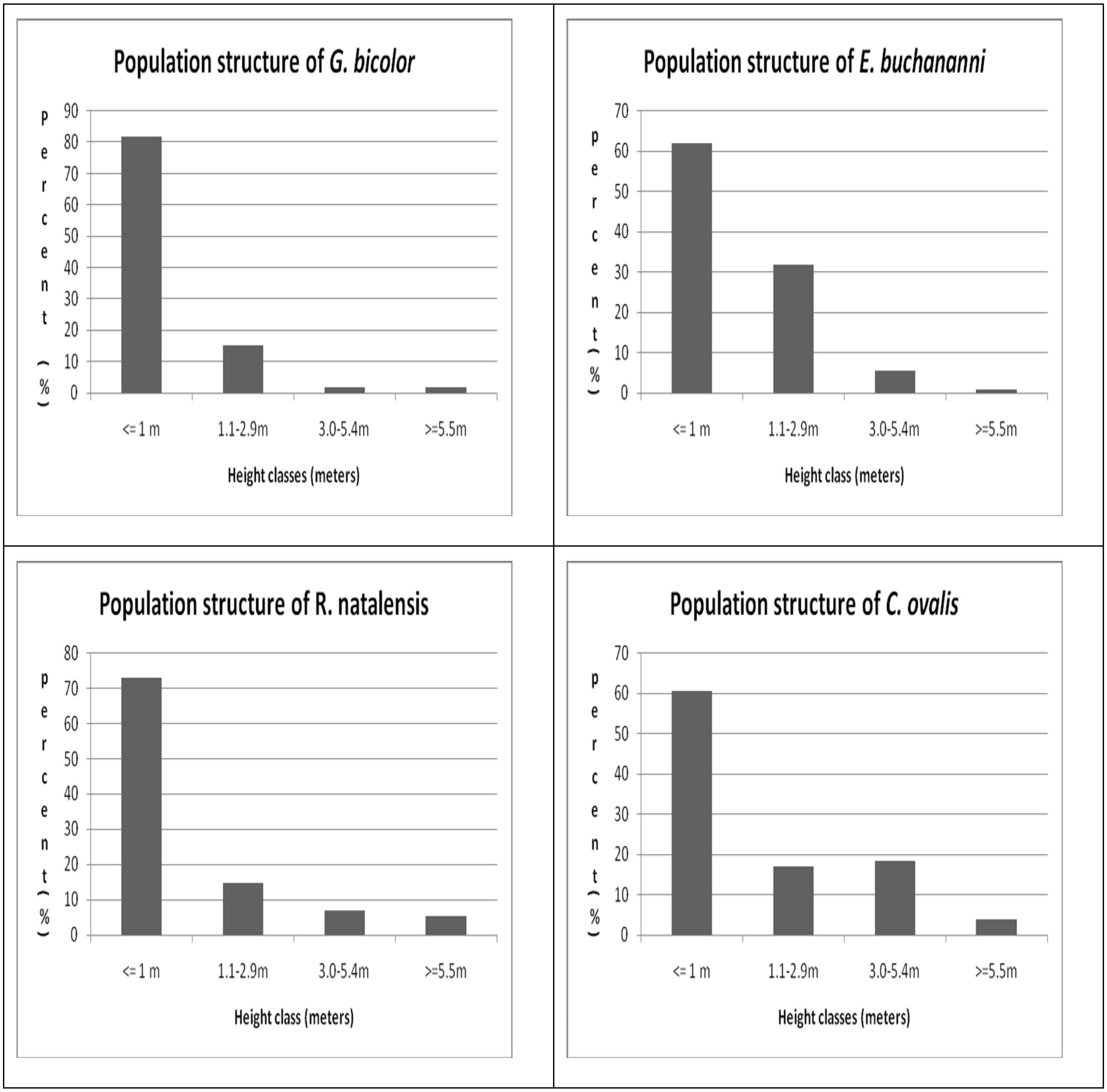


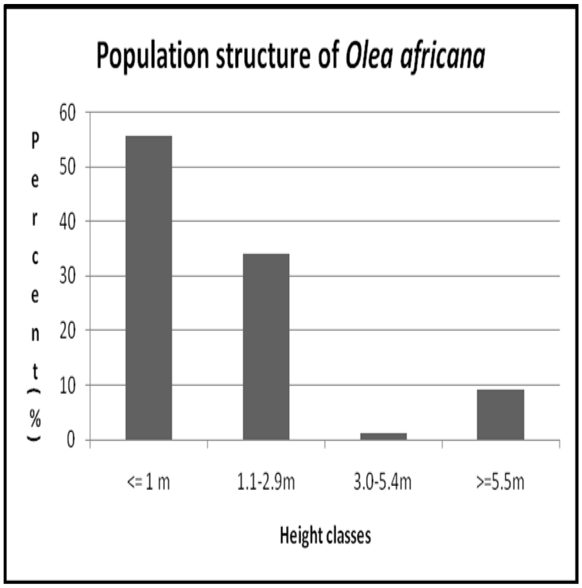
Figure 5.5: Graphs of species showing classical population structure

Tripathi *et al.,* (2010) categorized the regeneration status of the species as '(i) good, when seedlings>saplings>adult (ii) fair, when seedling>sapling**</=** adult (iii) poor, when species survives in only saplings stage but not as seedlings (though saplings may be less or equal to adult), (iv) none, when a species was absent both in seedling and sapling stage but present as adult, and (v) new, if a species was present only in seedling/sapling stage but not as adult trees.'

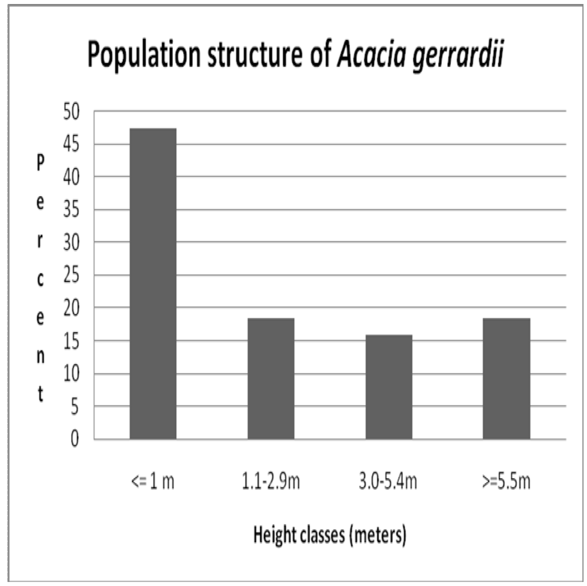
Most species seem to show a fair population structure (Figure 5.6). These species have a high regeneration though upper recruitment is lower than mature size classes. All the species (*Olea africana, Acacia gerrardii, Euclea divinorium and Acacia kirkii*) take the form of trees in their mature form in the study area and with exception of *A. gerrardii*, the species exceed 20 meters in height in the sampled study area. It therefore implies that the species could show classical population structure if additional or different, height categories are added after the 3 meter mark.

The population of *Olea africana* (Figure 5.6:A1) seem to have a fair population structure. The species is rated as the most important in the study area in terms of value from the focus group discussion. The numbers of the species are also said to be declining from the discussions. Species such as *Euclea divinorum* (Figure 5.6:A3)*, Acacia kirkii* (Figure 5.6:A4) and *Acacia gerrardii* (Figure 5.6:A2) appear to have fair regeneration in their population structures. Focus group discussions mention *Euclea divinorium* and Ac*acia gerrardii* as even increasing in the study area.

A 1



A 2



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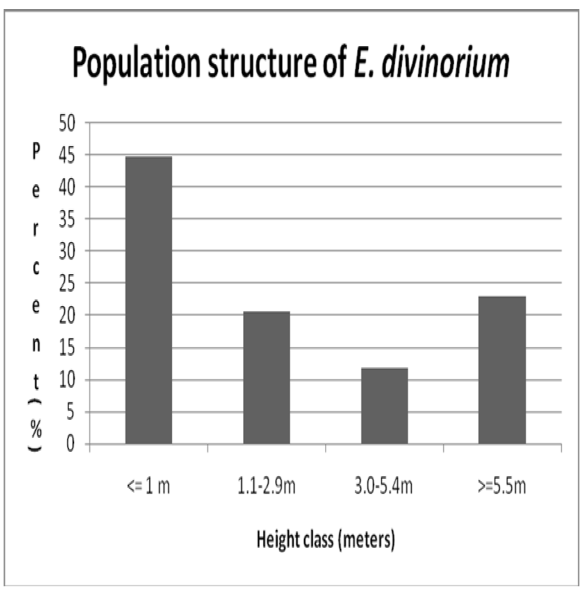

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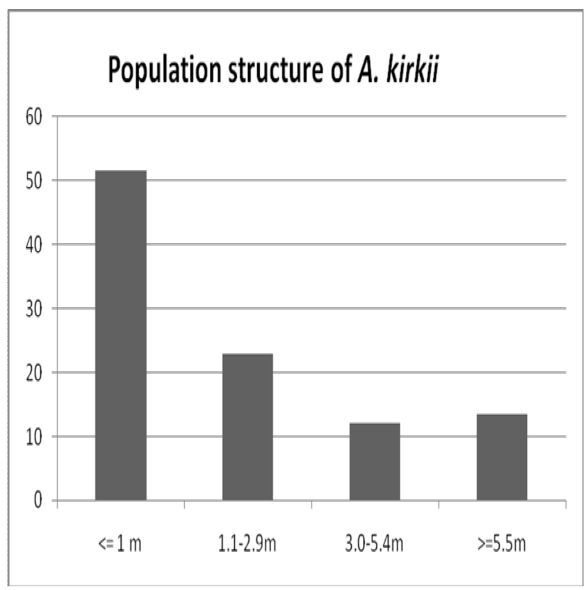


Figure 5.6: Graphs of species showing fair regeneration in their population structure

Some species showed abnormal regeneration (Figure 5.7). The abnormal regeneration occurred in species such as *Diospyros abyssinica, Croton dichogamus, Tarconanthus camporatus* and

Warburgia ugandensis. Abnormal regeneration occurs where the regeneration is less than either the recruitment or mature size classes.

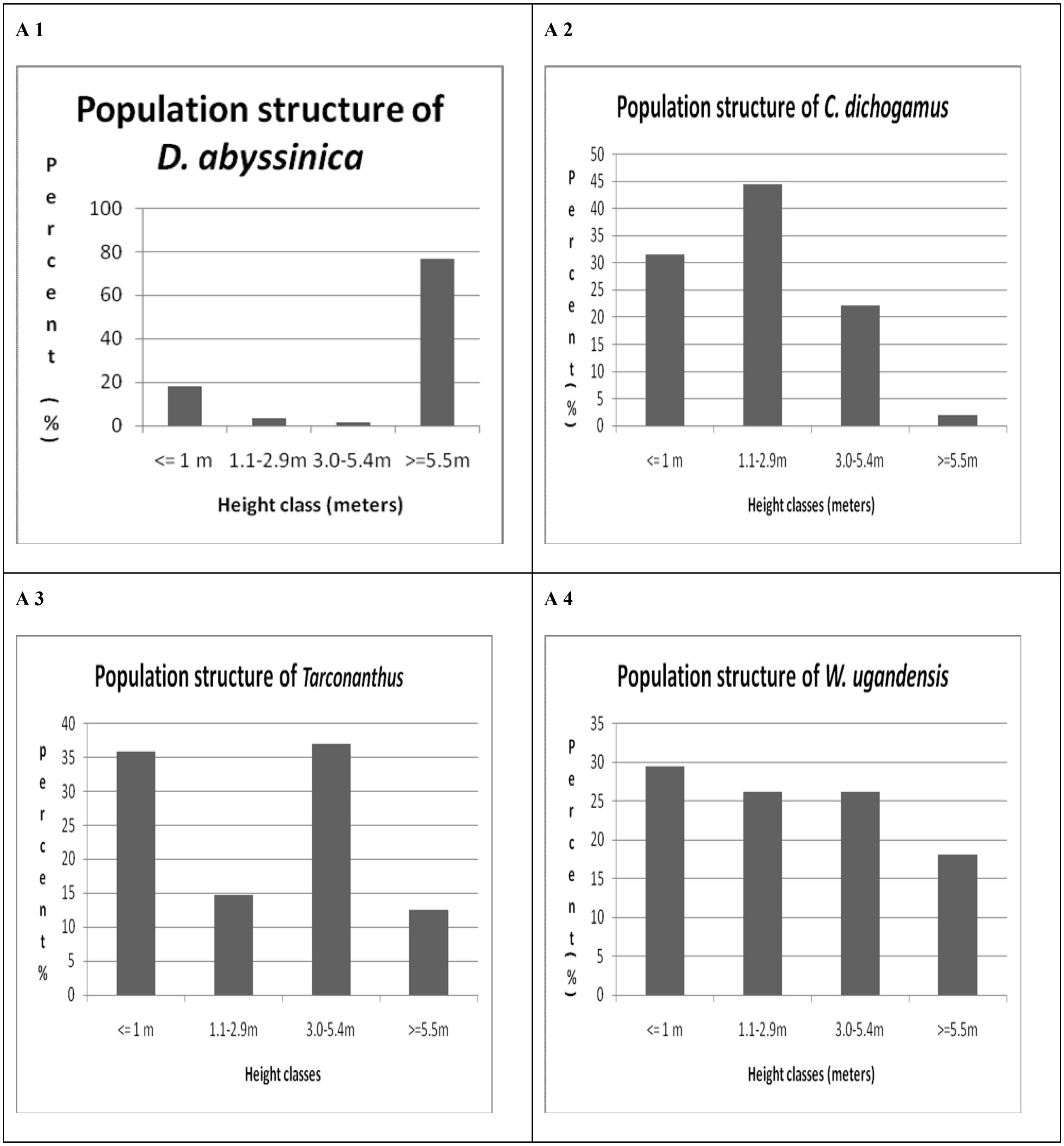


Figure 5.7: Graphs of species showing abnormal regeneration in their population structure

The abnormal trend was different for the species. For instance, the population of *Diospyros abyssinica* (Figure 5.7:A1) showed an abnormal trend where the numbers of mature size classes exceeded the number of regeneration. This species is disappearing in the study area. Extremely few young individuals make it unlikely that species populations can be maintained at the present level, because for a population to maintain a relatively constant population, individuals from smaller size classes need to be more than individuals in higher size classes (Lykke, 1998). It was also observed by Tripathi *et al.,* (2010) that most species did not show regeneration in closed forests. *Diospyros abyssinica* occurs as the canopy in evergreen woodland vegetation formation which usually has a closed canopy and this can explain the low numbers of regeneration and recruitment of the species.

The population of *Croton dichogamus* (Figure 5.7:A2) had a greater recruitment than regeneration numbers. However, focus group discussions from all the groups claimed that the species was even increasing in number. The explanation for the low regeneration rates can be attributed to the observation that the species usually occurred in dense clumps where competition can limit the development of regeneration. The species is shrubby and a height of 2-4 meters is mature in the study area. The species is not under threat in the study area.

Warburgia ugandensis population structure is showing almost no difference in the numbers of regeneration, recruitment and mature size classes, *Tarchonanthus camphoratus* is just showing slight differences between the height classes. According to Lykke (1998), flat distributions can indicate lack of rejuvenation and declining populations, but precaution ought to be taken while interpreting flat distributions as it is also possible that flat distribution is caused by rapid growth in small size classes and high survival rate overall. All the species showing abnormal distribution (Figure 5.7) showed low rates of browsing which is the major disturbance in the study area. It therefore means that the survival rates of the species are high except for *Diospyros abyssinica* that had extremely low recruitment and regeneration compared to other species. Additionally *C. dichogamus* and *T. camphoratus* have the characteristics of pioneer species as they occur in areas of disturbance. It is possible that their abnormality is caused by the fast growth of its lower size classes.

The number of *Balanites aegyptiaca* recruitment is low though the regeneration and mature phases have a high number. In fact, the sample did not record any recruitment of the species at height 3-5.4 meters (Figure 5.8). It appears that browsing is causing the *B. aegyptiaca* species to have few individuals in the recruitment stage as the species occur in grassland areas and the regenerations are heavily browsed.

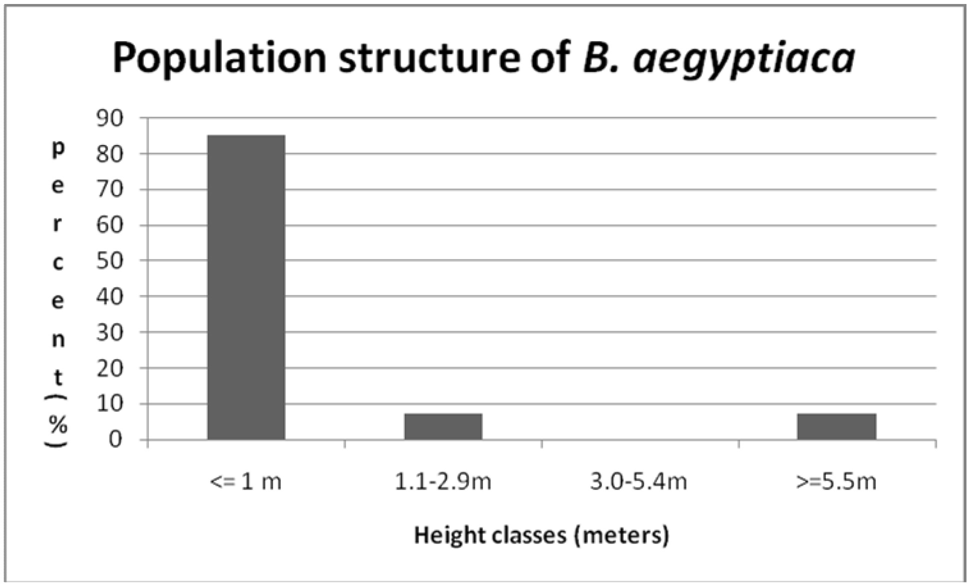


Figure 5.8: Population structure of *Balanites aegyptiaca*

Glover and Trump (1970) had predicted that it was unlikely that *Balanites aegyptiaca* would survive the predation of giraffes. However, the species still scatter the grasslands of Aitong, Talek and Mararienda as it did 40 years back albeit with few individuals making it to the recruitment size class. The species is still in danger of extirpation albeit the high regeneration rates because recruitments are minimal.

The general structure of woody species that take the form of trees in the study area such as *Warburgia ugandensis, Diospyros abyssinica, Olea africana, Teclea species* and *Balanites aegyptiaca* showed their populations are vulnerable to decline. Woody species that take the form of shrubs such as *Croton dichogamus, Dichrostachys cinerea, Acacia drepanolobium* and *Ormocarpum trichocarpum* are showing trends of populations on the increase. Some of the species that take the form of trees such as *Acacia gerrardii* and *Euclea divinorium* are also showing constant or increasing populations. Lykke (1998) analysis strongly suggested that species composition and vegetation structure in her study area of savanna in Fathala forest, Senegal, West Africa were changing in favour of shrubby species that are adapted to cope with disturbances, at the expense of large trees. The population structure of the sampled species in Maasai Mara conservancies also suggest that woody plants that are shrubby in form are increasing while trees are reducing.

5.4.2: Rare, exotic and threats to woody species

Some species such as *Osyris lanceolata* and *Kigelia africana* are known to occur in the conservancies but were not encountered in the samples. Other species such as *Toddalia asiatica* and *Pisticia aepithicum* were also rare with only one and two observations respectively. The prevalence of exotic woody species is also rare with only *Cassia spectabilis* being recorded from the transects. However, other exotic (non-native to conservancies' area) species such as *Croton megalocarpus, Eucalyptus saligna, Grevellia robusta, Dovyalis caffra* among others were present especially in or near homes, camps and schools in and around the conservancies.

The focus group discussions showed that people more so the youth would prefer non-native woody species such as *Eucalyptus spp, Croton megalocapus* and *Dovyalis caffra* near their homes. This is because, unlike indigenous woody species, they are faster growing and more importantly, are less preferred by elephants. Community members do not want elephants near their homes as they bring damage to property and sometimes human death. However, exotic species can have disastrous consequences to the ecosystem as *Opuntia spp* has shown some invasive tendencies in some areas of the study area from focus group discussions.

It was observed that some woody species appeared diseased. It was also observed thet the fruits of some species such as *Warburgia ugandensis* and *Grewia bicolor* usually were infected with insects. This is a threat because it can contribute to limiting their regeneration. Practice of small scale agriculture is increasing in Aitong area near the conservancies. Agriculture is a threat to natural vegetation formations as the natural vegetation has to be cleared to make room for crop agriculture.

5.4.3: Vertical and horizontal structure of the conservancy

The landscape of the Mara conservancy can be described by its vegetation. The vertical structure has been the primary criterion of delineating vegetation formation in this system. The tallest vegetation community was evergreen woodland whose canopy averaged at 15 meters while riverine vegetation had an average canopy height of 10 meters. However, riverine vegetation had variation in height ranging from 3-20 meters while the canopy range for evergreen woodland was shorter ranging from 12-20 meters high. The sub canopy was visible in evergreen woodland vegetation type while some riverine vegetation, more so the short canopied, missed the sub canopy layer. The sub canopy averaged at 2 meters for riverine vegetation and 5 for evergreen woodlands. Table 5.12 shows the summary of site characteristic including the vertical (height) and horizontal (cover) structure of the vegetation formations.

Table 5.12: Summary of vegetation formation characteristics

Vegetation type	Area M^2	Canopy height(m)	Sub_canopy height(m)	Canopy cover(%)	Ground cover(%)
Acacia_bushland	11870	6	2	35	74
Bushed_grassland	3330	5	2	14	70
Evergreen bushland	5730	7	3	57	74
Evergreen woodland	2840	15	5	57	79
Grassland	12000	0	0	8	88
Impeded drainage grassland	1400	2	0	17	72
Riverine	7970	10	2	65	75
Shrubland	1840	3	1	39	55
Tarconanthus bushland	3810	6	3	62	55

Source (Fieldwork, 2013)

Riverine vegetation has an average canopy cover of 65%, followed by *Tarchonanthus* bushland with 62%. Both evergreen bushland and woodland had the mean canopy cover of 57%. Riverine and evergreen woodland vegetation types occurred in small strips and patches, mainly in areas with modified topographies such that water can collect.

While the species composition of the different vegetation formations showed some overlap, the relative abundance and the structure of these species was different because of the site characteristics in different vegetation formations. *Euclea divinorum* for instance may be an important indicator species in riverine, evergreen bushland, evergreen woodland and *Tarchonanthus* bushland vegetation types but it was not as tall in *Tarchonanthus* bushland as it was in evergreen woodland.

The ground cover was highest in grasslands and evergreen woodland. However, the ground cover differed in composition, while grassland, *Acacia* bushland, bushed grassland and impeded drainage grassland ground was dominated by grassy species, riverine and evergreen woodlands were dominated by herbaceous layers of species such as *Abutilon hirtum* and *Hypoestes spp*. The other vegetation formation had both grassy and herbaceous composition but the greater the canopy cover, the lesser the grass composition and more herbaceous composition in the ground layer.

5.4.4: Density of woody plants

The density of woody plants varies with the different vegetation types. Table 5.13 shows the different density in terms of number of stems per hectare in the different layers (vertical structure).

Table 5.13: Indicative density of woody plants in different vegetation formation

	ACB	BGL	EVB	EVW	GSL	IDG	RVN	SRL	TBL
Regeneration	860	712	1014	722	457	2193	728	1386	2680
Recruitment_low	188	390	714	810	0	436	543	870	585
Recruitment_high	83	27	190	271	1	0	104	65	257
Mature	80	27	101	391	5	0	127	5	249
Total	1211	1156	2019	2194	463	2629	1502	2326	4026

Legend: ACB-Acacia bushland; BGL-Bushed grassland; EVB-Evergreen bushland; EVW-Evergreen woodland; GSL-Grassland; IDG-Impeded drainage grassland; RVN-Riverine; SRL-Shrubland; TBL: Tarchonanthus bushland

Source (Fieldwork, 2013)

In terms of stems per hectare densities of mature woody species, Evergreen woodland is the woodiest then *Tarchonanthus* bushland, riverine, evergreen bushland, acacia bushland, bushed grassland, shrubland, grassland and impeded drainage grassland in that order. Sahu *et al.,* (2012) report that tropical forests have tree densities of 276-905 stems per hectare for trees for over 15 cm diameter at breast height. In the study area, only evergreen woodland, evergreen bushland and *Tarchonanthus* bushland had some characteristics of tropical forests when trees greater than 3 meter height are included. When trees greater than 5.5 meters were included, only evergreen woodland had the characteristics of tropical forests.

Tarchonanthus bushlands and impeded drainage grassland show the highest regeneration density. High regeneration rates are characteristic of disturbed systems as shown by *Tarchonanthus* bushland and evergreen bushland. Olf and Ritchie (1998) showed disturbances by herbivores to increase plant diversity and regeneration. High regeneration density was also evident in shrublands. Impeded drainage grassland also had high regeneration density but predominately of one woody species, i.e., *Acacia drepanolobium* which rarely exceeds 2 meters in the study area.

Evergreen woodland had a comparatively low regeneration density and the highest in mature trees density. Areas with mature trees will tend to have lesser regeneration densities because they are climax succession and the sunlight penetration is low. Walpole *et al.,* (2004) calculated the densities of woody plant densities in different habitats in Maasai Mara National Reserve. Table 5.14 shows how the woody plant densities compare.

Table 5.14: Comparison of woody plant density to Walpole *et a.l* (2004)

Mara conservancy habitat types (Researcher, 2014)	**Density per Ha**	**MMNR habitat types (Walpole *et al.*, 2004)**	**Density per Ha**
Evergreen woodland	2194	*Diospyros* riverine forest	3096
Shrubland	2326	*Croton* slope thicket	5131
Evergreen bushland	2019	*Euclea* bushland	1578
Grassland	457	*Balanites* grassland	462

The selected habitat types (vegetation formations) do compare relatively well with the exception of shrubland and *Croton* slope thicket. The possible reason for this discrepancy is the sampling methods use and the patchiness characteristic of shrubland vegetation formation. The species (mainly *Croton dichogamus*) that is characteristic of shrubland vegetation formation occur densely in clumps and spaces between the clumps are not uncommon. It is possible that since the sampling method Walpole *et al.,* (2004) used were fixed transects of 10×30m and the ones used in this study were variable transects that could not exceed 10×60m, this study is likely to have sampled more of the 'spaces' in this vegetation formation. The other habitat types/vegetation formations are not as irregular for the sampling method to cause discrepancies when compared to Walpole *et al.*, (2004).

5.4.5: Temporal structure of woody vegetation

Trump (1972) identified 18 vegetation types in the former Narok district in the 70s, six of which occurred in the study area. Table 5.15 shows how the vegetation formations observed by Trump compare with the current study and a harmonized vegetation formation is derived.

Table 5.15: Comparison of Trump's (1972) vegetation types with current study formation

Trump Vegetation formation (1972)	**The current study (2014) equivalent(s)**	**Harmonized name**
Evergreen and Semi deciduous bushland (8)	• Evergreen bushland • Tarconanthus bushland • Riverine	Evergreen bushland
Grasslands (9) *derived from vegetation type 8	• Grassland	Grassland
Semi evergreen thicket and associated types (10) *Derived from vegetation type 8	• Evergreen woodland • Riverine • Shrubland	Evergreen bushland
Bushed and wooded grasslands (11) *Derived from vegetation type 10	• Bushed grassland • Acacia bushland	Bushed grassland
Grassland (12) *Derived from vegetation type 10	• Grassland	Grassland
Grassland on clay (15)	• Impeded drainage Grassland	Grassland

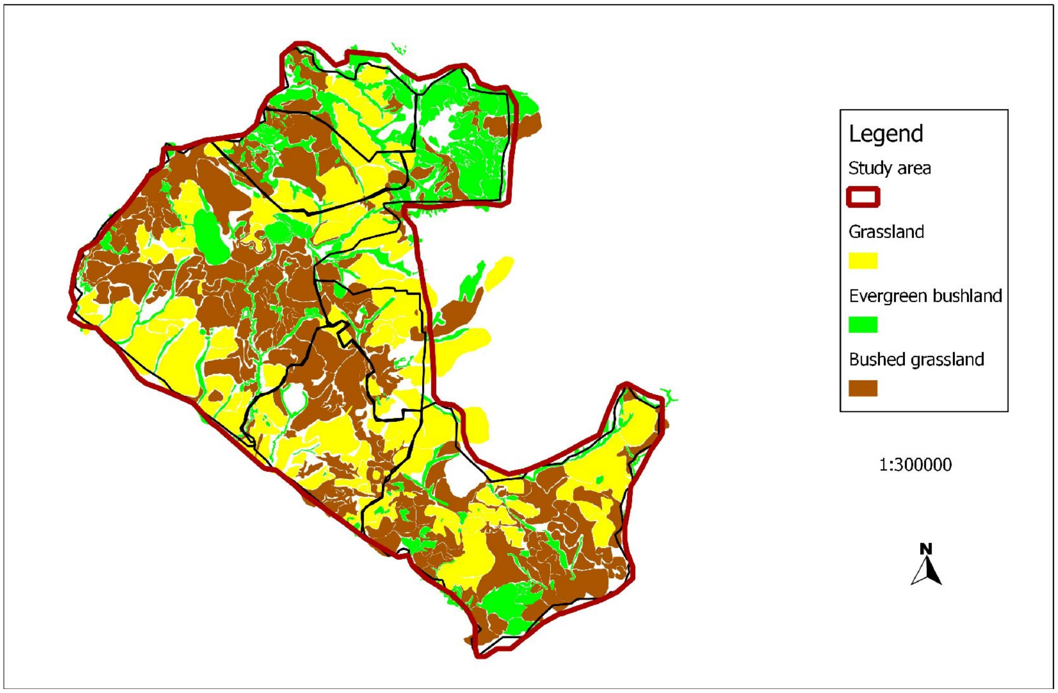
- Values in parenthesis show the vegetation type number as assigned by Trump (1972)

Trumps (1972) vegetation description claims that all except ‘grassland on clay’ vegetation formations arise from evergreen and semi deciduous bushland. This is consistent with the current study argument that most of the study area would revert to a more woody state if disturbances are removed. Trumps observation that evergreen and semi deciduous bushland are dominated by *Tarchonanthus camphoratus*, stunted *Olea africana* and *Rhus natalensis* is still evident in the study area. However other dominant species of this formation such as *Acokanthera frieosium*, *Euphobia candelabrum* and *Boscia angustifolia* as described by Trump are now very rare suggesting a change in species composition of this formation with time.

It was also observed by Glover and Trump (1970) that *Olea africana* was the dominant canopy in evergreen bushland in the semi-arid zones of former Narok district. This study however shows evergreen bushland communities as dominated by *Euclea divinorium*. This suggests a species change in this vegetation formation. Additionally observations of *Euphorbia candelabrum* in the current study are not as frequent as its descriptions in evergreen bushlands of the 70s by Glover and Trump (1970) and Trump (1972). The constituents of semi evergreen thickets and associated types are similar to evergreen bushland but since the thickets occur in areas with higher rainfall, there is addition of species such as *Euclea divinorium, Croton dichogamus, Acacia brevispica, Teclea nobilis, Scutia myrtina, Ziziphus macronata* and *Albizia spp*. The occurrence of these species were also observed in the current study in evergreen woodland, riverine, shrubland, evergreen bushland and bushed grassland vegetation types. However few classical impenetrable thickets were observed in the study area. This was also the case forty years ago as Trump (1972) notes that the thickets only occurred in depressions, hillside and other situations where they got some protection from fire with herbivores making paths for fire to penetrate. However, it was observed in the study area that the classical thicket vegetation formation can also occurs in heavily protected areas (from herbivores and fire) such as tourist camps and lodges.

Trump (1972) mapped the vegetation of the former Narok district in the seventies. The general behaviour of the woody vegetation seems to be the same. From both the current vegetation map (figure 5.9), and the Trumps (1972) map (figure 5.10) the vegetation formation tends to be less woody as one move towards the south east. There are more woody vegetation formations (e.g.

evergreen bushland, semi evergreen thicket) toward the north of the study area compared to the south which is characterised by bushed grassland and grasslands.



(Source, Researcher 2013)

Figure 5.9: Harmonized vegetation map of the current study 2013

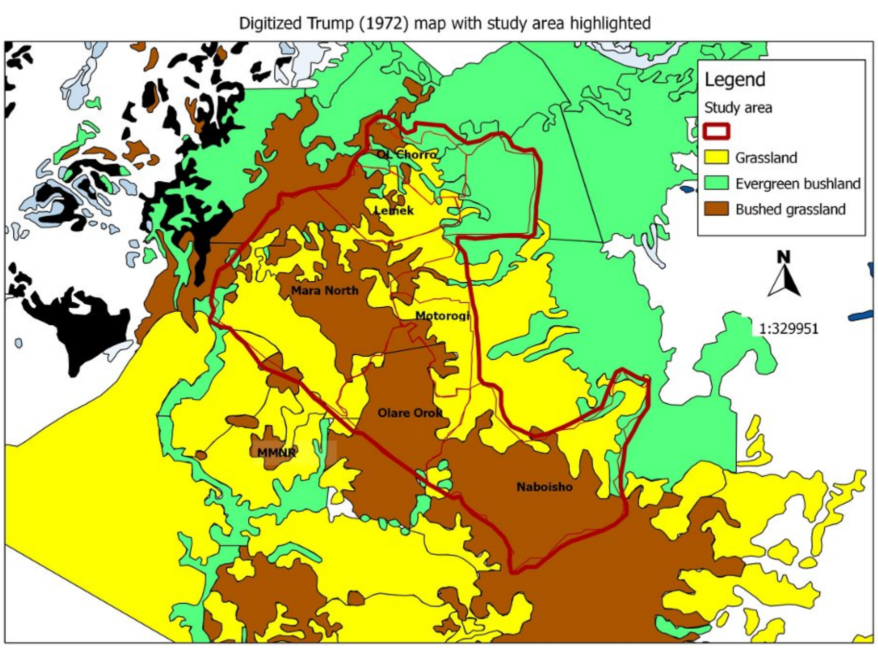


Figure 5.10: Harmonized vegetation map by Trump (1972)

The similarities between the vegetation formation map by Trump (1972) and the current study is striking. It validates Trump map of Narok district, especially of the study area, and show there has been no much change in the general vegetation formations of the study area in the past forty years. A conspicuous difference in the two maps is the presence of evergreen woodland patches especially in the south of the study area from the current vegetation map. It is also noticeable that the evergreen bushland is not as continuous in the north as it was by Trumps description. Olare Orok and Naboisho conservancies are virtually all bushed grasslands by Trump but current description show a significant increase of grasslands, a possible impact of breakages from elephants.

Comparing maps done at different scales can however be misleading (Stohlgren *et al.,* 1997). Woody vegetation occur in patches in the study area and maps done on a course scale e.g. Trump map, as he mapped the vegetation of the whole Narok district using aerial photography, would miss these patches especially in the south of the study area. This is vindicated by the fact that all the 9 focus group discussions in the study concluded that the woody vegetation areas such as bushlands, shrublands and woodlands have decreased in the study area. Some of the areas where this vegetation change has occurred include Kirrok, En Kikwei, Oloosukon, Mararienda, along rivers, Emorijoi and on hills. Bush encroachment of grasslands by *Acacia drepanolobium* and *Ormocarpum spp* is also observed especially near grazing sites.

CHAPTER SIX

6.0: SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the major findings conclusions and recommendations derived from the study. The conclusions are described under the thematic themes of species diversity, vegetation formations, disturbances and vegetation change. Recommendations based on these conclusions are also described in this section.

6.1: Summary of findings

The Masai Mara conservancies had nine vegetation formations of ecological significance. These included *Acacia* bushland, Bushed grassland, Evergreen bushland, Evergreen woodland, Grassland, Impeded drainage grassland, Riverine, Shrubland and *Tarchonanthus* bushland. evergreen woodland was the woodiest with highest canopy height (15 m) and a density of 3.91 stems per hectare of mature trees, impeded drainage grassland had the least density of mature trees (0 stems per hectare).

A species richness of 86 woody species was recorded in the Maasai Mara conservancies. Riverine vegetation had the highest species richness of 54 while impeded drainage grassland had the least richness score of 5. Riverine formation also had the highest Shannon diversity index of 2.98 and impeded drainage grassland formation the least of 0.22. *Croton dichogamus* (41.6), *Grewia bicolor* (33.4), *Acacia gerrardii* (26.5), *Euclea divinorium* (25.7) and *Diospyros abyssinica* (14.8) were the most dominant species as per their importance value index scores.

Browsing was the most common disturbance with 54% of the sampled woody plants showing some evidence of browsing. *Balanites aegyptiaca* was the most browsed species with an index of 2.8. Other important browse species were in the genera of *Grewia, Maytenus, Commiphora* and *Acacia*. The prevalence of other disturbances that affect the woody vegetation structure was 13% for breakages and 1% for human use.

Most woody species (e.g. *Grewia bicolor, Elaeodendron buchananni, Olea africana* and *Acacia gerrardii*) showed an inverse J and fair distribution. The populations of *Diospyros abyssinica* showed a non inverse J distribution. All the 9 focus group discussions agreed that the woody vegetation extent and species in the study area was decreasing with the decline of species such as *Olea africana*, *Warburgia ugandensis* and *Diospyros abyssinica*.

6.2: Conclusions

6.2.1: Vegetation formation

It is possible to group vegetation based on their physiognomy characteristics. The floral characteristics of the groupings were overlapping in the Maasai Mara conservancies but indicator species are apparent in most vegetation formations. However some vegetation formations e.g. Riverine and Bushed grassland did not show apparent indicator species. Bushed grasslands as is *Tarconanthus* bushland and shrubland are a characteristic of a system in disturbance from fire, herbivory or human use because they had high regeneration rates and numerous regeneration species. The climax woody vegetation formation in the study area is evergreen woodlands. It can be argued that in the long term absence of disturbances, the vegetation formation would develop to this type.

When the floral characteristic of the vegetation formations were further analyzed, it is observed that the difference in species composition in terms of abundance is significant between the different vegetation formations. Additionally, the form of a species differs between vegetation formations. For instance, *Euclea divinorum* is a common species in evergreen woodland and evergreen bushland formations. However, it is taller in the woodland formation but shorter and bushier in the bushland formation.

The vegetation formations are primarily determined by constraints such as rainfall, soil and topography. Disturbances such as herbivory, fires and human use modify and maintain the vegetation formation. The existing formation determines the human use of a landscape. For instance, most camps and lodges set up their facilities in areas with woody vegetation formations such as evergreen woodlands and bushlands.

6.2.2: Species diversity and disturbances

The Maasai Mara conservancies had diverse woody species in its vegetation structure. Over 80 woody plant species were recorded from samples. Diversity indices are however better measures of diversity compared to species richness. This is because they take into account the sample size and evenness. As a result some formations with high species richness had lower diversity indices as compared to formations with lower species richness if they have less evenness and greater sample size area. Disturbances affect species diversity but have little impact on species richness woody vegetation structure. The most common and abundant species are the least disturbed.

The disturbances on woody vegetation are mainly influenced by the species and height of the vegetation. The disturbances on woody vegetation include uses by humans and wildlife of the species. The uses of the species seem to affect the species diversity. The most useful species appear to be rarer compared to least used species. The use that is most significant in affecting the woody vegetation structure is browsing as the most preferred browsed species are also generally smaller in size compared to the least preferred species. If browsing were to be excluded, the number of preferred browse species such as *Grewia spp, Phyllanthus spp, lannea spp, Commiphora spp* and *Maytenus spp* would most likely be more, and they would be bigger.

Human use also affected the woody plant diversity of few species in the study area. High value woody plants such as *Olea africana, Albizia gummifera, Toddalia asiatica* and *Warburgia ugandensis* show decreasing trends possibly because of human uses mainly for firewood, construction and medicine. The human uses were an important factor in the past as current management strategies restricts human utilization of woody vegetation resources inside the conservancies. The effect of breakage as a disturbance to the vegetation structure is limited to woody plants in the mature size classes. While firewood is a common source of energy for households in the study area, human cutting of woody plants for firewood was rare as people make use of the wood breakages/ knock over from animals.

The disturbances of herbivory, breakages and human use influences the vegetation structure of the study area. Reduction or removal of these disturbances would transform the study area to a woodier state. The impacts of the disturbances are height specific. For instance, browsing was more pronounced in the regeneration and recruitment phases while breakages and human use were more pronounced on trees in the mature size classes. The disturbances are also species specific in that there are preferred species for different uses. Browsing from animals (except elephants) appear not to influence the occurrence of species but rather slow its growth or locks it in lower height classes.

While crop agriculture was not pronounced in the study area, it is still a pertinent disturbance threat to woody vegetation diversity as households around the conservancies are practicing small scale agriculture. Agriculture converts habitats into monocultures of introduced species. Additionally, exotic woody species are introduced for various purposes. The exotic trees are preferred by community members because of their fast growth and non-preference from elephants. Exotic trees were confined to human settled areas such as schools and homes.

Natural disturbance is necessary for the functioning of this ecosystem. Dense woody vegetation tends to limit the development of ground cover. The disturbances create spaces that encourage the development of ground cover. Ground cover which is mainly grass that is vital for grazers such as wildebeest, buffalo and zebras. In the absence of disturbances, the vegetation formation of the study area would tend to be woodier and probably limit habitats for some animal species. However, human caused disturbances are selective to species and habitats and can lead to extinction of preferred woody species.

6.2.3 Vegetation change

The general vegetation formations in the Maasai Mara Conservancies showed minimal change. However, the extent and composition of these vegetation formations appear to be changing for the last forty years. The changes that occur are mainly from woody state to less woody states; though some areas show changes towards more woody vegetation. Evergreen woodlands and bushlands are notably reducing as they are converted to shrublands, bushed grasslands and grasslands. The causes of these reductions can be natural and anthropogenic. Natural drivers include natural fires, herbivore browsing and breakages. Anthropogenic causes are more likely to be causes of vegetation change and they include human consumptive uses, settlement sprawl and management decisions that influence natural drivers, for instance, confining herbivores to a smaller area.

Most species showed healthy population structure where regeneration is greater than recruitment which is greater than mature size classes. Some species such as *Diospyros abyssinica* however show unhealthy population structures where mature size classes are greater than recruitment and regeneration suggesting possible extirpation of the species in the study area with time. But species close to normal population structures are also declining, for instance *Olea Africana, Balanites aegyptiaca, Albizia gummifera* and *Warburgia ugandensis* are declining. In general, big trees are declining and trees shrubby in nature are increasing.

6.3: Recommendations

6.3.1: Recommendations for researchers

- The study of ethnobotanical knowledge of the woody species in Masai Mara conservancies is necessary to document indigenous knowledge.

- Practical methods of obtaining diameter measurements of woody vegetation in the savannas need to be explored as the traditional method of using diameter at breast height is not applicable for heavily disturbed species in the savanna which are multi branched and shrubby.

6.3.2 Recommendations for resource managers

- Promote planting of indigenous big trees especially in areas with protection from disturbances.

- Design and implement management plans of woody vegetation based on research.

- Identify and protect woody vegetation keystone ecosystems.

6.3.3 Recommendations for policy makers

- Policy makers should encourage economic activities that are compatible with habitat conservation to discourage clearance of indigenous vegetation species and formations.
- Create awareness on the importance of indigenous vegetation to the community in the economy and environment.
- Create policies to identify and protect woody vegetation keystone ecosystems.
- Encourage more research on woody vegetation of conservation areas.

REFERENCES

Aboud, A.A., Kisoyan, P.K., Said, M.Y., Notenbaert, A., de Leeuw, J., Gitau, J.W., Manzano, P., Davies, J.M., Roba, G.M., Omondi, S.O., Odhiambo & Said M.O. (2012) 'Payment for wildlife conservation in the Masai Mara Ecosystem' - Natural Resource Management and Biodiversity Conservation in the Drylands of Eastern and Central Africa. ASARECA, Entebbe

Augustine D., & McNaughton S. (2004). Regulation of shrub dynamics by native browsing ungulates on East African rangeland. *Journal of Applied Ecology*, Vol. 41, No. 1 pp. 45-58. British Ecological Society.

Banda T., Schwartz M., & Caro T., (2006). 'Woody vegetation structure and composition along a protection gradient in Miombo ecosystem of western Tanzania'. *Forest Ecology and Management* 230 (2006) 179–185

Barrantes Gilbert & Sandoval Luis (2009) 'Conceptual and statistical problems associated with the use of diversity indices in ecology'. *Rev. Biol. Trop.* (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 57 (3): 451-460, September 2009

Bedelian, C. (2012). *Conservation and ecotourism on privatised land in the Mara, Kenya*. Land Deal Initiative. Brighton.

Beentje, H.J. (1994) *Kenya trees, shrubs and lianas*. National museums of Kenya, Nairobi, Kenya.

Bognounou F. Thiombiano A. Savadogo P., Boussim J., Odén P.C & Guinko S. (2009) 'Woody vegetation structure and composition at four sites along a latitudinal gradient in Western Burkina Faso'. *B o i s e t f o r ê t s d e s t r o p i q u e s* , 2 0 0 9 , no 3 0 0 (2)

Bridi L., Fersch A., Kohrs K., & Layman E. (2013). Comparing three sustainable reforestation and agricultural practice projects in Auroville, Tamil Nadu, India . KSAC Marine Science

Bromen M. & Said M.,(1995). 'Chapter 8: the population trend of ungulates around Masai Mara National Reserve'. Sinclair A.R. & Arcese P., (eds) *Serengeti II: Dynamics, Management, and Conservation of an Ecosystem.* University of Chicago Press. Chicago

Bussmann R.W, Gilbreath G.G., Solio J., Lutura M., Lutuluo R., Kunguru K., Wood N., & Mathenge S.G (2001). 'Plant use of the Maasai of Sekenani Valley, Maasai Mara, Kenya'. *Journal of Ethnobiology and Ethnomedicine* 2:22 doi:10.1186/1746-4269-2-22

Chapman A. G., & Underwood A. J. (1999). 'Ecological patterns in multivariate assemblages: information and interpretation of negative values in ANOSIM tests'. *Marine Ecology Progress Series* . Vol 180: 257-265.

Croze H. (1974). 'The Senerora bull problem. The elephants'. *East African Wildlife* 12, 1-27

Coulson R. & Tchakerian M. , (2011). *Basic landscape Ecology*. KelPartners Incorporated. Texas.

Commission of revenue allocation (2011). *Kenya counties factsheets.* Commission of Revenue allocation. Nairobi. Kenya.

Curtis, J. T., & McIntosh, R. P. (1951). 'An upland forest continuum in the prairie-forest border region of Wisconsin'. *Ecology*, *32*(3), 476-496.

Darling F.F (1960). *An ecological reconnaissance of the Mara plains in Kenya Colony.* Wildlife Society publication. Nairobi.

Devi, L. S., & Yadava, P. S. (2006). Floristic diversity assessment and vegetation analysis of tropical semievergreen forest of Manipur, north east India.*Tropical Ecology*, *47*(1), 89-98.

Dittrich A., Buerkert A. , & Brinkmann K (2010). Assessment of land use and land cover changes during the last 50 years in oases and surrounding rangelands of Xinjiang, NW China. Journal of Agriculture and Rural Development in the Tropics and Subtropics Vol. 111 No. 2 (2010) 129-142

Druce D.J., Shannon G., Page B.R., Grant R. & Slotow R. (2008) 'Ecological thresholds in the savanna landscape: developing a protocol for monitoring the change in composition and utilisation of large trees'. *PLoS ONE* 3(12): e3979. doi:10.1371/journal.pone.0003979

Dublin H. T., Sinclair A.R.E & McGlade J., (1990). 'Elephants and fire as causes of multiple stable states in Serengeti-Mara ecosystem'. *The Journal of Animal Ecology*, 59 (3), 1147-1164.

Dublin, H.T. (1995) 'Vegetation dynamics in the Serengeti-Mara ecosystem: the role of elephants, fire and other factors'. Sinclair A.R. and Norton-Griffith M. (Eds). *Serengeti II: Dynamics, Management and Conservation of an Ecosystem*. University of Chicago Press, Chicago, IL.

Foster R., Hernández N., Kakudidi E., and Burnham J. (1998). Rapid assessment of tropical plant communities Using variable transects: An informal and practical guide. Unpublished

Giliba R., Boon E., Kayombo C., Musamba E., Kashindye M., and Shayo P. (2011). Species Composition, Richness and Diversity in Miombo Woodland of Bereku Forest Reserve, Tanzania. J Biodiversity, 2(1): 1-7 (2011)

Glover P.E & Trump E.C (1970). An ecological survey of Narok District Kenya Masailand. Part II Vegetation. Kenya National Parks. Nairobi.

Google Earth 7.1 (2013) *Masai Mara Conservancies, 1°13'40"S, 35°01'59"E- 1°18'11"S, 35°25'41"E, elev 1700M.*.Vegetation data layer [Accessed 23 February 2014]. Google Earth images (© 2014 Digital Globe, © Cnes/Spot)

Gruntblatt J., Ottichilo K. and Sinange R.K., (1989). 'A hierarchical approach to vegetation classification in Kenya'. *Africa Journal of Ecology* Volume 27 page 45-51.

Hanus M., Marshall D., & Hann D. (1999). *Height–diameter equations for six species in the coastal regions of the Pacific Northwest*. Forestry publication Office. Oregon State University

Holdo M. R., Holt D. R. & Fryxell M. J., (2009). 'Grazers, Browsers and fire influence the extent and spatial tree cover in the Serengeti'. *Ecological Applications,* 19 (1), 95-109.

Homewood, K., Lambin, E. F., Coast, E, Kariuki, L, Kikula, J.… Thomson, M. (2001). 'Long term changes in Serengeti-Mara wildebeest and landcover: pastoralism, population or policies'. *PNAS* 98 (22), 12544-12549.

Houehanou D.T., Assogbadjo A. E., Kakaï R. G., Houinato M., Sinsin B. (2011) Valuation of local preferred uses and traditional ecological knowledge in relation to three multipurpose tree species in Benin (West Africa). Forest Policy and Economics 13 (2011) 554–562

House J., Archer S., Breshears D., Scholes R., & NCEAS Tree–Grass Interactions Participants (2003). 'Conundrums in mixed woody Herbaceous Systems'. *Journal of Biogeography*, 30, 1763–1777

Jansson, L. (2011). Elephant damage in Masai Mara. Report. Swedish University of Agricultural Science.

Kent M., (2011) *Vegetation descriptions and data analysis; a practical approach*. John Wiley and Sons. West Sussex. United Kingdom.

Kindt R & Coe R. (2005). *Tree diversity analysis. A manual and software for common statistical methods for ecological and biodiversity studies*. World Agroforestry Centre (ICRAF). Nairobi.

Kindt, R., van Breugel, P., Lillesø, J.-P. B., Bingham, M., Sebsebe Demissew, Dudley, C., Friis, I., Gachathi, F., Kalema, J., Mbago, F., Minani, V., Moshi, H. N., Mulumba, J., Namaganda, M., Ndangalasi, H.J., Ruffo, C. K., Jamnadass, R. & Graudal, L. (2011) 'Potential natural vegetation of eastern Africa. Volume 4: Description and tree species composition for bushland and thicket potential natural vegetation types'. *Forest & Landscape Working Paper* 64-2011

Lamprey, R.H. & Reid, R.S. (2004) 'Expansion of human settlement in Kenya's Masai Mara: what future for pastoralism and wildlife? '*Journal of Biogeography*, 31, 997–1032.

Laszlo Z. &Tothmeresz B. (2012) Landscape and local effects on multiparasitoid coexistence . Insect Conservation and Diversity (2012) doi: 10.1111/j.1752-4598.2012.00225.x

Lekoyiet S. T (2006). *Woody species comparisons between conserved and communal sites and woody plant use by local communities: A case study of Eselenkei and Kimana group ranches in Southern Kajiado, Kenya.* MSc Thesis. University of Addis Ababa.

Legendre P, Borcard D & Peres-neto P (2005) 'Analyzing beta diversity: partitioning the spatial variation of community composition data'. *Ecological Monographs,* 75(4), 2005, pp. 435–450. Ecological Society of America

Lykke Annemette (1998). 'Assessment of species composition change in savanna vegetation by means of woody plants' size class distributions and local information'. Biodiversity and Conservation 7, 1261-1275

Maundu, P., Berger, D.J., ole Saitabau, C., Nasieku, J., Kipelian, M., Mathenge, S.G., Morimoto, Y., Höft, R. (2001). *Ethnobotany of the Loita Maasai: Towards Community Management of the Forest of the Lost Child - Experiences from the Loita Ethnobotany Project.* People and Plants working paper 8. UNESCO, Paris. http://www.rbgkew.org.uk/peopleplants/wp/wp8/index.html

Ministry of Planning (2011). *National Census 2009 Report.* Government of Kenya

Nath D.C., Pe´lissier and R. Garcia C. (2010). 'Comparative efficiency and accuracy of variable area transects versus square plots for sampling tree diversity and density'. *Agroforest Syst* 79:223–236 DOI 10.1007/s10457-009-9255-5

Naveh, N. 2000: 'What is holistic landscape ecology? A conceptual introduction'. *Landscape and Urban Planning* 50(1-3): 7-26.

Niklas J (1994) 'Size dependant allometry of tree height, diameter , and trunk taper'. *Annals of Botany* 75: 217-227. Ithaca USA.

Norton-Griffith, M. (1979). 'The influence of grazing browsing and fire on the vegetation dynamics of the Serengeti'. Sinclair A.R.E.S and Norton Griffith (Eds). *Serengeti: Dynamics of an Ecosystem*. University of Chicago Press. Chicago.

Olff, H., & Ritchie, M. E. (1998). Effects of herbivores on grassland plant diversity. *Trends in ecology & evolution*, *13*(7), 261-265.

Opdam P.., Foppen R. & Vos C. (2001) 'Bridging the gap between ecology and spatial planning in landscape ecology'. *Landscape Ecology* 16**:** 767–779, 2002. Kluwer Academic Publishers. Printed in the Netherlands.

Osano P., Leeuw D. J. & Said H., (2012). 'Wildlife PES Schemes and Pastoral Livelihoods in Arid & Semi-Arid Lands (ASALs) in Kenya'. Global agenda of action in support of sustainable livestock sector development consultation focus area number 2: *restoring value to grasslands* 7-10 May 2012, Brasilia, Brazil. ILRI.

Ottichilo K.W, De Leeuw J.,, Skidmore A.K,,. Prins H.T & Said M.Y. 'Population trends of large non-migratory wild herbivores and livestock in the Masai Mara ecosystem, Kenya, between1977 and1997'. *East AfricanWild Life Society, Afr. J. Ecol*., 38, 202-216

Pellew, R. A. (1983). 'Impacts of elephant, giraffe and fire upon Acacia tortilis of the Serengeti'. *Afri. J. Ecol* 1983 (21) 41-74.

R Core Team (2012). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Reed D. N., Anderson, T. M., Demplewolf, J., Metzger K. & Serneel, S. (2008). 'The spatial distribution of vegetation types in the Serengeti ecosystem: the influence of rainfall and topographic relief on vegetation patch characteristics'. *Journal of Biogeography*, 2009 (36), 770-782.

Reid, R.S., Rainy, M., Ogutu, J., Kruska, R.L., Kimani, K., Nyabenge, M., McCartney, M., Kshatriya, M., Worden, J., Ng'ang'a, L., Owuor, J., Kinoti, J., Njuguna, E., Wilson, C.J.,

& Lamprey, R. (2003). *People, Wildlife and Livestock in the Mara Ecosystem: the Mara Count 2002. Report, Mara Count 2002*. International Livestock Research Institute, Nairobi, Kenya.

Richmond-Coggan (2006). *Assessing wildlife distribution and population trends in the greater Mara ecosystem, Kenya: the synergistic effects of landscapes and threats*. University of Kent. Msc. Thesis.

Sahu S.C, Dhal N. K. & Mohanty R. C. (2012) 'Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malyagiri hill ranges, Eastern Ghats, India'. *Tropical Ecology* 53(2): 163-168, 2012

Sala O. (1988). The Effect of Herbivory on Vegetation Structure. Plant form and vegetation structure. SBP Academic Publishers. Hague. Netherlands.

Sandiford, E. M., and Barrett, S. (2010). Albany Regional Vegetation Survey, Extent Type and Status, A project funded by the Western Australian Planning Commission (EnviroPlanning "Integrating NRM into Land Use Planning" and State NRM Program), South Coast Natural Resource Management Inc. and City of Albany for the Department of Environment and Conservation. *Unpublished report. Department of Environment and Conservation, Western Australia*, 6.

Sankaran M., Ratnam J., & Hannan L (2004). Tree-grass coexistence in the Savanna revisited; insights from an examination of assumptions and mechanisms invoked in existing models. Natural resource ecological laboratory. Colorado State University.

Sankaran M., Hannan L., Scholes R., Ratnam J., Augustine D., Cade B., ...Zambastin N. (2005) 'Determinants of woody cover in African savannas'. *Nature* 438:8, 846-849.

Savadogo, P., Tigabu M., Sawadogo and L., Odén, P.C. (2007). Woody species composition, structure and diversity of vegetation patches of a Sudanian savanna in Burkina Faso. BOIS ET FORÊTS DES TROPIQUES, 2007, N° 294 (4)

Scholes, R.D. & Archer, S.R. (1997) 'Tree–grass interactions in savannas'. *Annual Review of Ecology and Systematics,* 28, 517–544.

Schulz T.T & Leininger W.C, (1990) 'Differences in riparian vegetation structure between grazed areas and exclosures'. *Journal of Range Management* 43 (4) 295-299.

Serneels, S.&Lambin, E.F. (2001) 'Impact of land-use changes on the wildebeest migration in the northern part of the Serengeti– Mara ecosystem'. *Journal of Biogeography*, 28, 391–407.

Shackleton, C. M., Shackleton, S. E., Buiten, E., & Bird, N. (2007). 'The importance of dry woodlands and forests in rural livelihoods and poverty alleviation in South Africa'. *Forest Policy and Economics*, *9*(5), 558-577.

Sharam G., Sinclair ARES & Turkington R. (2006) 'Establishment of broad leaved thickets in thickets in the Serengeti'. *Biotropica* 38(5): 599–605

Sinclair, A.R.E., Mduma, A.R., Grant, J., Hopcraft, C., Fryxell J.M., Hilborn, R. & Thirgood, S. (2007). 'Long term ecosystem dynamics in the Serengeti: lessons for conservation'. *Conservation Biology* 21 (3), 580-590. Doi: 10.1111/j.1523-1739.2007.00699.x

Sombroek, W.G., Braun, H.M.H., & van der Pouw, B.J.A., (1982). *Exploratory soil map and agro-climatic zone map of Kenya, 1980, scale 1:1,000,000*. Exploratory Soil Survey Report No. E1. Kenya Soil Survey, Nairobi.

Stohlgren, T. J., Coughenour, M. B., Chong, G. W., Binkley, D., Kalkhan, M. A., Schell, L. D., ... & Berry, J. K. (1997). 'Landscape analysis of plant diversity'. *Landscape Ecology*, *12*(3), 155-170.

Thomson, M., Serneels, S. & Lambin E. F. (2002). 'Land use strategies in the Mara: A spatial analysis linking socio-economic data with landscape variables'. *Linking people places and policy: a GIScience approach*. Walsh.K, Kelly (Eds.) A. Kluwer Academic Publisher. Massachusetts. USA

Tripathi K. P., and Singh B. (2009). 'Species diversity and vegetation structure across various strata in natural and plantation forests in Katerniaghat Wildlife Sanctuary'. *Tropical Ecology* 50(1) International Society for Tropical Ecology www.tropecol.com North India

Trump, E.C. (1972). Vegetation and land use survey of Narok district. UNDP/FAO/GOK. Nairobi.

Turner M., O'Neill R., Gardner R., & Milne B. (1989). 'Effects of changing spatial scale on the analysis of landscape pattern'. *Landscape Ecology* vol. 3 nos. 3/4 pp 153-162 (1989) SPB Academic Publishing. Hague

Van de Vijver C., Foley C., and Olff H. (1999). Changes in the woody component of an East African savanna during 25 years. Journal of Tropical Ecology (1999) 15:545-564.

van Essen, L.D., Bothma, J., Du, P., van Rooyen, N. & Trollope, W.S.W. (2002) Assessment of the woody vegetation of Ol Choro Oiroua, Masai Mara, Kenya. Afr. J. Ecol. 40, 76–83.

Walker B. H. Ludwigt D., Holling C. S. & Petermant R.M. (1981). 'Stability of semi-arid savanna grazing'. *Journal of Ecology* 69,473-498 systems Institute of Animal Resource Ecology, University of British Columbia, Vancouver, B.C., Canada

Walpole J. M, Naabala M, & Matankory C. (2004). *Status of Mara Woodlands in Kenya.* Durrel Institute of Conservation & Ecology.

Wessels K. J., Mathieu R., Erasmus B., Asner G, Smit I., van Aardt J., Main, Fisher, Marais, Kennedy-Bowdoin, Knapp D., Emerson R. and Jacobson J. (2010). 'Impact of communal land use and conservation on woody vegetation structure in the Lowveld savannas of South Africa'. *Forest Ecology and Management* 262; 19-29.

Western D. and Maitumo D. (2004). 'Woodland loss and restoration in a Savanna Park: A 20 year experiment'. *African Journal of Ecology*, 42, 111–121.

Wezel A.and Lykke A. (2006) Woody vegetation change in Sahelian West Africa: evidence from local knowledge. Environ Dev Sustain (2006) 8:553–567 DOI 10.1007/s10668-006-9055-2

White, F. (1983). The vegetation of Africa: a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa by F White. Natural Resources Research Report XX. p. 356. U. N. Educational, Scientific and Cultural Organization, Paris.

Wiens J. A, Stenseth N., Van Horne B., Ims R. (1993) 'Ecological Mechanisms and Landscape Ecology'. *Oikos*, Vol. 66, No. 3. pp. 369-380.

Wiens A., J. (2009). 'Landscape Ecology as a foundation of sustainable development'. *Landscape Ecol* (2009) 24:1053–1065 DOI 10.1007/s10980-008-9284-x

Wu J. and Loucks L. (1995) *From balance of nature to hierarchical patch dynamics; a paradigm shift in ecology*. Quarterly review of Biology. University of Chicago.

APPENDIX: DATA SHEETS

APPENDIX 1A: Species characteristics (variable transects)

[redacted]

Symbols : a/d- alive/ dead; reg- regeneration; reg. t- regeneration rate; diam- diameter; dieb- dieback; canp-canopy ; grnd- ground

APPENDIX 1B: General site characteristics (car transects)

[redacted]

APPENDIX 1C: Qualitative data

Focus group discussion (thematic questions)

Aim of focus group is to obtain shared perceptions among groups on the use and status of woody plant formation in and around the conservancies.

Time: 1 hour 30 minutes

Focus groups: Elderly men, women and youth

Focus group areas: Aitong, Mararienda and Ngoilale Centres

QUESTIONS

Theme 1: Woody plant use

List the uses of woody plants in the conservancy

Rank three most important tree species for?

- Construction and fencing
- Firewood
- Medicine

Theme 2: Vegetation change

Do you think there has been change of woody vegetation structure over time?

Has the woody vegetation change over the past years?

- Bush encroachment
- Grassland to woodland
- Woodland to grassland

Where has the change occurred?

Top five most important woody vegetation species in the community?

What is the status (increasing, decreasing or constant) of these top five species?

Theme 3: Reforestation program

Would you prefer a wooded area near your home?

- Which species?
- How near, why or why not.

Rank top three most important/useful species and three least preferred species for reforestation.

Would you support indigenous woy676ody species reforestation program?