AN ASSESSMENT OF ENVIRONMENTAL IMPACTS OF PLANT INVASIVE SPECIES ON MULANJE MOUNTAIN FOREST RESERVE (MMFR) IN SOUTHERN MALAWI

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DECLARATION

I, **Laura Makhambera**, declare that this project report is my original work and has not been submitted for an award at any other university.

Signed _____ Date 05.11.14

This project report has been submitted for examination with our approval as University supervisors.

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DEDICATION

This Research project is dedicated to my father Mr. Thomas Makhambera who chose to define his life purpose in the successful education of all that were willing.

LIST OF ABBREVIATIONS/ACRONYMS

CBD	Convention on the Biological Diversity
CFMC	Community Forestry Management Committee
D.F.O	District Forest Officer
EAD	Environmental Affairs Department
FAO	Food and Agriculture Organization
FD	Forest Department
GPS	Geographical Positioning System
IAS	Invasive Alien Species
ISSG	Invasive Species Specialist Group
IUCN	International Union for Conservation of Nature
MA	Millennium Ecosystem Assessment
MMBCP	Mulanje Mountain Biodiversity Conservation Project
MMCT	Mulanje Mountain Conservation Trust
MMFR	Mulanje Mountain Forest Reserve
OECD	Organisation for Economic Corporation and Development
PCQM	Point Centered Quarter Method
SPSS	Scientific Package for Social Scientist
SSC	Species Survival Commission
TRECC	Trans-disciplinary Resource Efficiency for Climate Change
UNESCO	United Nations Education, Scientific and Cultural Organization
USAID	United States Agents for International Development

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With a heavy heart, I would like to pay tribute to my late Mother and Sister, May their souls continue resting in Peace.

ABSTRACT

An environmental impact assessment of woody plant invasive species was conducted on Mulanje Mountain Forest Reserve in Malawi where plant invasive species are regarded as the second largest threat to conservation of biodiversity after direct habitat destruction (EAD, 2006). The main aim was to investigate the ecological and social impact of plant invasive species on Mulanje Mountain Forest Reserve (MMFR) in order to ascertain means of addressing the possible effects on the communities in adjacent to the reserve and on its ecology. Specifically, the study aimed at assessing the spatial distribution and ecological impacts of invasive species on MMFR, evaluating the social impact of invasive species on adjacent communities and identifying appropriate methods for managing invasive species and their impacts on the reserve. It was hypothesized that invasive species have no significant ecological impacts on the biodiversity of Mulanje Mountain Forest Reserve, that invasive species have no significant social impacts on the communities adjacent to the Reserve and that Current methods used in managing impacts of invasive species in Mulanje Mountain Forest Reserve are not effective.

In order to meet the objectives, both primary and secondary data were used for the study. A semi-structured questionnaire was used to collect primary data from the household respondents to get their views on invasive species impact and their management from a sample of 30 respondents who were systematically selected from the five villages surrounding the reserve. Questionnaires were also used to collect data from the key informants. The key informants that were interviewed included the Mulanje district Forest Officer (D.F.O.), Mr. Jeffrey Juwawo, the technical officer for the Mulanje Mountain Conservation Trust (MMCT), The Chairperson of the Village Forest Management Committee (CFMC) and these were purposively selected based on their familiarity with the reserve.

Data on ecological impacts were collected using a baseline transect approach through the Point Centred Quarter Method (PCQM) to measure the spatial distribution of invasive species. This involved the use of three 1 – 1.2 km long transects (eastern, middle and the western transects) while using the PCQM to assess distribution of woody vegetation along the three transects. An interval of 50 – 100 m was estimated between any two consecutive observation points along depending on the variability of vegetation cover

along the transects. Species diversity was calculated for each transects using the Shannon-Weiner method, (Harris et al. 1983).

Data collected were analysed using Chi square and at 95% confidence level after data had been entered and stored in SPSS computer package version 16.0 and Microsoft Office Excel. Views of respondents on invasive species, knowledge of the invasive species, invasive species effect on beneficial plants and on the supply of other ecological goods and services, species form was analysed using chi square test. Chi square test was used to obtain levels of significance for the non-parametric data. Species use, source of invasive Species, Species abundance was assessed using descriptive statistics such as frequencies and Cross Tabs. Crosstabs were used to summarize categorical data and creation of contingency tables.

Following the analysis and discussion of the findings of this study, presence of the invasive species is much more significant on the western side of the reserve as the results shows significant difference on the presence of the invasive species ($p=0.003$). The identified invasive species include *pinus patula* and *Rubus ellipticus*. Invasive species have proved to have both positive and negative impact on the livelihood of the surrounding communities of the Reserve as communities benefit from the invasive species through the provision of the ecological goods and services such as timber, firewood and medicine and only 3 % of the respondents included that they are not useful to them. On the other hand, invasive species have also affected the ecosystem by reducing the population of useful species the results have shown that invasive species increase the frequency of forest fires and this lead to biodiversity loss and threatened endangered species by destroying their habitat and thus leading to their extinction. Ecologically, invasive species have caused considerable loss of biodiversity on the reserve through prevention of regeneration of the native species that are endemic to the reserve. They have also shown to be altering plant and animal habitat as well as disturbing the water flow. The fact that invasive species benefit or please someone, their eradication may impose costs to those in benefit; as a result, there may be some resistance in the control or restriction on the use of the invasive species. Therefore management options should take into consideration of both costs as well as the negative. It was therefore recommended that reforestation programs should be implemented by planting trees with the same values

as those of the invasive species to replace then so as not to lose the benefits at the same time maintaining the ecological integrity of the reserve.

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CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION AND BACKGROUND

Invasive alien species (IAS) are species that are non-native (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health (CBD, 2002;). Invasive species can be plants, animals and other organisms. Specifically, invasive tree species are species that are able to survive, reproduce and spread, unaided and sometimes at alarming rates across an ecosystem causing detrimental effects on the growth of commercial tree species and giving rise to particular management problems (Van Wilgen & Van Wyk, 1999). Invasions by alien species are considered to be one of the largest threats to the ecosystems of the earth, and the services that they provide to humanity (Kaiser, 1999). Some alien tree species used in commercial forestry and agro-forestry cause significant problems as invaders of natural and semi-natural ecosystems. The magnitude of the problem has increased significantly over the past few decades, with a rapid increase in afforestation and changes in land use (Richardson, 1997). Alien invasive species are known to generate substantial costs to the forest sector in lost revenues, in expenses for their control and in lost conservation values and ecosystem services. Richardson (1998) asserts that the most direct economic impact of alien invasive species on the forest sector is related to the loss or reduced efficiency of production.

Invasive species are increasingly recognized as having important impacts on landscapes, ecosystems and levels of biodiversity (Baskin, 2002). These impacts are not all negative and invasive plant species bring both costs and benefits to local people. Costs are incurred if the exotic species inhibit the effective functioning of the local social and ecological systems, such as when invasive species become weeds within agricultural or forestry systems, inhibit vital ecosystem functions or affect animal or human health (Pimentel *et al*, 2001). Ecosystem level change can also deplete peoples' sense of the value of place. Consequently, exotic species can form the base of many economically important resource management systems such as agriculture, horticulture and forestry. Invasive tree species tend to be multi-sectoral in their

impact, and thus need to be addressed with a multi-sectoral approach. In some cases invasive trees provide useful products or services and, when eradication is not possible, management options should be identified in order to balance the positive and negative aspects (Cock, 2003).

Four key features are associated with invasive plants: they show prolific seeding and early age of first reproduction, have unpalatable foliage, can easily establish in degraded environments, and have an ability to regenerate profusely from direct seeds, stems or roots. These features make them good competitors amongst other plant species and allow their survival and abundant establishment (Ahimbisiwe, 2009).

There is a link between invasive plants, ecological integrity and human social livelihoods. First and foremost, maintaining the integrity of ecological systems is an important part of achieving sustainable use of natural resources. Ecological integrity is often disrupted by invasive species which encroach vigorously upon native species and degrade ecosystem services such as soil conservation and water catchment protection, thus causing severe damage to the economy and social livelihoods (Sudmeier-Rieux & Ash, 2009).

Although there is a growing global awareness of invasive plants and the disasters they cause, little attention has been paid to them and few studies have been conducted in tropical Africa (Binggeli *et al*., 1998; Wakibara & Mnaya 2002). Invasive plants are regarded as species that are capable of penetrating and replacing the existing indigenous vegetation of a location. Classically invasive plants are defined as exotic plants that have been introduced in a location, either intentionally or unintentionally, and that reproduce and spread on their own (Rejmanek, 1995).

The Millennium Ecosystem Assessment (MA), an international assessment initiative, has shown strong links between human wellbeing, human security, livelihoods and intangible benefits such as equality and freedom of choice with ecological or ecosystem services. The MA also highlights that a number of human activities (that include introduction of invasive species) degrade the ecological integrity of ecosystems. In Malawi, most of the invasive plant species are introduced ornamental and food species which were brought in to provide economic and recreational gains. Most of the exotic species were deliberately planted on Mulanje mountain forest reserve as a

source of timber for economic and recreational gains, for example Mexican Pine *Pinus patula*, eucalyptus species and Himalayan yellow Raspberry *Rubus ellipticus* for ornamental and as a source of food. These exotic species ended up colonizing the indigenous habitat and became invasive posing a threat to the reserve hence the need to study their impacts on Mulanje mountain forest reserve and the surrounding communities.

1.2 STATEMENT OF THE PROBLEM

IUCNN/SSC/ISSG (2004) elucidates that changes which invasive species cause in the environment reduce availability of environmental goods and services as well as increasing the physical threats to human habitats thereby threatening human habits. For instance, many invasive species enhance frequency and intensity of fires threatening homes or other infrastructure. Furthermore, invasive species cause habitat loss affecting endangered species and consequently their extinction. Invasive species affect forestry as well as human beings by directly contributing to poverty as well as food insecurity which necessitates the need to control the invasive species (FAO, 2008).

In Mulanje Mountain Forest Reserve in Malawi, plant invasive species are regarded as the second largest threat to conservation of biodiversity after direct habitat destruction (EAD, 2006). MMFR is a rare forestry ecosystem and a major centre of diversity. Furthermore, it has been termed the UNESCO world heritage site that supports numerous watersheds, birdlife and is a habitat of many endangered plant and animal species. Regardless of this, the Reserve is endangered or threatened by the invasion of alien Himalayan yellow raspberry *Rubus ellipticus* and the Mexican pine *Pinus patula*. Apparently, the surrounding communities depending on the forest for firewood (domestic use and for sale) and collection of other non-timber forest products (medicine, grass for thatch, wild fruit, mushrooms, honey, and fibre) are under threat due to the presence and potential impacts of invasive species hence an impact on their livelihoods. Despite the consequences of this, there is limited published and consolidated information on invasive species on MMFR.

The study was of significance, as it suggests viable means of conserving biodiversity, and improving livelihoods of surrounding communities to ensure that Mulanje Mountain remains a biodiversity hotspot capable of sustainably sustaining livelihoods of surrounding communities. It

will also help in minimizing the damage caused by the invasive species as it build a spectrum that various stakeholders could refer to in addressing issues of invasive species through investigating the social and ecological impact of invasive species on MMFR.

1.3 RESEARCH QUESTIONS

This study intended to answer the following questions;

1. What are the social and ecological impacts caused by invasive species on the communities surrounding MMFR?
2. To what extent are the communities affected by these impacts?
3. Which members of the community are greatly affected by these impacts?
4. To what extent have the invasive species spread in MMFR?
5. What methods are currently in place to remove or reduce invasive species in MMFR?
6. What conservation plans and measures have been formulated to address the issue of invasive species in MMFR

1.4 OBJECTIVES OF THE STUDY

1.4.1 Main Objective

The main objective of this study was to investigate the ecological and social impact of plant invasive species on Mulanje Mountain Forest Reserve (MMFR) in order to ascertain means of addressing the possible effects on the communities in close proximity of the reserve and on the ecology of the reserve.

1.4.2. Specific Objectives

The Specific oobjectives of the study were to:

1. Assess the spatial distribution of invasive species on Mulanje Mountain forest reserve
2. Evaluate the social impacts of invasive species on the communities within close proximity of Mulanje Mountain Forest Reserve.

3. Assess the ecological impacts of invasive species on the biodiversity of Mulanje Mountain Forest Reserve.
4. Identify the appropriate method of managing the invasive species on Mulanje Mountain Forest Reserve and preventive measures for further invasion.

1.5 HYPOTHESES

Null hypothesis 1

- H_0: Invasive species have no significant ecological impacts on the biodiversity of Mulanje Mountain Forest Reserve.

Null Hypothesis 2

- H_0: Invasive species have no significant social impacts on the communities neighboring Mulanje Mountain Forest Reserve.

Null hypothesis 3

- H_0: Current methods used in mitigating the impacts of invasive species in Mulanje Mountain Forest Reserve are not effective.

1.6 JUSTIFICATION OF THE STUDY

It is widely acknowledged that good information and understanding is the basis for sound policy and management. Impacts of invasive species affect different receptor environment and are often divided into environmental and socio economic impacts. O'Dowd *et al, (*2003); Pientel *et al, (*2005); Reaser *et al, (*2007); and Vila *et al, (*2010) explained that some of these impacts can result in substantial monitory costs as well as alteration to the environmental ecosystem and social system.

Aichi Target 9 stipulates that by 2020 invasive alien species and pathways are identified and priotised, priority species are controlled or eradicated and measures are in place to manage pathways to prevent the introduction and establishment. Furthermore, Target 12 states that by 2020, the extinction of known threatened Species has been prevented and their conservation status, particularly, of those most in decline has been improved and sustained. Therefore, there

has been recognition that societies need to mitigate negative impacts of invasive species and find appropriate means to manage them in a way that the impacts are at least minimized. As such, the study was undertaken to assist decision makers to facilitate optimal allocation of resources to manage invasive species that are most harmful in the area. The findings of this study will also provide information of the various invasive species and their impact allowing decision makers to priotise certain high impacts species for management.

1.7 SCOPE OF THE STUDY

The study synthesized the existing knowledge about observed ecological and social impacts of species invasion on MMFR and reviewed methods that may be used in controlling and extraction of invasive species on Mulanje Mountain Forest Reserve and identifying the best method to reduce and/or remove the invasive species. The study therefore provided an inventory of the spatial distribution of the invasive plant species on Mulanje Mountain forest reserve and tries to analyze the potential ecological and social impacts on MMFR in different parts of the mountain based on the changes since the species were introduced.

This study aimed to provide the Department of Forestry with an improved understanding of the ecological and social implications of species invasion for MMFR and provide adaptation options for the reserve. It also aimed to assist policy makers and planners as they take up the invasion challenge and develop measures to reduce the vulnerability of the Reserve to species invasion.

The findings of this study will contribute to the objectives of the Mulanje Mountain Conservation Trust that proposes to encourage adaptation of the endangered Mulanje Cedar *Widdringtonia whytei* tree species.

1.8 ORGANISATION OF THE PROJECT REPORT

This research report is structured along chapters. Chapter one covered the introduction and background, study objectives, study hypothesis, study significance, research design, and general methodology while Chapter Two presents literature review. Chapter Three presents research methodology, Chapter four presents the results and discussions of the study, and finally Chapter Five presents the summary of the key research findings, key conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

An integral part of sustainable forest management is to protect forests from natural threats such as fire, insects and diseases. Increasingly, according to FAO, (2013), an additional and more severe threat has been affecting the forest sector worldwide - invasive species. The increasing global movement of people and products is also facilitating the movement of alien species around the world. These species may be unintentionally introduced to new environments in shipments of food, household goods, wood and wood products, new and used tyres, animal and plant products, containers, pallets, internal packaging materials and humans. In the absence of their natural predators, competitors and pathogens, they can prosper in new environments and spread at the expense of native species, affecting entire ecosystems. Not all invasive species have been inadvertently introduced, however. Particularly challenging to natural resource management are non-native species that have been intentionally introduced into an ecosystem to provide economic, environmental or social benefits.

Many species of plants, trees and animals have been introduced outside their native ranges as ornamentals for gardening or for the pet industry. These species have escaped to become serious problems in forests and other ecosystems. This is a considerable concern in the forest sector since many of the tree species used for agroforestry; commercial forestry and desertification control are alien or non-native to the area. It is vital to ensure that such species serve the purposes for which they were introduced and do not escape to cause negative effects on native ecosystems. While the definitions and impacts of invasive species on the forest sector are still debated and need reviewing in the context of forest management, a number of initiatives, programmes and activities have been initiated. Most programmes focus on damage caused to local forest ecosystems, or to a particular species or group of species, by a given pest over a period of time. There is an overall lack of information on invasive species within the forest sector at the global scale. Liu, *et. al*, (2011, 2012) state that in many cases, effects of invasive species on environment have not been thoroughly studied, as well as the social impact. As in the

whole invasion process, the uncertainty level of impacts can therefore be high and communicating these impacts is crucial in decision making process

2.2 EMPIRICAL STUDIES DONE ON PLANT INVASIVE SPECIES.

Recent studies (Van Wilgen et al., (1992, 1996, and 1997); Le Maitre et al., (1996, 2000); Chapman and Versfeld, (1998) on invasive species in South Africa have shown to cause both environmental and economic impacts. They have been shown to have negative impacts on all components of biological diversity from genes to the whole ecosystem. In South Africa, invasive tree species and shrubs have shown to have the following negative impacts, increasing costs of fire protection, changing habitat suitability for native animal species, loss of biological diversity and threat to native plant species, reduction in stream flow and available water poisoning of humans and livestock e.g. Lantana, *Lantana camara* and increase in wild fires among others, loss of biodiversity and threat to native plant species, changing biomass ecosystem, changing of animal habitat and hybridization with local related genera thus exchanging genes.

Results from the research in North Eastern Zimbabwe in another context indicate that *Widdringtonia nodiflora,* which occurs in small quantity, was found to be glowing slowly due to invasive species like Mexican pine (*Pinus patula).* Among the pines, Mexican pine (*Pinus patula)* is the most aggressive invader of Afromontane forests and grassland and Miombo woodlands in localities above 1600m above sea level where it is able to produce viable seeds. (FAO, 2008)

Invasive plant species are hazards that have shown negative environmental and socio-economic impacts in East African dry lands. They have degraded the environment and led to serious impacts on human wellbeing such as reduced availability of goods and services for local communities, increased spread of diseases and reduced economic opportunities. This, in turn, has led to loss of livelihoods, and reduced food security. Obiri conducted a study in 2010 on invasive plant species and their disaster-effects in dry tropical forests and rangelands of Kenya and Tanzania and found that, invasive plants are a hazard in the tropical dry forests and rangelands of East Africa. Although often not reported, they have increasingly created disasters that have affected the environment and socio-economic wellbeing of communities inhabiting these dry regions. The study was largely based on secondary data analysis and supported by surveys in the

affected dry lands. The findings of the study show ten key invasive plant species that affect the dry lands. Their disaster-effects vary and include: causing the death of livestock by poisoning and destroying livestock foliage, accelerating biodiversity loss via suppression of native plants, to increasing diseases by offering a breeding ground for mosquitoes and other insects that carry ailments like Nangana and sleeping sickness. Other prolific woody invasive plant species which was discovered during the study include the *Lantana camara* and the White thorn tree *Acacia polyacantha.* All these invasive plants and trees have had serious socio-economic impacts and ultimately increased poverty in the local communities. Although this study took an East African approach, it was limited in scope as the dry lands of Uganda, which are part of the region, were not included. Thus the researcher recommended that future studies need to explore other regions such as Uganda and also increase the number of regions under study in each country hence the need of carrying out the research in Malawi southern part of Africa.

In the study by Cock, (2003), it was asserted that while there is a growing national and international awareness of the possible risks of invasiveness of forestry trees, it is likely that some stakeholders in forestry remain ignorant of the risks, particularly since there is a general lack of quantitative information on the ecological and economic impacts of invasive forestry trees. It was therefore recommended that a number of case studies be conducted in countries that have a high dependence on forestry. Such case studies should cover a range of forestry situations (e.g. commercial and environmental) and include the development and promotion of tools for making ecological and economic assessments. Particular attention should be paid to those regions of the world where there is little information on the invasiveness of exotic forestry trees (e.g. tropical and temperate regions).The general lack of relevant information and methodologies was noted to prevent many countries from implementing risk assessments, control and management schemes.

The lack of information on the socio-economic impacts of IAS has been singled out as a major barrier to the implementation of comprehensive national IAS management programmes and as one of the main reasons for the failure of IAS issues to feature prominently in the mainstream agenda of most countries (Ahimbisiwe, 2009)

A significant proportion of invaders, even some quite noxious ones, benefit or please someone, and this makes regulation politically and socially complicated (Baskin 2002). Because of this, restrictions on cultivation of invasive species may impose costs to local people who may have previously been able to exploit their production. As a result, there may be substantial political opposition to strict controls on the introduction and use of certain exotic species. For effective control of invasive species, management approaches need to be perceived by local people as aiming for socio-economic, as well as ecological sustainability. People make choices that augment or diminish the chances of species becoming invasive, largely via intentional introductions to support economic activities including agriculture, forestry, gardening, and international trade (Bright, 1999). Conflicts of interest arise from time to time in cases where important tree species become invasive and spread beyond the areas where they are cultivated such as S. spectabilis did in Uganda. Others include plantation forestry (Pinus species and acacia species where alien plants provide firewood (Higgins et al., 1997). It is thus clear that forestry has been one of the major targets of alien infestation (Richardson, 1998). These conflicts have to be dealt with in a sensitive manner if progress is to be made in reducing the significant negative impacts of invading alien plants in Uganda and elsewhere in the world

2.3 STATUS OF INVASIVE SPECIES IN MALAWI

Malawi is particularly prone to alien invasive species due to its geographical position, pan tropical climate and agriculturally based economy and also the country relies heavily on imported products. A number of invasive species have been introduced by tourists, smugglers, cargo and sometimes researchers (Wisborg & Jumbe, 2010).

While there is currently limited published and consolidated information on invasive species in Malawi, the invasion of important ecosystems such as mountains and aquatic ecosystems has been well documented. For example, Studies on the Status of Invasive species have shown that invasive alien species have caused various levels of damage to Malawi's biodiversity Mulanje Mountain; a major centre of diversity is endangered or threatened by the invasion of alien Himalayan yellow raspberry *Rubus ellipticus* and the Mexican pine *pinus patula*. The Central American mesquite *Prosopis juliflora* present at Swang'oma, on the plains of Lake Chirwa in

Phalombe District and in the Lower Shire Valley is a threat, particularly to the biodiversity of the wetlands. Furthermore, due to its induced growth, it has overgrown and replaced indigenous vegetation in some parts of Lake Chirwa wetland (Swang'oma area).

The mountain's boundary communities depended on the forest for firewood (domestic use and for sale) and collection of other non-timber forest products (medicine, grass for thatch, wild fruits, mushrooms, honey, and fibre). Mulanje Mountain Forest Reserve (MMFR) is suffering from a situation approaching 'open access' to all who may wish to enter and utilise her resources, coupled by inadequate management capacity of the Forestry Department due to lack of labour, equipment and funding.

The four major threats to the mountain regularly cited according to (MMCT-PAD, 2001) are; unsustainable resource use stemming from high population density, pervasive poverty, and lack of awareness of and weak incentives for sound conservation practices; agricultural encroachment on the lower slopes due to a combination of population pressure and insecure land tenure; bush fires due to an incomplete system of fire breaks and inadequate response capacity; and invasion of alien species. These are the management priorities for MMFR, however, the simultaneous goals of irradiating one of these invasive species; *Pinus patula* presents complications in management aspirations. At the same time, areas protected from fire provide opportunity for *Pinus patula* and W*iddringtonia whytei* to establish in competition. The fast growth of *Pinus patula* gives it the distinct advantage over indigenous species and led Edwards (1982) to express his concern that such a fire protection policy could cause succession to closed pine forest rather than the intended indigenous forest. The alarming success with which pine has been invading grassland is particularly evident on the plateau of Sombani, where comparisons of aerial photographs from 1972 and 1992 demonstrate the advancement of the pine across the Sombani River and onto other areas of the plateau. (Wisborg and Jumbe, 2010)

Species of the genus Pinus are amongst the most aggressive indigenous and exotic tree invaders in the tropics. Fire-disturbed sites with exposed mineral soil, especially in tropical mountainous regions, are easily colonised by pines and because of their ability to cope with water stress, pines

are extremely competitive against broadleaved species on exposed shallow soil sites (Goldammer & Manan, 1996).

2.4 ERADICATION OF INVASIVE ALIEN PLANTS IN MALAWI

Mulanje Mountain is an isolated mountain plateau in the South-Eastern part of Malawi with rich forest ecosystems and woodlands. For almost ten years, the Mulanje Mountain Conservation Trust (MMCT) has been seeking to improve the environmental and socio-economic situation in the area, in cooperation with the Forest Department (FD). It was aided during the initial years by a number of external donors, including the Global Environment Facility, the World Bank, USAID, and more recently Norwegian aid. During recent years, MMCT has been working on registration and mapping of the natural resources on the mountain, and they have developed a local monitoring program that partly satisfies the need for a natural resources baseline as defined for the Norwegian environmental Action Plan. The biodiversity is very rich on and around the mountain, particularly in the more inaccessible spots, where the ecosystems are still intact. It contains a vast number of trees, plants, as well as several (endemic) smaller mammals, reptiles and birds. A small population of wild cats (leopard and serval) is also present in the area. Inspite of tremendous pressure for their exploitation, a limited number of the Mulanje cedar are still found on the mountain. Apart from biodiversity conservation, MMCT is engaged in a number of activities, including development of alternative livelihoods to replace unsustainable forest extraction and making efforts to eradicate invasive species, mainly exotic pines. The area covered by invasive pines has been established in the local baseline, enabling the level of reintroduction of native species to serve as a positive environmental indicator.

Article 8h of the Convention on Biological Diversity calls upon member states to take appropriate measures to prevent the introduction of and to control or eradicate alien species that threaten ecosystems, habitats or other species. One of the key management actions under the Mulanje Mountain Biodiversity Conservation Project (MMBCP) has been to eradicate invasive alien plants that are displacing indigenous vegetation. According to MMCT (2006), there are over twenty known invasive alien plant species in and around the MMFR. Some of the key invasive species include *Pinus patula*, Himalayan Raspberry *Rubus ellipticus*, Bracken fern *Pteridium aquillinum*, and blue gum *Eucalyptus spp*.

Over the years, MMCT and District Forestry Officers involving the surrounding communities have cleared some of these alien species. The major emphasis has been on Mexican pine and Himalayan raspberry. A major remaining challenge, according to MMCT, is the Bracken fern *Pteridium aquillinum* which suppresses indigenous vegetation and accumulates considerable amounts of dry matter to become a fire risk (MMCT 2008a, 2010b).

There is an overall lack of information on invasive species and the forest sector at the global scale. Liu *et al*, (2011, 2012) enlighten that in many cases, effects of invasive species on environment have not been thoroughly studied, as well as the social impact. As in the whole invasion process, the uncertainty level of impacts can therefore be high and communicating these impacts is crucial in decision making process. Where similar studies have been conducted, most studies have focused on the environment in broad-spectrum; this study focused on the ecological impact of plant invasive species on species diversity in particular. Furthermore, other studies have focused on invasive species in plantation and the economic impacts associated with. As the demand for involving communities in environmental management escalates, it is important to study the social impacts of invasive species on the resource user.

2.5THEORETICAL FRAMEWORK

2.5.1Land Use Theory

(Wood, *et. al*. 2000) explains that ecosystem service and biodiversity are interlinked in order to retain ecosystem productivity and stability. It is necessary to maintain adequate biodiversity in the ecosystem as the well-being of the global human population is fundamental and directly dependent on ecosystem. Demographics and socio economic change have a consequence on land use. Human population affects land use through production, recreation and consumption behaviours. Increase in population result in greater consumption of vegetation and higher levels of construction of buildings and infrastructure. It also increase demand for forestry resources such as fuel wood and fodder resulting in overconsumption of vegetation. In order to meet the demand of the growing population, various species are introduced through afforestation programmes and these species mostly natives result into change in land use and lead to species invasion as they begin colonizing the area. Invasive alien species threatens the indigenous plants and slowly leading to their extinction. Native species alter biotic composition of invaded

communities and often physical structure of invaded regions. This can lead to extinction of several native species as well as goods and services they provide and therefore impact on human wellbeing. This can best be presented in the Driver, Pressure, State, Impact, Response (DPSIR) relationship framework which has been recently proposed as a method for assessing ecosystem service.

2.6 CONCEPTUAL FRAMEWORK

In this study, DPSIR framework (Figure 1) was adapted to analyze the connections among biodiversity loss, ecosystem services, human wellbeing and society's responses to preserve the ecosystem service flow on Mulanje Mountain Forest Reserve in Malawi.

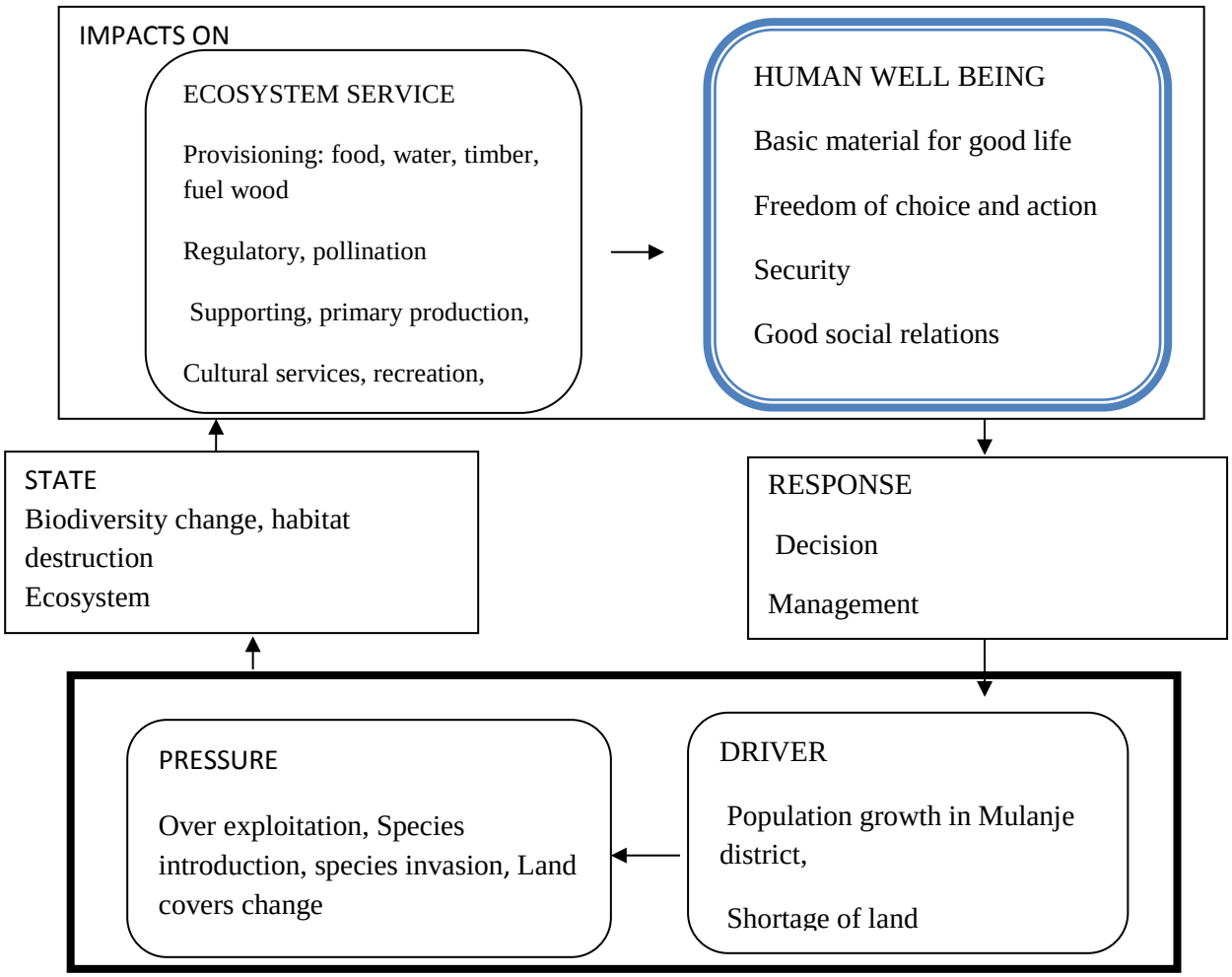

Figure 1: DIPSIR FRAMEWORK, Adapted and modified from (OECD, 2001)

In this study, drivers are the underlying factors promoting environmental change on the Mulanje mountain forest reserve. These factors include demographic factors, and are also defined as indirect drivers of change. The drivers population growth in this case produce different pressures, such as land use change, invasive alien species (due to species introduction), and overexploitation of forest resources on the MMFR, which may affect ecological integrity of the reserve. Pressures (defined as direct drivers of change) change the state of ecosystems and biodiversity thus affecting the ecosystem service delivery to society. Therefore, impacts can be understood as changes in both the supply of ecosystem services and human wellbeing. Depending on the social perception of wellbeing, governments and society perform different actions (responses) to control the effect of drivers in this case invasive species to preserve the ecosystem's capacity to supply services.

CHAPTER THREE

MATERIALS AND METHODS

3.1 DESCRIPTION OF THE STUDY AREA

The study took place on Mount Mulanje forest reserve. Mulanje Mountain is situated in the far southeast corner of Malawi. It is the largest mountainous massif in the afro-montane archipelago ($15^{o}75'S$ $35^{o}38E$). The massif itself is a huge syenite intrusion of $640km^2$, rising steeply and abruptly from the south-central African plains to form a broad plateau of basins and deep river gorges at 1800m, and steep rocky peaks that reach 2800m.

The forest reserve (gazetted in 1927) is an ecological island of unique biodiversity as well as a critical water catchment area, alimenting an estimated 400,000 people living in the Mulanje district (Davis *et al,* 1994) as well as many more beyond, as well as tea and coffee estates below the southern slopes. Its rich and diverse flora and fauna include at least 30 endemic plants, and the Mulanje cedar (, a distinctive conifer and national icon tree of Malawi, which only grows to a full height of 40m tall on the mountain (Chapman 1994, Lawrence *et al,* 1994, Nyirenda *et al,* 1996,). Mulanje Mountain falls under silviculture Zone M (Hardcastle, 1979) and experiences mean annual temperature of 20°c with an annual rainfall of 800mm. Mulanje Mountain boasts a variety of ecosystems; the Likhubula dry woodlands areas are unique with cycad species found nowhere else in the world. The cycad species grow while facing a westerly direction. The Ruo River has tropical rain forest vegetation with trees growing as high as 150 ft. This area receives up to 100 inches of rain annually. The Mulanje cedar is Malawi's national tree and grows at heights of 2,000 - 2,500 meters. Mulanje Mountain Forest Reserve spans the two districts of Mulanje and Phalombe, n around the mountain is estimated to be 37,000 in 85 villages, the average land holding being 0.4 hectares. Mulanje is considered a maize-deficit area that contains approximately 66% of the poorer households of the population. Poverty is therefore a particularly important factor in resource use (Sambo, 2001). The original settlers around Mulanje Mountain were the Mang'anja who also extended to Thyolo and Chikwawa (Lowore, 1999). Since the later part of the 19^{th} century the area has been subjected to influxes of people from elsewhere, particularly Lomwe from Mozambique. The outskirts of the mountain are mainly

surrounded by tea estates and the majority of the local people attain their livelihoods through working in the tea estates.

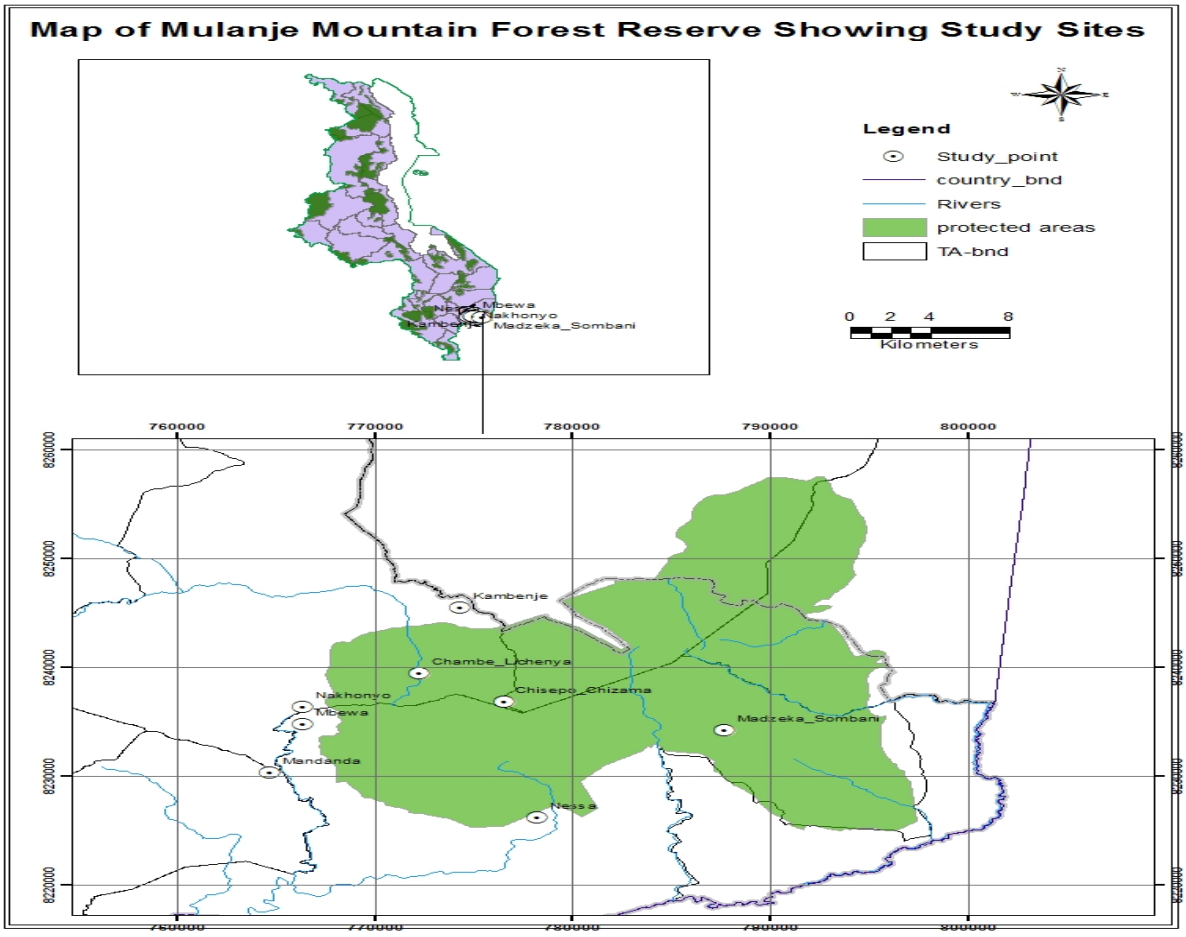

Figure 2: Map showing Mulanje Mountain Forest Reserve

(Source: Department of Forestry, 2014)

3.2 RESEARCH DESIGN

The study used cross sectional design which entails survey research. It involved day to day collection of data using a random sample. Major focus was on spatial distribution of both ecological and social impact of plant invasive species.

3.3 SAMPLING METHOD AND PROCEDURE

Social data collection was done along settlement patterns targeting villages surrounding MMFR. A sample of five villages: Nakhonyo, Mbewa, Kambenje, Nnesa, and Mandanda were purposively selected for the study from the Eastern, Western and southern part of the reserve so

as to consider various sides of the reserve. These Villages represent the communities that surround the reserve. Systematic random sampling method was used to select the number of households in the selected villages whereby every 11th household was included in the sample.

3.3.1Sample Size

A sample of 30 out of 320 households from the five villages was used representing 9.4%

Table 1: Distribution of sample Households in the study area

Village	Total Number of Households	Number of households sampled
Nnesa	72	7
Kambenje	81	7
Mandanda	75	7
Nakhonyo	49	5
Mbewa	43	4
Total	320	30

The sample size was arrived at by accepting the confidence interval of 13 at95% confidence level using the sample size calculator (http://www.creativeresearchsystem.com). Systematic sampling of respondents was done using a list of households which was obtained from the village headmen. Household samples to be interviewed in each village were arrived at using the method below:

$$\text{Sample Size} = \frac{\text{Number of Households of the Village} * 30}{\text{Total Households of the 5 Villages}}$$

Where 30 = Total Sample size

The interval was arrived at by the following:

N/n

Where N= total population in the five Villages, N= sample size

Therefore, N/n = 320/30 = 10.6 = 11

Ecological data collection was done by the use of transect approach through the Point Centred Quarter Method (PCQM) to analyse the distribution of invasive species. PCQM is a method for sampling woody vegetation composition and density (Mwaura & Kaburu, 2008). It is undertaken by using baseline transect along with representative numbers of controlled observations with a minimum of 20-30 recommended. Therefore, the sampling strategy for this study involved the use of three 1-1.2km long transects (eastern, middle and the western transects).The Western transect run from Chambe to Lichenya, Eastern transect run from Madzeka to Sombani and the middle transect which was set from Chisepo through Minunu to Chinzama. The PCQM was then used to assess the distribution of woody vegetation through transect walks made along the three transects. The distant interval between one observation points to another was 50m to 100m depending on the environmental variability in terms of vegetation cover. At each observation point, the area was divided into four quarters as shown in Figure 3

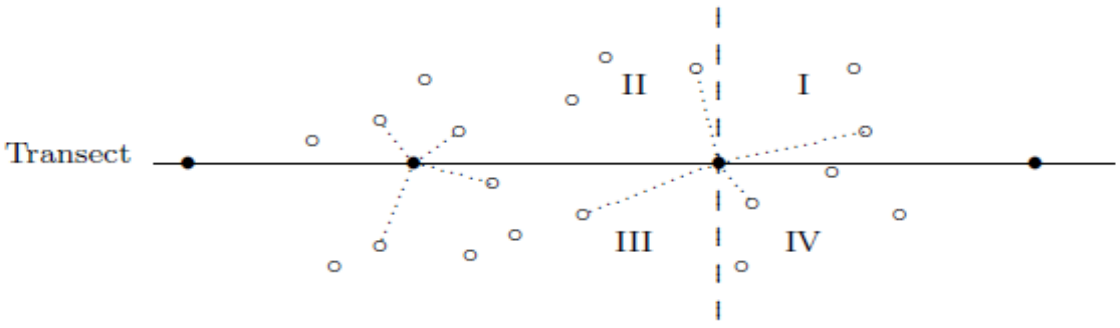

Figure 3: Sample plots along a transect line (source: Quantitative Analysis by the Point-Centred Quarter Method, Mitchell 2007).

3.3.2 Reconnaissance Survey

A reconnaissance survey was done prior to data collection in order for the researcher to get acquainted with the study area.

3.4 DATA COLLECTION METHODS AND SOURCES

Both primary and secondary data was collected in the study.

3.4.1 Primary Data

3.4.1.1 Household survey method

Social data was collected from 21st to 25th April, 2014 using the household survey method through structured questionnaires which comprised both open and closed questions. Open ended questions were used to seek opinions from the respondents with regard to utilization of resources from the reserve and how the invasive species have impacted them.

3.4.1.2 Direct Observation

This was used in the households while conducting the survey so as to obtain and confirm information about utilization, direct observations was done on the reserve to note the presence of invasive species.

3.4.1.3 Interviews

Key informants interviews (KII) were conducted so as to get a clear knowledge of the invasive species with regards to origin and cause of their infestation, their benefits as well as their notable environmental impacts and the management systems that have been applied so far and to get their perceptions about the invasive species and what should be done to solve the problem. These key informants were purposively sampled and were used to collect data on social and ecological management on the invasive species. The Key informants included the forest department (the district forestry officer for Mulanje District), Community Forest Management Committee (CFMC), the civil society such as the Mulanje Mountain Conservation Trust (MMCT) and other stakeholders with interest on Mulanje Mountain.

3.4.1.4 Point Centred Quarter Method (PCQM)

This was done from 1st to 9th April, 2014. The sampling strategy for the ecological data collection of this study involved the use of three 1-1.2 km long transects. The baselines for the western transect was set from Chambe towards Lichenya (1km) and the middle transect ran from Chisepo to Chinzama through Minunu (1.1km) while the eastern Transect was set from Madzeka to Sombani (1.2.km). These transects were set using GPS compass in order to maintain a consistence.

The Point Centred Quarter (PCQ) method was used to assess the woody vegetation characteristics in the area. The PCQ is a distance method used for sampling woody vegetation composition and density (Mueller –Dombois and Ellenbeg 1974 cited in Herlocker 1999).The PCQ method is undertaken using baseline transects along with a representative number of controlled observation points. The accuracy of the PCQ method increases with the number of observation points but a minimum of 20 -30 is recommended for better results (Herlocker, 1999). The distance interval between the observation points was measured by GPS and varies between 50m-100m depending on the degree of the environmental variability in terms of altitudinal gradient and change in vegetation cover as deduced through visual assessment. The interval was shortened in the transect sections of high variation and lengthen in section of low variation. At each observation points, the area was divided into four quarters using a PCQ stick. The nearest woody species to the observation point in each quarter was identified using local indigenous knowledge and taxonomic aids. The distance to the nearest tree was or shrub was estimated using a tape measure. A total of 66 sites and 264 quarters were examined including 21, 20 and 25 sites each in transect 1-3 respectively.

And at each observation point the following was recorded on the field data sheet (Appendix 3).

a. Name of the species

b. Common uses of the species

c. Total species count within a 10m radius at the point

Species diversity was calculated for each transects using the Shannon- Weiner method (Harris et al. 1983). The index varies from zero for one species and increases with an increase in species heterogeneity. It is computed from the species present in a sample and takes account of both rare and common species without giving extra weight to either. This index has previously been used in vegetation studies in Kenya (Mwaura, 2004). The Shannon Weiner index is calculated using the following equation according to Harns et al (1983).

$$H' = \sum [ni/N] \log_e [ni/n]$$ where,

H’ is the Shannon index;

Ni is the total number of individuals of the ith species in a sample.

N is the total number of all individuals of all species in a sample and

Ni/N is the proportion of the ith species in a sample.

3.4.1.5. Pre-Testing of Questionnaires

This was done on the 30th 0f March, 2014 before administering the questionnaire to ensure that all errors associated with the survey research are minimized. During the exercise, problems regarding the terminology used in the study arose among both the enumerators and the respondents and were addressed accordingly. This helped to improve the quality of the data and was done on a small sample of respondents from the target population in one of the selected villages.

3.4.2 Secondary Data

3.4.2.1 Document Studies

This was done to collect secondary data from the existing maps, reports, books, internet and journals.

3.4.3 Data Processing and Presentation

After collecting data, it was checked for gaps and any irregularities as well as the outliers and necessary adjustments was made accordingly. The questionnaire data was coded and entered into SPSS Computer package. It was then summarized using descriptive statistics such as percentages, frequencies, cross tabs and presented using graphs, tables and charts. Ecological data was used in the estimation of frequency or incidence of occurrence of the species and species abundance.

3.5 Data Analysis

After processing, data was then analysed by inferential statistics such as *chi square* and at 95% confidence level using analytical methods in SPSS computer package version 16.0. Chi square test is the sum squared difference between observed and the expected data divided by the expected data in all possible categories. Chi square test was used to obtain levels of significance

for the non-parametric data and was used to analyse the following variables: Knowledge of the invasive species, invasive species effect on beneficial plants and on the supply of other ecological goods and services, Views of the respondents on the eradication of invasive species and species form. The Null hypothesis was rejected if the calculated value was greater than the critical value and the difference was considered significant if the p- value found to be less than 0.05 and non-significant if the p- value was considered to be greater than or equal to 0.05. Species use, source of invasive Species, Species distribution, Species abundance was analysed using descriptive statistics such as frequencies and cross tabulations. Cross tabulations were used to summarize categorical data and creation of contingency tables

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS AND FINDINGS

4.1.1 Spatial Distribution of Woody Species ON MMFR

A total of 27 woody species were observed within the three transects of which two (*Pinus patula and Rubus ellipticus)* were identified as invasive species as shown in Table2. The distribution of species varied across and within transects on the western, middle and eastern sides of the MMFR. Western transect had 20 species in total dominated by *Hypericum revolutum* (28.8 %), *Pinus patula* (12.3 %), and *Rubus ellipticus* (10.4%). Nine (9) species were recorded in the middle transect and the dominant species were *Protea Nyasae* (26.7%), *Kotschya Africana* (26.7%), and *Xerophyta* species (15.5%). The Eastern transect had 15 species observed and the most abundant were *Hypericum revolutum* (37.5 %), *Buddleia salviifolia* (11.9%) and *Kotschya Africana* (9.1%). Of the total 623 observations made, the top five dominant species recorded were *Hypericum revolutum* (22.6 %), *Kotschya Africana* (10.9%), *Protea Nyasae* (8.3%), *Pinus patula* (5.3 %), and *Heteomorpha trifoliata* (4.7 %). Amongst the list of the top five dominant woody species was one of the identified invasive species *pinus patula.* This is in line with the report by FAO, (2008) which stated that pinus patula is the greatest invader of the afro-montane forests amongst the pine as it is able to produce viable seeds.

There was no significant difference (P=0.740) between life form of the observed woody species where 49 % were trees and 51 % were shrubs. The identified invasive species were found to be more concentrated on the western part of the MMFR and the majority of the household respondents (43%) indicated that the invasive species were more abundant on the western part of the MMFR.

Table 2: Woody species per transect

No	Woody species	Origin of Woody Species	Total Frequency (%)		Abundance according to Total Count		
					Transect 1 Western	Transect 2 Middle	Transect 3 Eastern
1	*Hypericum revolutum*	Indigenous	22.6	75	0	66	
2	*Kotschya africana*	Indigenous	10.9	2	50	16	
3	*Protea Nyasae*	Indigenous	8.3	2	50	0	
4	*Pinus patula**	Exotic	5.3	32	1	0	
5	*Heteomorpha trifoliata*	Indigenous	4.7	0	23	6	
6	*Xerophyta*	Indigenous	4.7	0	29	0	
7	*Erica nyasana*	Indigenous	4.3	8	6	13	
8	*Rubus ellipticus**	Exotic	4.3	27	0	0	
9	*Aeschonomen megalophylla*	Indigenous	4.0	10	15	0	
10	*Buddleia salviifolia*	Indigenous	3.9	3	0	21	
11	*Maesa lancolata*	Indigenous	3.7	10	0	13	
12	*Morella serrata*	Indigenous	3.5	20	0	2	
13	*Cusonia spicata*	Indigenous	2.6	15	0	1	
14	*Erythroxylum emarginatum*	Indigenous	1.9	5	0	7	
15	*Indigofera iyallii*	Indigenous	1.9	12	0	0	
16	*Psychotria zombemontana*	Indigenous	1.9	12	0	0	
17	*Agarista salicifolia*	Indigenous	1.8	7	0	4	
18	*Halleria elliptica*	Indigenous	1.8	0	0	11	
19	*Maytenus undulata*	Indigenous	1.4	1	8	0	
20	*Nuxia oppositifolia*	Indigenous	1.4	9	0	0	
21	*Ilex matis*	Indigenous	1.3	1	0	7	
22	*Mrysine africana*	Indigenous	0.8	0	5	0	
23	*Pittosporium viridiflorum*	Indigenous	0.8	0	0	5	
24	*Tremma orientalis*	Indigenous	0.8	5	0	0	
25	*Dodonia viscosa*	Indigenous	0.6	4	0	0	
26	*Macaranga capensis*	Indigenous	0.3	0	0	2	
27	*Rapanea melanophloes*	Indigenous	0.3	0	0	2	

*Invasive species Rubus *ellipticus and Pittosporium viridiflorum* among the list of IUCN invasive species database

Source: Researcher, (2014)

4.1.2. Ecological Impacts of Invasive Species ON MMFR

The western transect was found to be dominated by both an indigenous species *Hypericum revolutum* (28.8%) and two exotic species *Pinus patula* (12.3%) and *Rubus ellipticus* (10.4%). These two exotic species were identified as invasive species and were recorded as not present

and/or scarce in the middle and Eastern transects. *Hypericum revolutum* (22.6%) had also the most representation in the Eastern transect but was not present in the middle transect. *Pinus patula* was not present in the Eastern transect but was recorded to be present in the middle transect (0.5%). Overall, *Hypericum revolutum* (22.6%) was the most abundant specie observed in all transects (Figure 4). In terms of species diversity, the Shannon index showed that the western transect had more variation in species followed by the eastern transect and the middle transect (Table 3). Despite the greatest variation on the western transect, it is also revealed that it is heavily infested with the invasive species. This has the potential impact on the ecosystem of the reserve as well as the services that it provides which is in agreement with Liu, *et. al,*, (2011).

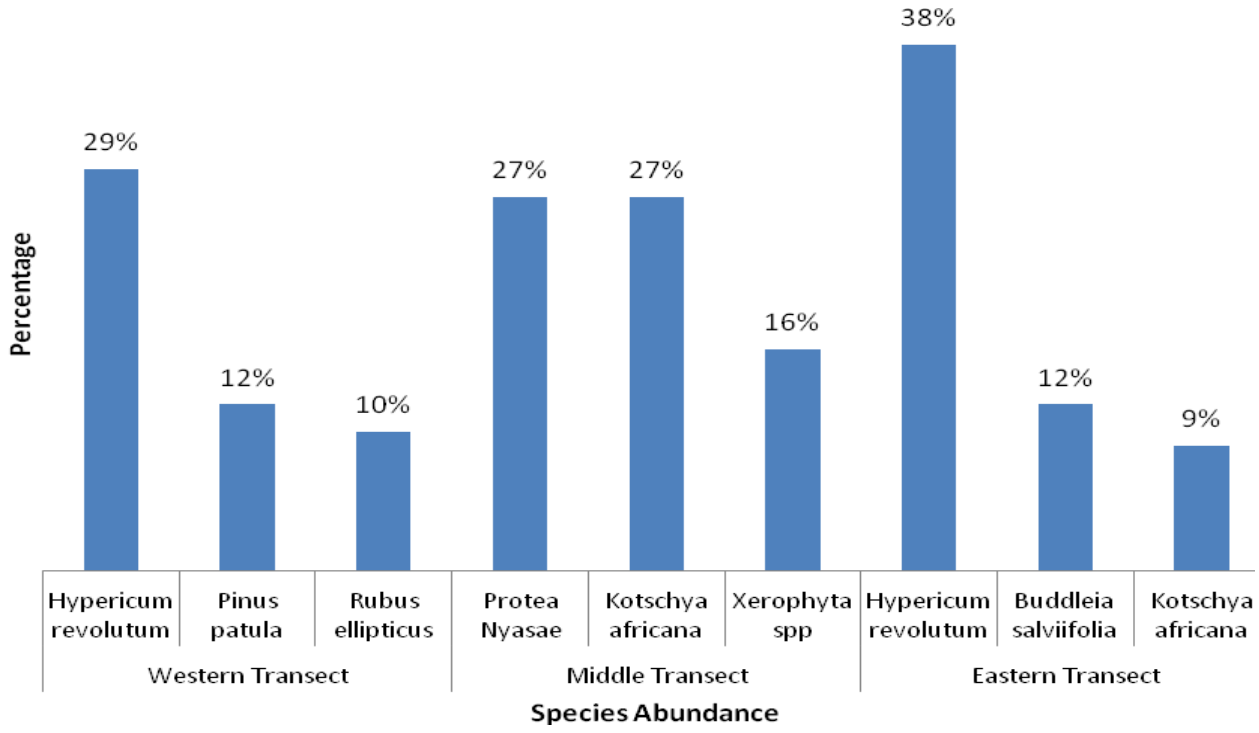

Figure 4: Distribution of top 3 woody species within transects. (Researcher, 2014)

Table 3: Species diversity summary

Description	Transect 1	Transect 2	Transect 3
Number of species	20	9	15
Number of individuals	260	187	176
Number of species in common	2	2	2
Shannon diversity	2.4543	1.8246	2.1385

Source: Researcher, (2014)

Respondents were also asked to mention the effects of invasive species on the supply of other ecological goods and services. The main effects recorded were loss of land (30%), loss of timber (20%) and increased fire intensity (20%) and no significant differences (P=0.180) were observed in terms of effect of woody/invasive species on environmental goods and services. This is in agreement with the IUCN/SSC/ISSG (2004) which states that invasive species increase intensity of fire. These losses affect the livelihood of the people living adjacent to the reserve as they directly depend on the products from the reserve for their survival. Increment in fire intensity destroys habitat of other plants and animals leading to their extinction thus affecting the ecological integrity of the reserve and the services that it provides.

Many respondents (47%) indicated that the invasive species had in no way affected other tree species and that they had not experienced any loss of benefits from non-invasive species due to the presence of the invasive species. This indicates significant differences (P=0.005) on the effects of invasive species on beneficial tree species with a fair proportion of the respondents (33%) feeling that the invasive species were reducing population of other beneficial plants.

4.1.3 Social Impacts of Invasive species on MMFR

General woody species uses were recorded during collection of data from transects using the PCQM so as to find out how the invasive species might affect some useful plants on the reserve. The woody species observed were found to be useful in many ways by the communities around the MMFR. In total, 7 uses were identified and these are provided by different species as shown in Table 3. This is in line with MMCT (2008) which highlighted that MMFR is of great importance to those who live in and around it. Providing food, medicinal plants and building materials. The main use of the woody species identified by the communities was a combination of firewood, construction and medicine (Figure 5) and both men and women were recorded as the major users of the species. This showed significant differences (P=0.0005) on usage of the invasive species and non-significant differences (P=0.122) on users of the invasive species. These results agrees with Katerere & Chenje, (2003), Obiri, (2010) who pointed out that invasive species play an important role in the livelihoods and the economy of the people through the supply of ecological goods and services.

Table 4: General woody species uses

	Key Uses of Woody Species	Total number of woody species
1.	**Wild fruits**	1
2.	**Firewood**	21
3.	**Fodder**	1
4.	**Construction (Timber)**	1
5.	**Construction (Poles)**	7
6.	**Medicinal use**	10
7.	**Brushes**	1

Source: Researcher (2014)

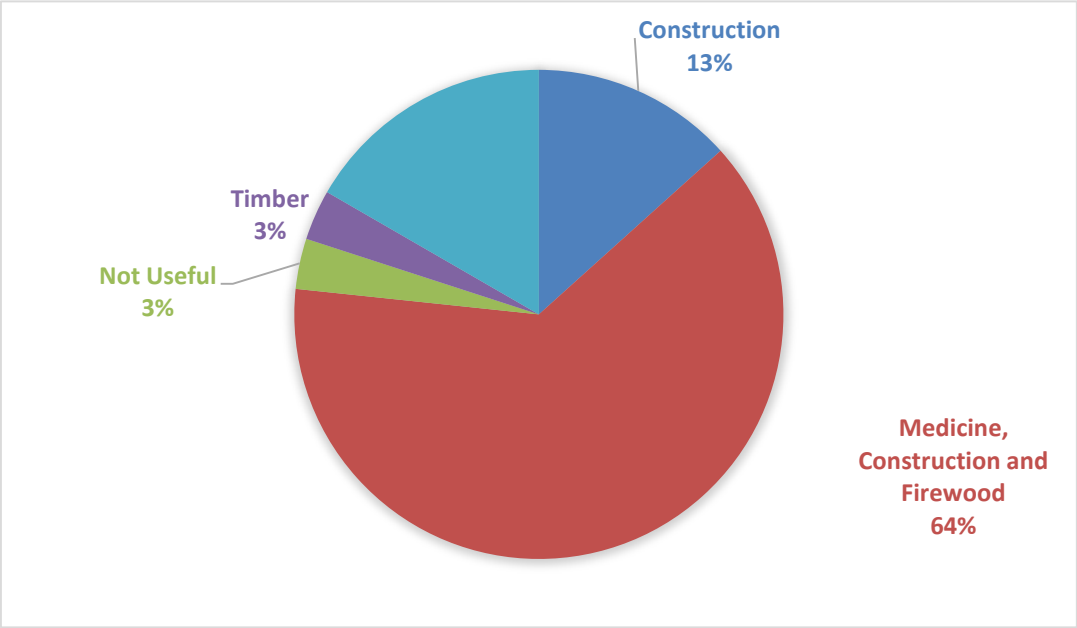

Figure 5: Uses of woody invasive species by communities
(Researcher, 2014)

It was also found that there was a significant difference (P=0.003) on use of woody species which was mainly both domestic and commercial (60%) with few incidents of domestic use (30%) alone and very few incidents of commercial use (10%) alone (Figure 6). Fruits and wood (60%) were recorded as the most used parts of the woody invasive species. The respondents' findings also showed that the woody invasive species are of cultural significance to the communities (70%) and the most common cultural uses were identified as ancestral sacrifices (50%) and initiation ceremonies (10%).

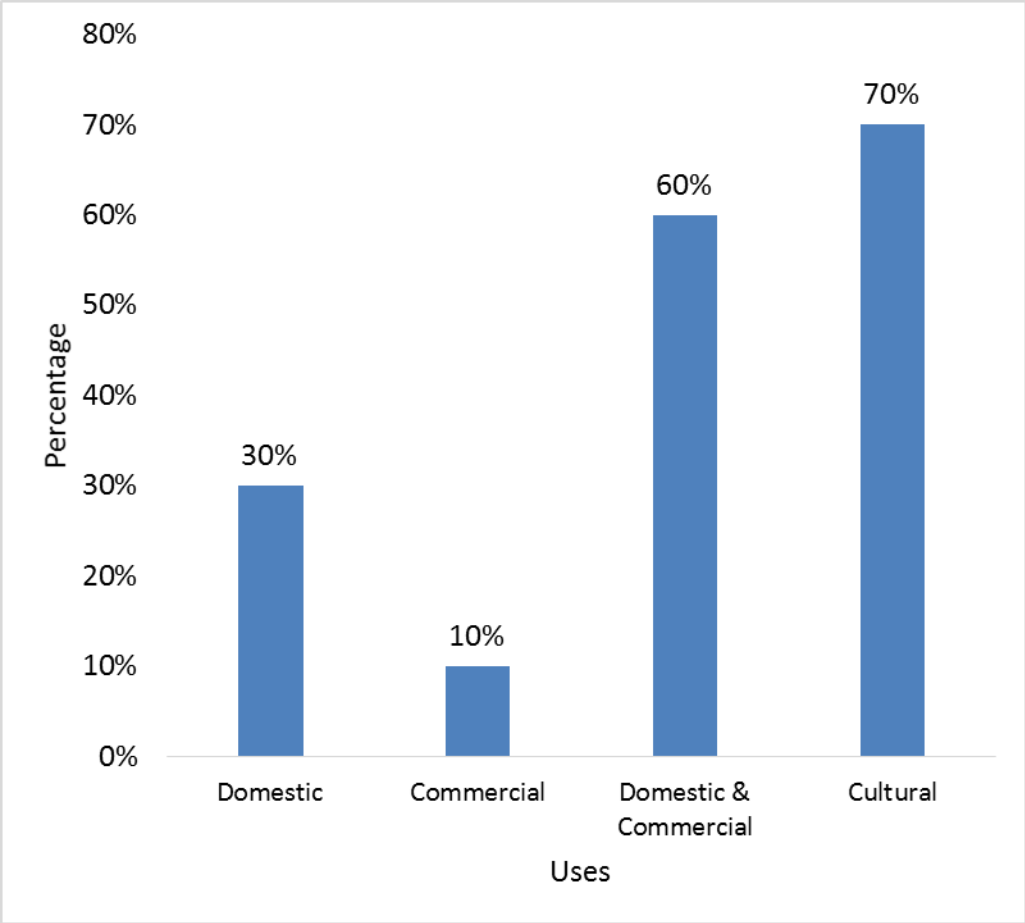

Figure 6: Categorised uses of woody invasive species.
(Researcher, 2014)

There were significant difference (P=0.005) on the effects of woody invasive species on beneficial exotic and indigenous trees. The woody invasive species were found to have a non-significant effect (P=0.028) on the behaviour of respondents. A large proportion of respondents (Figure 7) indicated that they acquire products of invasive species from the MMFR implying that the invasive species play a role in their daily livelihoods.

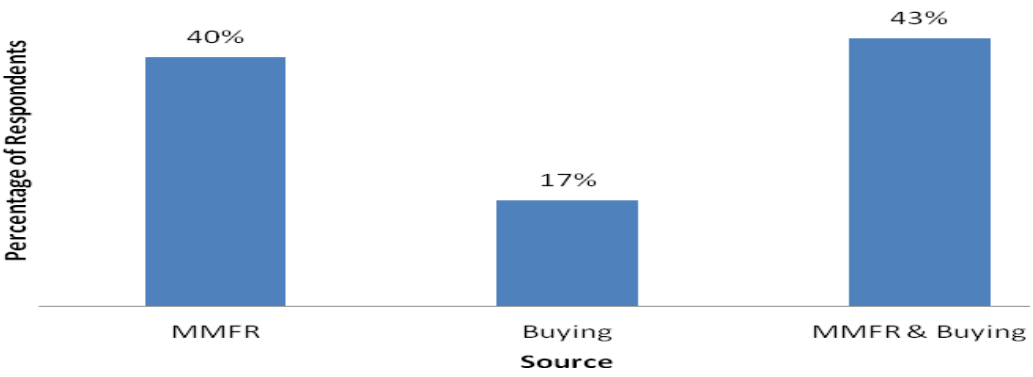

Figure 7: Sources of woody invasive species products.
(Researcher, 2014)

It was also found that most respondents (63%) had a view that the invasive species should not be removed from the MMFR (Figure 8). This is because these invasive species benefit therefore their eradication will make them lose all the benefits they were obtaining from these species. As a result, this makes the management regulation complicated. This concurs with Baskin, (2002) who explained that a significant of invaders even some quite noxious ones benefit or please someone and makes regulation socially or implicated

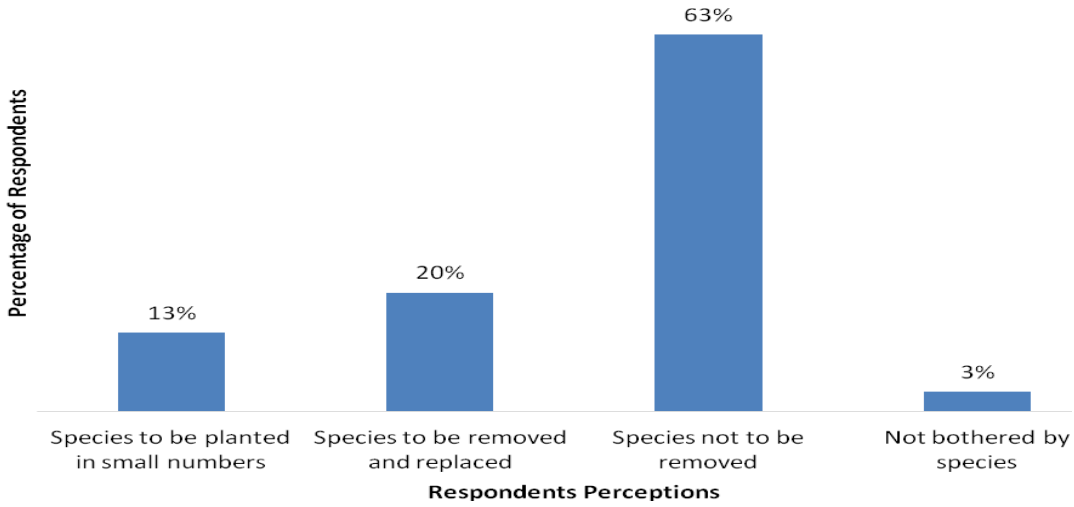

Figure 8: Respondents perceptions on woody invasive species.
(Researcher, 2014)

4.1.4 Management of Invasive Species on MMFR

The majority (98%) of the respondents acknowledged to know what invasive species were and most were able to give examples such *Gmelina arborea*, *Eucalyptus spp* and *Pinus patula*. All the invasive species identified at both household and transect level were exotics which were said to have been introduced by the Forestry Department. Respondents also identified the Western part (43.3%) of the reserve as having a high concentration of the invasive species. Findings also portrayed non-significant differences (P=0.133) between respondents (53%) who felt attempts to get rid of the invasive species were not being done and other respondents (47%) who felt efforts were being made in attempt to remove the invasive species. The majority of the respondents that felt attempts were being made to remove invasive species indicated that the most (79%) common method of removing the invasive species was through cutting (Table 5). Non-Significant differences (P=1.000) were observed between respondents who indicated that currently measures were put in place to deal with invasive species and those who thought no measures were put in place. Of the respondents that said measures were being taken at present to remove invasive species, the majority (93%) were of the opinion that the Government of Malawi through the Forestry Department was leading in removing the invasive species in the MMFR (Table 6). Most respondents (66%) indicated that local and government leaders were most appropriate mediums to champion the act of dealing with invasive species in the reserve (Figure 9). This showed non-significant differences (P=0.221) on what respondents thought should lead the fight against invasive species. This disagrees with Ahimbisiwe, (2009) who pointed out that for the effective control of invasive species, management approaches needs to be perceived by local people as aiming for social economic or ecological integrity.

Table 5: Methods of removing invasive species

	Response	Methods of getting rid of the invasive species			
		Cutting	Digging	Burning	Total
Attempt to get rid of Invasive Species	Yes	11	1	2	14
	No	0	0	0	16
Total		11	1	2	30

Source: Researcher, (2014)

Table 6: Actors taking measures in removing invasive species

		Forestry Department	Concerned NGOs and Private Companies	Total
Measures currently in place to get rid of invasive species	Yes	14	1	15
	No	0	0	15
Total		14	1	30

Source: Researcher, 2014

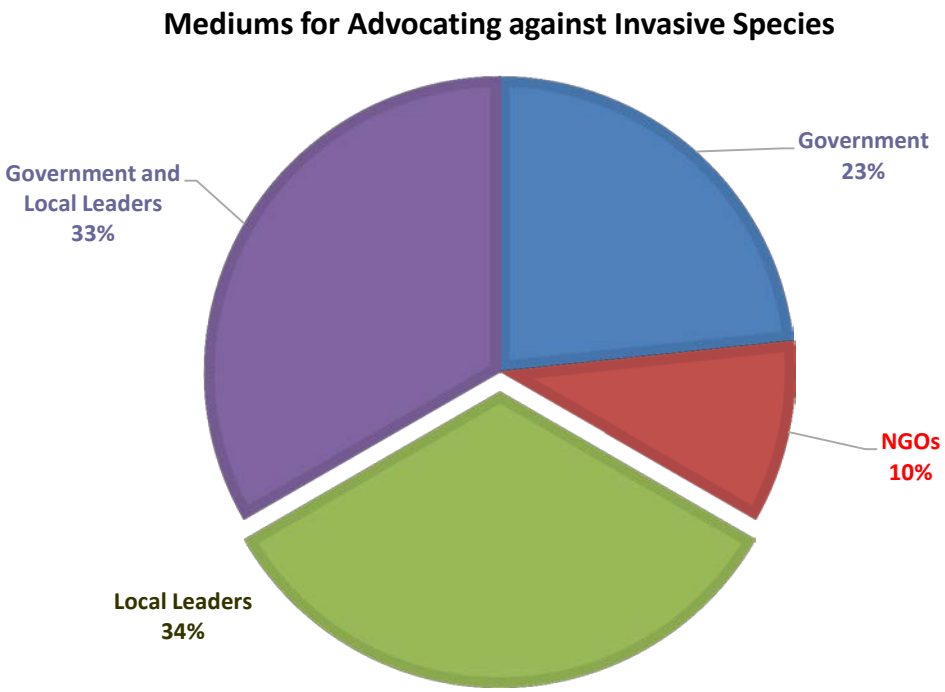

Figure 9: Ways of advocating against invasive species. (Researcher, 2014)

4.2 DISCUSSION

4.2.1 Spatial Distribution of Plant Invasive Species on the MMFR

The study found that the identified invasive species were of exotic origin and had a significant representation in terms of spatial distribution across transects. However, it was observed that the species distribution varied with the western transect having a higher proportion of the invasive species. This could be as a result of previous efforts to get rid of the invasive species on other sides of the MMFR. It is evident that more effort be concentrated to the side having higher distribution of the invasive species and lessons from methods used to remove the invasive species on the other parts of the MMFR be applied in the western side. The other two transects showed no presence of the woody invasive species except for blacken fern which covers almost the entire reserve and most respondents reported higher concentration of invasive species on the western side. This shows that the invasive species have a higher spatial distribution on the western part of the MMFR. Furthermore, it has been found that species utilisation, altitude and climate could be contributing to the variation in spatial distribution. This is in line with Nangoma et.al. (2008), who mentioned that invasive species spatial distribution is subject to altitude, soil, and species utilization. The spatial distribution extent of the two identified invasive species on the MMFR in this study is therefore moderate if we consider MMFR as a whole; however, it is becoming a serious problem looking at it with focus on the western side of the MMFR. As shown from the results as shown in (Table 2), there is a probability that the invasive species can with time reduce the diversity as they increase in abundance and take over more area.

4.2.2 Ecological impacts of invasive species on MMFR

Findings from both the field and household surveys indicate a high concentration of the invasive species on the western part of the MMFR (Table 2) which was explained to be due to the clearing of invasive species in the other parts of the reserve. The difference in abundance of species in the three transects (Figure 4) is due to management prescriptions that were carried in the reserve whereby *Pinus patula* species was clear felled and burnt off. Initially, Mulanje Cedar used to cover most of the MMFR but since the introduction of *Pinus patula*, the abundance of the cedar has significantly decreased. The Shannon index (Table 4) shows that the diversity of the species in the MMFR is high on the western and eastern sides which could be linked with

altitude and rock outcrops on the top/middle of the MMFR where species diversity was found to be low. Another reason for the low diversity on the middle and the eastern transect could be the presence of blacken Fern, a non woody invasive species which was observed during the transect walks. This species was observed to be more aggressive than the woody invasive species observed and covered almost the entire reserve.

The invasive species in the MMFR have therefore had significant impact in terms of reduction of useful species (33%) such as the Mulanje Cedar. Although other respondents (47%) indicated that they have experienced no impact from invasive species, this could be explained as rooting from the fact that they only focus on the beneficial effects and ignore the negative effects. The MMFR has experienced change in vegetation cover which may have varying reasons; however, invasive species have in a way contributed to the change in vegetation cover. Contrary to this, many respondents (63%) are of the opinion that the invasive species in the MMFR must not be removed. This is the case due to the economic value of the invasive species especially *Pinus patula* and therefore people would rather benefit from the invasive species and forego the negative ecological impacts that come with the invasive species.

The overall vegetation cover change resulting from invasive species is expected to impact negatively the population of natural plants in the MMFR since micro-climates are also bound to change. This has in effect also negatively affected the water catchment areas in the MMFR and therefore biodiversity in general. Mulanje Mountain boasts of high biodiversity which is threatened by these invasive species. It is very likely that the reduction in population of the Mulanje Cedar has an impact on the micro-climate in the MMFR considering that Mulanje Cedar is an endemic species of Mulanje Mountain. The replacement of Mulanje Cedar by *Pinus patula* has been so eminent and there are fears that if not controlled ecological processes will definitely be affected. The results give us enough evidence to reject the null hypothesis that invasive species do not have negative impact on the ecology of the Reserve and allow us to adopt the alternate hypothesis

4.2.3 Social Impact of Plant Invasive Species on MMFR

The invasive species were found mainly being used for timber, firewood and medicine. This shows that the invasive species have social significance in the livelihood of people as almost 64% indicated that they use the species for both domestic as well as commercial purposes. Domestically, they use the products of the species such as *Pinus patula* and *Rubus ellipticus* mainly for various purposes ranging from construction, cooking, medicine and other household activities and majority of these domestic users obtain these resources from the reserve implying that the reserve is really playing a significant role in the livelihoods of the people. This agrees with the publication by MMCT (2008) which says that The Mulanje Mountain Forest Reserve is of great ecological and economic importance to those who live in and around it, providing a source for freshwater, food, medicinal plants, building resources, recreation, and job opportunities.

Some members of the communities surrounding the mountain indicated that invasive species are playing a significant role in their lives as they benefit a lot from the sales that they make after selling the products of the species. One respondent has managed to open a carpentry shop where he uses *Pinus patula* among other species. Timber from the *Pinus patula* obtained from the mountain is sold and some of the processed timber is processed into wooden furniture such as doors, windows and door flames, chairs and other domestic items. These are also sold and the money used to buy other household items, feed the family, pay hospital bills as well as school fees for his siblings. Other people also sell products from the invasive species as firewood and medicine to other people who cannot afford to climb the mountain to fetch these products. The roots of *Rubus ellipticus* is used to cure various ailments including stomach pains. Therefore this is also assisting various people including herbalists as a source of medicine.

Another respondent confirmed that fruits of *Rubus ellipticus* are important to their lives as they provide food for the family in terms of fruits which are eaten raw or processed into a very sweet wine. Money raised from the wine sales is used to feed the family on daily basis. This agrees with Katerere & Chenje (2003), which states that invasive species play an important role in livelihood an economic opportunities through the supply of ecological goods and services

Apart from these invasive species, communities from the five neighbouring Villages with the reserve interviewed also mentioned other species that they benefit from the reserve such as *Widdringtonia whytei, Heteromorphy spp, Faidherbia albida, Flacourtia indica, Terminalia* spp among others which they use for various purposes ranging from medicinal, water conservation, cultural and domestic purposes among others. The results of the baseline survey shows a reduction of these species as most of these species were not captured in the survey. For instance, nearly all the respondents in the five villages surveyed mentioned Mulanje Cedar as one of the species that they benefit from the reserve. Both the communities and the Forestry Department indicated that Mulanje cedar used to cover the entire mountain and the people were sorely depending on it as their source of timber as it produces good quality timber which lasts longer as it never rots. The results of the PCQM also indicate that there are other useful plant species in the reserve such *as Nuxia oppositifolia, Ilex matis Aeschonomen megalophylla*. that are used for firewood, poles and forage respectively. These species are also endangered by the invasive species thereby having some potential impact on the people surrounding the Reserve

Department of Forestry introduced Pinus Patula as the nursery seedling for Mulanje Cedar which was under serious threat to deforestation. Despite this effort by the forestry department, Mulanje cedar significantly reduced in its population which poses a significant impact on the ecology as well as the communities in close proximity of the reserve as the species grows naturally and takes years to mature.

Other useful species which was not captured in the ecological survey is Rivera which is also running towards extinction. Communities raised concern that the species used to be found in the reserve but now they have to walk long distances or even days in search of the species. The species is mainly used for initiation ceremonies especially that of girls when they have come of age.

During the interview, other people raised concern that during the past, one could go to the mountain for hunting with the hope that you will come back with something but now this is a story of the past as most of the animals have become extinct possibly due to the change of habitat as supported by Charles & Dukes, (2001) who mentioned that invasive species can alter the

physical habitat. He further pointed out that invaders are capable of outcompeting natives and taking over habitat and certain invaders additionally make the habitat less suitable for other species of both plants and animals. Such being the case, most of the trees that used to be in the reserve providing thick forest and attract some animals as the hiding place are no longer there hence affecting peoples livelihoods. Thus, changes in species community structure have affected ecosystem services directly and indirectly. Direct effects include decline in the abundance of economically valuable species in particular those used for fuel wood, food as well as medicine.

MMFR is well known for its unique sites which are used for cultural and spiritual purposes. These sites were regarded as sacred and People used to go to such places to perform some rituals such that nobody could just go to such places unless for ceremonies. Respondents also raised concern that these places are no longer feared because most of the species that used to cover these sites are no longer there, the places are just in open places and these have somehow affected their ancestors. During ceremonies or in times of hardships of rainfall scarcity, people used to come to such places to appease their ancestors and play against the evil spirits. Some of the places include the Sapitwa peak and the Dziwe la Nkhalamba. These places have now become the tourism sites as people travel from various places both nationally as well as internationally to visit the places which are well known for their mysterious acts, although this is helping the tourism industry in boosting the economy of the country, it has also affected the social cultural aspect of the nation.

On the other perspective, invasive species have led to conflicts between the concerned and the affected parties as others wants them removed due to their negative aspects while others want them to remain because they are benefiting from them. Based on these facts, the hypothesis that invasive species do not have the negative social impact on the surrounding communities of the forest Reserve is rejected since it has the results of the study has shown that there are significant impacts of the woody Plant invasive species on the people surrounding the Reserve

4.2.4 Management of invasive species on MMFR

Management of invasive species is an important aspect in ensuring that the negative impacts of invasive species are reduced and the positive ones enhanced. This requires a multi-sectoral

approach involving various stakeholders. Respondents in this study indicated that they were aware of what invasive species are which provides a good background in management approaches in dealing with the invasive species. In any management strategies involving invasive species, it is vital that bottom-up approaches be used to ensure success. The fact that people in the study area know invasive species is very beneficial in managing the species in the MMFR, a resource which greatly contributes to their livelihoods. The study also found that currently there is no strong evidence of efforts being done to remove the invasive species in the MMFR. This in effect implies that little is being done to address the issue of invasive species in the MMFR according to the respondents. The study also identified cutting as the main method of getting rid of the invasive species. Although the ecology of the invasive species identified in the area was not analysed in this study, it should be noted that cutting alone may not be an effective way of removing the invasive species. According to Jeffrey Juwawo[1], *Pinus patula* has previously been removed in some parts of the MMFR through cutting method by the Forestry Department with some success reported (personal communication, March, 2014). This agrees with the findings of this study which has found that removal of invasive species on the MMFR has been done and the majority of respondents identified the Forestry Department (Table 4) as the main lead in the removal of invasive species in the MMFR. As discussed earlier, dealing with invasive species requires a synergy from different stakeholders and apparently this is not the case regarding the invasive species in the MMFR. Much as other organizations such as the Mulanje Mountain Conservation Trust (MMCT) are working hand in hand with the Forestry Department, there seems to be inadequate collaboration between the Forestry Department and other actors with interest in the MMFR including the communities around the MMFR. Despite this, many respondents would still like to see the Forestry Department and local leaders (Figure 9) take the lead role in championing action against invasive species. This is a finding that probably may not have been considered by the Forestry Department since current efforts to remove the invasive species have barely involved the local communities and this is likely to affect the effectiveness of these current efforts. It is imperative that Non-Governmental Organisation and local communities be actively involved in any approach being implemented in managing invasive species if desired outcomes are to be achieved. Current policy on management of invasive species in Malawi is very porous and most environmental policies barely mention management

[1] Jeffrey Juwawo, Forestry Technician, Mulanje District Forestry Office, Mulanje, Malawi.

of invasive species. This development is likely to affect effectiveness of actions being carried against invasive species in the MMFR. There seems to be a gap on awareness amongst communities around the MMFR on the negative impacts of invasive species on the livelihoods and ecosystems in and around the MMFR. The MMCT has over the past years attempt to raise awareness on invasive species but the emphasis has been on deforestation and environmental management (Ashry, 2001). With structures already in place, the best option to raise the awareness amongst the communities would be the collaboration between MMCT and the Forestry Department. It is vital that advocacy be done from grassroots level complemented by research and development in order to develop and/or revise policies that will carter for invasive species management. The lack of proper awareness campaigns has had a detrimental effect where politics have come into play regarding removal of invasive species. Some politicians support the removal while others are against the removal therefore bringing conflicts amongst different actors. The high cost associated with removal of invasive species has significant impact on the success of invasive species removal programs. Though well-coordinated strategies it could be possible for all stakeholders to save costs and relocate the saved money to other development projects.

When asked about the conservation plans, Jeffrey Juwawo[1] explained that Plans are underway to remove invasive species that have occupied the mountain terrestrial ecosystem. It was further explained that one noted species is *Pinus patula* and Bluegum *Eucalyptus* which occupy 3,000 hectares of the mountain. The mountain top has 800 hectares of invasive species and MMCT intends to remove these plants which are not indigenous to the area. The alien species are posing a threat to species like the cedar and other plant and animal species, hence the need to remove them.

MMCT intends to raise hundreds of thousands of seedlings of indigenous species to replace the invasive species that have occupied the mountain. Therefore, we fail to reject the null hypothesis that Current methods used in mitigating the impacts of invasive species in Mulanje Mountain Forest Reserve are not effective.

CHAPTER FIVE

SUMMARY OF RESEARCH FINDINGS, CONCLUSIONS AND RECCOMMENDATIONS

The study was carried out on Mulanje mountain forest Reserve with the main aim of investigating the ecological and social impact of plant invasive species on Mulanje Mountain Forest Reserve (MMFR) in order to ascertain means of addressing the possible effects on the communities in close proximity of the reserve and on the ecology of the reserve. This Chapter therefore provides the summary of major research findings, Recommendations and ends with the conclusion of the study

5.1 SUMMARY OF FINDINGS

Spatial distribution of woody species varied across the three transects. A total of 27 woody species were observed during the study of which two were both exotic and invasive in nature. The top five abundant species across all transects were *Hypericum revolutum, Kotschya Africana, Protea nyasae, Pinus patula,* and *Heteomorpha trifoliate* of which *Pinus patula* was identified as the invasive species. Another woody invasive species which was identified during the transect walk was *Rubus ellipticus* and both of the identified invasive species were dominant on the western transect.

The diversity of woody species was more evident on the western side of the MMFR based on the Shannon index. Main ecological effects of woody invasive were found to be loss of land, loss of timber and increased fire intensity which eventually alters plant and animal habitats.

Results have shown that invasive species have positive and negative significant impact on the social livelihoods of the people living in close vicinity of MMFR. Overall, the negative effect reported was the reduction in the supply of the ecological goods and services. It was also found that communities obtain numerous benefits from the woody species from the MMFR. The main uses identified were wild fruits, firewood, fodder, timber, and medicinal use. Majority of respondents were found to obtain woody species from the MMFR citing the vital link between

the reserve and the people. The study also found that most respondents were not in support of removing the woody invasive species.

The study found evidence that communities in the study area were knowledgeable of woody invasive species. Furthermore, it was found that attempts to remove woody invasive species were in existence. Findings of the study reveal the current common method identified for getting rid of the woody invasive species was through cutting. It is therefore evident that that the current method used in eradication of invasive species is not effective since cutting only reduce the abundance but does not completely remove the species. Local and government leaders were identified as the best possible medium of dealing with woody invasive species.

5.2 CONCLUSIONS

This study has proved the availability of invasive species on Mulanje Mountain Forest Reserve (MMFR) and has shown to have the greatest representation on the western side of the reserve especially the chamber area. For this reason management decisions should be made with priority given to the western side of the reserve to reduce and control the spread of the invasive species to other sides of the reserve.

Invasive species on the reserve have damaged a number of natural ecosystems on MMFR and caused considerable loss of biological diversity. They are particularly damaging during forest regeneration but can also negatively affect mature forests. The invasive species reduce regeneration through competition. It is noted that presence of invasive species in MMFR is preventing regeneration of native tree species that are endemic to the Reserve e.g. Mulanje Cedar. Other impacts include altering habitat of wild animals, and disturbing the water flow.

Invasive species have proved to have both positive and negative impact on the livelihood of the surrounding communities of the Reserve as communities benefit from the invasive species through the provision of the ecological goods and services. On the other hand, invasive species have also affected the ecosystem by reducing the population of useful species

Management of invasive species is not effective as the main method identified was the cutting method and burning. Cutting only reduces the abundance of the invasive species and eventually

regenerates while burning also lead to the destruction of other useful plants as it has shown that fire damages habitat of both plants and animals.

5.3 RECOMMENDATIONS

Local communities should be involved in the management of forest resources in their vicinity so as to improve the efficiency and sustainability of forest management. Engaging locals to monitor instead of regular national staff, together with increased tangible benefits to the local communities will greatly improve the management of woody invasive species.

Eradication of invasive species would come at a cost as various groups of stakeholders would lose all the many benefits they obtain from them such as fuel wood, timber and medicine. Therefore, reforestation programme should be implemented by planting trees with the same values of the invasive species to replace them so as not to lose the benefits

The value of a vibrant forest should be recognized and actively managing the spread of Plantation trees; using non-invasive species wherever possible, or ensuring that bio control is introduced at the start of new Reforestation and afforestation programme to reduce the invasive potential of otherwise useful species without killing them. Introducing bio control at the same time as new plantation or woodlot species, would also be a way of reducing the risk of unwanted invasions

Furthermore, research into possible tree species that can provide the same benefits as the *Pinus patula* and *Rubus ellipticus* should be carried out to avail replacement trees that are not invasive so as to mitigate the resistance to invasive species eradication that might stem from those that benefit from its existence.

There is a need to give the problem of invasive species the special recognition and attention that it deserves considering the adverse effects on peoples socioeconomic livelihoods, the environment, biodiversity and the national economy as a whole. Invasive species need to be mainstreamed into national policies and laws such as the forest act, National forestry policy as well as the environmental protection act.

There is need for continuous sensitization on the dangers and magnitude of the problem posed by invasive species on the socioeconomic livelihoods of stakeholders, the environment and biodiversity.

The forest sector can form a partnership with various stakeholders with a clearly stated intention of developing a relationship, based on collaboration, integrity, and a shared vision to enhance: the control of invading alien species; the utilization of local communities for cheap labour and support in such activities; the sustainable management of the country's natural resources; and the best management practices.

There is need for establishment and coordination of technical support from affected agencies for purposes of planning for both short and long term management programmes. During this phase; appropriate, regulatory and management action plans to be taken against invasive species can be made.

5.3.1 Further research areas

During the transect walk, it was observed that there was another non woody invasive species (Blacken Fern) which seem to more aggressive than the identified woody ones and covered almost the entire reserve. There is dare need for more research on determining the real magnitude of environmental and economic losses and benefits caused by invasive species and the possible implications on the ecosystems that they inhabit as well as on the national economy. This is necessary as an initial step towards formulation of possible control strategies that are affordable by the affected stakeholders. It is vital that research on non-woody invasive species be conducted on the MMFR since there were several non-woody species with invasive characteristics that were observed during this study. An investigation on these potential non-woody species would complement the findings of this study and contribute to proper management of plant invasive species on the MMFR in order to minimise the negative effects and enhance the positive effects of the plant invasive species on the ecology of the MMFR and the communities in its vicinity.

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APPENDICES

Appendix 1

UNIVERSITY OF NAIROBI

ENVIRONMENTAL IMPACT ASSESSMENT OF PLANT INVASIVE SPECIES ON MULANJE MOUNTAIN FOREST RESERVE (MMFR) IN SOUTHERN MALAWI

My name is Laura Makhambera, a post-graduate student at the University of Nairobi. I am conducting a research project to assess environmental impacts of plant invasive species on Mulanje Mountain Forest Reserve (MMFR) in Southern Malawi. To meet the objectives of the study several techniques are being used including conducting discussions with local households. Please assist by completing this questionnaire. The information obtained will be used sorely for the purposes of this study and shall be confidential. Thank you.

HOUSEHOLD QUESTIONNAIRE

Name of Village _____ Date_____

Household number _____ GPS Location _____

Name of enumerator_____ Distance from MMFR _____

SECTION A: General characteristics of the respondents

1. Gender of respondents

(a) Male (b) Female

2. Marital status of respondents

(a) Single (b) Married (c) Widowed (d) Divorced

3. Occupation of respondents

(a) Farmer (b) Civil Servant (c) Self-Employed (d) Business (e) Piece Work (f) Others (**specify)**

_____

4. Age class of respondents

(a) 10-20 (b) 21-30 (c) 31-40 (d) 41-50 (e) 51-60 (f) 60 and above

5. Level of education of respondents

(a) Primary (b) Secondary (c) Tertiary (d) None

SECTION B: Impacts of Invasive Species

6. How long have you lived in this area? (Number of years)

(a) 1-5 (b) 6-10 (c) 11-15 (d) 16-20 (e) 21-25 (f) 25-30 (g) >30

7. Do you know what an invasive species is? Yes ( ) No ( )

8. List down invasive species which you use (in the order from mostly to less used)

i _____ iv_____

ii _____ v _____

iii_____ vi_____

9. Where did the species originate from?

(a) Introduced as timber species by forestry department

(b) Introduced as agroforestry species by forestry department or NGO

(c) No idea

10. In which part of the MMFR do you think the above mentioned species are highly concentrated?

(a) Eastern (b) Western (c) Southern (d) Northern (e) Other_____

11. Which part of the species mentioned in **question 8** above is used?

(a) Fruit (b) Wood (c) Whole plant

12. What are they used for?

(a) Domestic (b) Commercial

13. Who uses the species?

(a) Males (b) Females (C) Both

14. In what ways are the invasive species good for the people in this village?

(a) Provide medicine (b) Provide building materials (c) Provide firewood

(d) Attract birds or wild animals (e) Not important

15. Where do you get the products of these species?

(a) Collect from the MMFR (b) Buy (c) Both

16. In what way is the invasive species bad for people in this community?

(a) Reduce agriculture yields (b) Reduce grazing land (c) Damage infrastructures

(d) Compete with medicinal trees (e) Compete with firewood trees

(f) Reduce animal population (g) Reduce tourism

(h) Others (**specify**)

_____

17. A. Are there any other trees you benefit from the reserve? Yes ( ) No ( )

B. If yes, mention the species and how you benefit from them

_____
_____
_____
_____

18. A. Have the trees mentioned in **question 17** been affected by invasive species?

B. If yes, explain how.

_____
_____
_____
_____

19. How do invasive species affect supply of other ecological goods and services?

(a) Water provision (b) loss of useful land (c) loss of grazing land (d) loss of animals

(e) Loss of timber (g) others (**specify**)

_____

20. What are your perceptions about these invasive species?

_____
_____

_____
_____

22. A. Do you use the species for any ritual/cultural purpose? Yes ( ) No ( )

3 B. If yes, what?

_____
_____
_____

23. A. Does the species grow in areas of special cultural significance Yes ( ) No ( )

B. If yes, where?

_____

24. A. Have the trees caused people to change their work or move away Yes ( ) No ( )

B. If yes how?

_____

(a) People plant different crops
……

(b) People have stopped
planting…….……..

(c) People have stopped raising
animals……

(d) People have left the
village…….....

(e) Others
(**specify**)……

24. A. Do you or people in this area do anything to get rid of these trees Yes ( ) No ( )

B. If yes how? (a) Cutting (b) Digging (c) Burning (d) Apply herbicides

25. A. Are there any measures currently in place to deal with invasive species

Yes ( ) No ( )

B. If yes,

(a) What is being done?

_____

(b) What is your reaction towards this?

26. Who do you think should champion the control of the troublesome invasive species?

(a) Government (b) NGOs (c) Local Leaders (d) Other_____

27. Any comments

_____
_____
_____
_____

Thank You.

Appendix 2

UNIVERSITY OF NAIROBI

ENVIRONMENTAL IMPACT ASSESSMENT OF PLANT INVASIVE SPECIES ON MULANJE MOUNTAIN FOREST RESERVE (MMFR) IN SOUTHERN MALAWI

My name is Laura Makhambera, a post-graduate student at the University of Nairobi. I am conducting a research project to assess environmental impacts of plant invasive species on Mulanje Mountain Forest Reserve (MMFR) in Southern Malawi. To meet the objectives of the study several techniques are being used including conducting discussions with local households. Please assist by completing this questionnaire. The information obtained will be used sorely for the purposes of this study and shall be confidential. Thank you.

KEY INFORMANTS QUESTIONNAIRE

Name of Respondent _____ Date _____

Department/section/unit _____

Name of enumerator _____

1. What is the origin of these invasive species and what is the cause of their infestations?

_____

_____

_____

2. How long have the invasive species been here?

_____

_____

_____

_____

3. A. Has the abundance changed over the last 5-10 years?

B. If yes, how?

(a) Increased (b) Decreased (c) Both

C. What do you think is the reason for the change?

_____

_____

_____

_____

4. A. Are there areas in the landscape where species invasion is the most common?

Yes ( ) No ( )

B. If yes, where does it like to grow?

_____

_____

_____

5. A. Are there areas in landscapes where you don't want the species to grow? Yes ( ) No ( )

B. If yes, where and why?

_____

_____

6. A. Do invasive species cause problems to the people surrounding the reserve? Yes ( ) No ( )

B. If yes, what are the problems?

_____

_____

_____

_____

7. A. Are there any ecological impacts of the invasive species? Yes ( ) No ( )

B. If yes, what are examples of these ecological impacts?

(a) Change in physical habitats: (loss of native habitats)

(b) Hydrological impact: (alteration of ground water regime)

(Alteration of surface water flow

(Drying of rivers)

(c) Biological community: (loss of native species)

(Alteration of species biomass)

(d) Species population impacts: (loss/ decrease of native species through competition for food shelter, habitat etc.

(e) Harbors pathogens which lead to loss of native species

(f) Decrease in growth rate of native species

Others (**please specify**)

_____

8. A. Do rural communities invest time in managing the invasive species? Yes ( ) No ( )

B. If yes, how?

_____

_____

_____

_____

9. Which legislation has been introduced to support eradication of invasive species?

_____

_____

10. What are the communities' reactions towards this?

_____

_____

_____

11. What is currently done to eradicate the invasive species?

_____

_____

_____

12. What do you think should be done to reduce the impact of invasive species on the reserve?

_____

_____

_____

Thank You.

Appendix 3

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ENVIRONMENTAL IMPACT ASSESSMENT OF PLANT INVASIVE SPECIES ON MULANJE MOUNTAIN FOREST RESERVE (MMFR) IN SOUTHERN MALAWI

Field DataSheet

General Site Information	
Location (GPS)	
Elevation	

Sampling Details			**Distance Interval (m)**	**Species Name or Code**	**Tree/Shrub**	**Indigenous/Exotic**	**Total Number of woody within 10m radius**	**Species Uses**
Transect	**Site**	**Quarter**						