THE EFFECT OF INTRODUCED TREE SPECIES ON THE SOILS OF NAMWASA CENTRAL FOREST RESERVE, MUBENDE-UGANDA

A THESIS

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MASTER OF SCIENCE IN ENVIRONMENT MANAGEMENT AND

DEVELOPMENT

BY:

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DECLARATION A

"This Thesis is my original work and has not been presented for a degree or any other academic award in any University or Institution of learning".

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5th/09/2011

Date

DECLARATION B

"I/We confirm that the work reported in this thesis was carried out by the candidate under my/our supervision".

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APPROVAL SHEET

This Thesis entitled "The effect of introduced tree species on the soils of Namwasa Central forest reserve". was prepared and submitted by Munubi Abdallah in partial fulfillment of the requirements for award of the degree of Master of science in Environment management and development has been examined and approved by the panel on oral examination with a grade of PASSED

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DEDICATION

This Thesis is dedicated to Rev. Fr Peter Gerald Picavet and my mother Mrs. Nakato Monic.

ACKNOWLEDGMENTS

I am greatly indebted to Rev Fr Peter Gerald Picavet for the parental, financial, moral, spiritual and logistical support throughout my education. Thanks go to Mr. Henk Gjansens, Wim mol, Mrs. Rinty Pulkkel, Frances David, Hetty Vandarlaar, Suzan and David Bugler for their logistical support.

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ABSTRACT

Humans move tree species beyond their native ranges both deliberately and unknowingly. In areas around Namwasa central forest reserve, most of the trees have been cleared by charcoal burners and cultivators who are residents of the area. The study assessed the diversity and abundance of introduced tree species, assessed the effects of introduced tree species on some selected soil properties and evaluated how significant these trees are economically and ecologically.

Floristic information on the tree species was obtained by transects made from five compartments of the forest reserve. Eight small sample plots of dimensions 30m by 15m were made on each transect line separated by a distance of 100m using tape measures and marked with flagging tapes. Four introduced tree species namely Pinus caribaea, Pinus oocarpa, Eucalyptus grandis and Eucalyptus Urophylla and twenty two native tree species were identified.

Random core soil samples (8cm diameter x 15cm height) were collected around the selected tree species in sample plots using a trowel and put in Ziploc bags and later transported to the Uganda government analytical laboratory for analysis. Soil samples were collected from both introduced tree species and the natural forest for comparison. Samples were analyzed for soil parameters such as texture, structure, pH, Mg, Pb, Cl, electrical conductivity, bulk density, No_3, Ca, Mn, Cu, So_4, Po_4, Fe, NH_3, Na, K, Ni, Zn, and organic matter.

Shannon Weiner index (H') was -1.514, species richness (S) was 24 and species evenness (EH) was 0.477. ANOVA results indicated that introduced tree species significantly affect the selected soil properties. The coefficient results indicate that three introduced tree species have a significant effect on the selected soil properties. Correlation results indicated that ph is negatively correlated all other soil properties ($r<0$).

There is need to establish a monitoring and sensitization team to educate residents of Namwasa Central forest reserve to stop setting fires and charcoal burning in the forest

reserve since they destroy plantations. The planting of introduced tree species such as Eucalyptus which are tolerant to severe periodic moisture stress, low soil fertility is here by encouraged.

CHAPTER ONE
INTRODUCTION

Background of the study

Humans move species beyond their native ranges both deliberately and unknowingly, and many of these species become established and spread in new habitats (Caraco et al., 1997).

Large areas of deforested and degraded land exist in the humid tropics .In the decade of the 1990s; approximately 0.38% per year of the world's forests were converted to other land uses. The annual rate is much higher in many developing countries where some 200 million ha of forest are estimated to have been lost in the period 1980–1995 (FAO, 1997). Common soil Quality problems in the deforested tropics include aluminum toxicity, low pH and phosphorous fixation (Fisher, 1995). Many such areas are difficult to reforest even with current methods of intervention. In the humid tropics, either "exotic"or native tree species may perform better. Among the commonly planted exotics are various tropical pines, *Eucalyptus spp.*, *Tectona grandis*, *Gmelina arborea* and some *Acacia species*. Annandale and Keenan (1999) studied a range of species in tropical northern Queensland, Australia. They tested *Eucalyptus pellita, E.grandis*, *E. tereticornis*, *E. grandis, Acacia mangium* and several provenances of *Cedrela odorata,* as well as *Pinus caribea var. hondurensis*.

Interest in establishing plantations of native species has grown in recent years (Gonzalez and Fisher, 1994). Although some native species (for example members of Meliaceae) may be less broadly adapted and more susceptible to native pests, others may be well suited to particular conditions such as low levels of soil nutrients characteristic of degraded land (Nichols et al., 1997).

Although it is well known that plant species can have differing effects on carbon (C) and nitrogen (N) cycling through litter chemistry (Hobbie, 1992), the influence of plant species on soil C and N pools and their dynamics is less understood. Although litter decomposition processes can be studied relatively easily over short time scales using litter isolated from plants, studying plant species influences on soil processes requires research on monospecific stands on the timescales of Soil Organic Matter (SOM) turnover which can be decades to millennia (Trumbore, 2000). SOM is mostly derived from plant inputs that have undergone processing by micro-organisms in the presence of potential reactions with soil minerals (Stevenson,1994) Thus, whether plant species should have a discernable signature on SOM is unclear. Nevertheless, understanding how species influence soil organic matter dynamics is important in predicting how soil C sequestration and fertility will respond to management as well as global environmental changes that alter plant species composition across landscapes (Eviner and Chapin, 2003).

Statement of the problem

In Sub Saharan Africa, per capita food production has been declining over the past decades (FAOSTAT, 2005). Projections indicate that by 2020, Africa will have to import more than 60 million metric tones of cereal yearly so as to meet the population demand (Henao and Baanante, 2006). Soil fertility decline is increasingly regarded as a major constraint to food production, especially in tropical environments (Smaling *et al.*, 1997). Biophysical factors such as low inherent soil fertility (Bekunda *et al.*, 1997) and inability to use external nutrients efficiently have been cited as key causes of low crop yields.
In Mubende district, most of the trees have been cleared by charcoal burners and cultivators who are residents in the area (NEMA, 2008). In Namwasa Central forest reserve, Neighbors have private land on which their houses are built, but are attracted by the fertility of the forest soils. They grow all types of crops such as maize, beans, groundnuts and bananas.

The soil on hilltops and hill flanks of Bwacapira are predominantly dark-grey, sometimes black, with a depth of 10 – 30cm, very fertile and productive (NEMA, 2008). The subsoils are brown and occasionally red-brown. This suggests that the effective rooting depth is much more than 50cm. Until recently, the human population density of Mubende District and Namwasa in particular remained low and the soils were able to rest for many decades, thus naturally retaining their fertility. Massive plantations of exotic tree species were, and are still, being established hence prompting my interest to conduct a study in Namwasa Central forest reserve so as to document the effects of introduced tree species on the soils.

Objectives

General objective

The general objective of this study was to evaluate the effect of introduced tree species on the soils of Namwasa central forest reserve in Mubende district in central Uganda.

Specific objectives

The specific objectives of the study were;

(i) To evaluate the ecological and economic benefits of introduced tree species

(ii) To determine the distribution, abundance and diversity of introduced tree species

(iii) To assess the effect of the introduced tree species on some selected soil properties

Research questions

This study was guided by the following research questions:

(i) What are the ecological and economic benefits of introduced trees species in Namwasa central Forest reserve?

(ii) What are the distribution, abundance and diversity of introduced tree species in Namwasa central forest reserve?

(iii) What are the effects of introduced tree species on some selected soil properties?

Scope of the study

The study was conducted in Namwasa Central forest reserve, Mubende district, particularly in the sub-counties of Bukuya and Kassanda in Kassanda County.

The forest reserve occupies a series of hills in the Central part of Mubende District locally known as "Singo Hills". Some of these hills such as Mporogoma, (1441m), Buliro, (1386m), Kigude (1408m) and Bwacapira, (1356m) mark the highest altitude in the surrounding area.

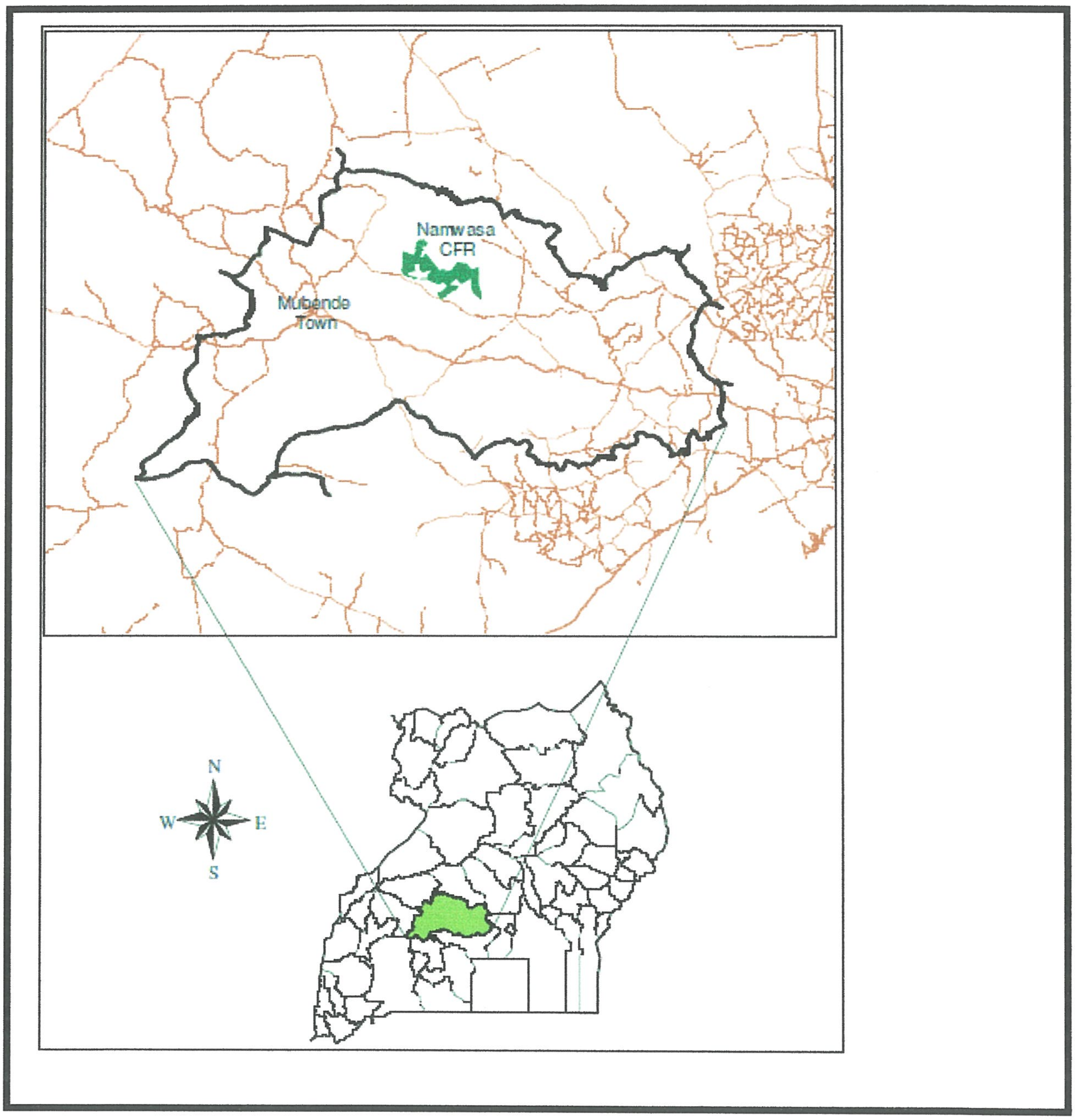


Figure 1: Map of Uganda showing the location of Namwasa CFR in Mubende District

Significance of the study

The study provided and documented baseline information on the distribution, abundance and types of trees in Namwasa central forest reserve and how these affect soils. The results will be useful in formulating and designing the best use and inventory management of forest resources in Namwasa CFR, and in particular provide interventions to promote conservation of forests in general. Hence, this study could serve as a foundation for effective monitoring and management of forest resources.

Operational Definitions of Key Terms

Introduced tree species - An introduced, alien, exotic, non-indigenous, or non-native species, is a species living outside its native distributional range, which arrived there by human activity, either deliberate or accidental (Meyerson *et al.,* 2000). According to Windham and Lathrop (1999), some introduced species are damaging to the ecosystem they are introduced into, others negatively affect agriculture and other human uses of natural resources or impact on the health of animals and humans; and that introduced species and their effects on natural environments is a controversial subject and one that has gained much scrutiny by scientists, governments, farmers and others.

Tree - A tree can be defined as a large, perennial, woody plant with secondary branches supported by a primary stem. There is no set definition regarding minimum size, though most authors cite a tree species as being one which regularly reaches 6 m tall (Vitousek, 1990).

Tree basal area – This refers to the cross-sectional area of a tree trunk measured at breast height over the bark. It can be thought of as the surface area of a cut stump at a height of 1.3 m.

Canopy cover – is a measure of the percentage of ground covered by a vertical projection of tree crowns.

A species is defined as a group of organisms which are able to interbreed freely amongst themselves under natural conditions to produce viable offsprings.

Species evenness is the relative abundance or proportion of individuals of a species among the species.

Species abundance – refers to a variety of species living within a geographical area.

Species richness (s) refers to the number of species present in an ecosystem.

Soil is the top layer of the Earth's crust containing unconsolidated rock and mineral particles mixed with organic material.

Soil pH is a measure of the soil acidity or alkalinity. An acid solution has a pH value of less than 5.

Soil texture is a measure of the proportion of mineral particles of different sizes that are found in the same sample of soil (sand, clay, and silt).

CHAPTER TWO

LITERATURE REVIEW

Ecological effects of introduced tree species

The ever-increasing population in sub-Saharan Africa has caused numerous development strains and put pressure on forest resources. For instance, in Uganda, the population grew at an average annual rate of 3.4% between 1991 and 2002 (UBOS, 2001). This has been accompanied by increased standards of living. Human activities have touched every region of the world, often leading to the introduction of allientree species. Ecologists now view biological invasions as a global phenomenon that can threaten the structure and function of ecosystems (D'Antonio and Dudley 1995). After habitat conversion, biological invasions are the second leading cause of biological diversity loss (Crooks and Soule, 1999). In many cases, when pollution or other anthropogenic disturbances cease, ecosystems can recover. However, biological invasions differ from other forms of perturbation because when the introductions stop, invasive species often do not disappear, but may continue to spread or create legacy effects that persist even after species eradication (Meyerson and Griscom, 1999).

Soil parameters such as pH are important in influencing species abundance and distribution in western Uganda forests. Climatic factors such as rainfall and soil parameters (e.g. pH, N and P) are important in influencing the diversity and distribution of plant species. However, human induced disturbances and land-use histories (Foster, 1992) are as important as other biophysical variables in influencing tree species distribution.

Plant species have the potential to influence soil C pools and their dynamics through variation in C inputs (that is, net primary production) and by influencing C losses, including SOM decomposition. Among tree species, O-horizon pool sizes are largely controlled by the difference between inputs via litterfall and outputs via litter decomposition (Olson, 1963) and thus should exhibit marked differences among species that vary in those attributes (Binkley and Giardina, 1998). The influence of species on mineral horizon SOM dynamics is more complex. Plant species can potentially influence three general mechanisms of SOM stabilization (that is, decomposition): biochemical recalcitrance, chemical stabilization and physical protection. Species may influence biochemical recalcitrance via the chemistry of organic matter inputs. For example, organic inputs via root turnover and exudation influence labile soil C pool sizes (Neff and Asner, 2001) and current theories of SOM formation suggest the potential for plant species effects on stabilization of soil C into more recalcitrant pools (that is, humus), as well. It has long been thought that plant lignin is an important source of polyphenols that ultimately form quinones that in turn react with amino-compounds to form humus. Therefore, variation among plant species in detritus lignin concentrations influences the availability of N-compounds. This could affect the formation of more stable humus with species having higher lignin concentrations or those species that stimulate N mineralization promoting the formation of more stable SOM. However, soil microbes also produce polyphenols (Kogel-Knabner, 2002). The importance of plant- versus microbe-derived polyphenols in forming reactive quinones is unknown. In addition, plant species could indirectly influence humus formation through their influence on the composition of the microbial community, even if plants themselves are not an important source of polyphenols.

Plants species could also influence the chemical stabilization of organic matter at mineral surfaces. Because SOM constituents differ in their affinity for mineral surfaces, species-induced variation in the contribution of organic acids, proteins and polysaccharides to the SOM pool is expected to influence sorptive interactions at mineral surfaces (Chorover and Amistadi, 2001). Furthermore, because plant species cause divergence in the concentrations of cations in soils (Reich et al., 2005), they could influence polyvalent cation "bridging" of negatively charged SOM to negatively charged clay particles, thereby reducing its accessibility to decomposers (Mulder et al., 2001). Polyvalent cations can also complex directly with SOM molecules, inducing their coagulation, thereby reducing their solubility (Oste et al., 2002). Thus, plant species could potentially cause differences in the degree to which SOM is chemically stabilized via their influence on cation chemistry.

Finally, plant species could differ in their influence over the physical protection of ;OM into aggregates. For example, Jastrow et al (1998) demonstrated that fine roots ınd mycorrhizal hyphal length (characteristics that vary among plant species) are mportant in promoting aggregate formation. Earthworms have also been shown to nfluence soil aggregate formation (Bossuyt et al., 2005) and their abundance and :omposition can also be influenced by plant species composition (Reich et al.,2005), ndicating a potential indirect route for such effects.

Common introduced tree species

A number of exotic plants species have been introduced around the world. Amongst the woody plant species are Pinea (*Pinus Caribea),* Grivellia (*Grivellia robusta),* Musizi (*Maesopsis eminii),* Cyprus (*Cupressus lusitanica),* Eucalyptus *(Eucalyptus grandis),* Albizia (*Albizia ferruginea),* Prickly Acacia (*Acacia nilotica*), Rubbervine (*Cryptostegia grandiflora*) and Prickly Pear (*Opuntia spp*.). A range of herbaceous species have also been introduced either deliberately or accidentally, including Rhodes grass and other *Chloris* species, Buffel grass (*Cenchrus ciliaris),* Giant rat's tail grass *(Sporobolus pyramidalis*), Parthenium (*Parthenium hysteropherus*) and Stylos (*Stylosanthes spp.*) and other legumes. These introduced tree species have the potential to significantly alter the structure and composition of savannas worldwide and have already done so in many areas through a number of processes, including altering the fire regime, increasing grazing pressure, competing with native vegetation and occupying previously vacant ecological niches.

Importance of exotic or introduced tree species

Plantations have some advantages over natural forests from the management and economic points of view to ecological advantages such as concentrated production. There has been increasing recognition of the importance of obtaining species adapted to a particular area. After successive elimination, provenance, growth and yield trials, some promising species such as *Eucalyptus camaldulensis* and *Acacia auriculiformis* have been recommended for large scale afforestation/reforestation programs (Hossain et a.l, 1996). But recently, there has been a campaign against the cultivation of Eucalyptus and Acacia in plantation programs based on some media reports that these species have a damaging impact on soil ecosystems

Successful plantation technologies have been developed in many countries (Kanowski and Savill, 1992). Light demanding, colonizing exotic species have been the most successful in monocultures under plantation management (Hughes, 1994). Tropical and sub-tropical plantation forestry has focused on a small number of fast growing, colonizing species such as *Acacia, Eucalyptus, Gmelina, Pinus, Populus* and *Tectona*. These species have the ability to capture the site rapidly and tolerate harsh soil and climatic conditions and abuse from animals, humans and fire. These characteristics of exotics are a pre-requisite for success on the often highly degraded sites. Higher yield advantages of exotics over indigenous species have been attributed to their greater tolerance of degraded sites and their escape from specialized pests and diseases. Thus, the diminishing natural forest resources are being compensated for by rapid expansion of planted exotic trees worldwide.

Effects of introduced tree species on the environment

Research to date suggests that different plant species can influence soil nutrient cycling. For example, soil base cation status and pH may diverge under different plant species (Reich et al., 2005; Oostra et al., 2006). Numerous studies have demonstrated divergence in soil N cycling under different species of both herbaceous and woody plants; (Wedin and Tilman 1990; Gower and Son, 1992; van Vuuren et al.,1992; Mack et al., 2001; Mack and D'Antonio, 2003; and Lovett et al., 2004).

Compared to nutrient cycling studies, studies of plant specie effects on SOM pools and their dynamics are less common. The O-horizon mass can vary substantially among tree species. There was no variation among tree species in mineral soil C pools in north eastern USA. Similarly, Chen and Stark (2000) found no differences in C mineralization rates between soils under crested wheat grass and sagebrush. In contrast, a study in grasslands demonstrated significant variation in mineral soil C pools, C mineralization ates, and C:N ratios associated with different plant species (Vinton and Burke, 1997). Voody encroachment into grasslands sometimes alters soil C pools (Jackson et al., 2002) but at other times does not (Briggs et al.,2005). Oostra et al. (2006) demonstrated variation among European tree species in mineral soil C content in unreplicated plots.

It is argued that the number of tree species tends to increase with rainfall seasonality and soil (Givnish, 1999). Other authors for example Denslow and Hartshorn, (1994) suggest that canopy cover and height are important in determining species composition at a local level. Different introduced tree species form different canopy cover and are of different height. Logging, as a management practice, can affect forest structure (including canopy cover) and species diversity depending on the scale, nature and frequency of logging.

The impacts of introduced or invasive species on ecosystem services have attracted worldwide attention. Inspite of the overwhelming evidence of these impacts and a growing appreciation for ecosystem services, researchers and policymakers rarely directly address the connection between invasions and ecosystem services. Various attempts have been made to address ecosystem processes that are affected by invasive species (Levine et al., 2003; Dukes and Mooney, 2004). While advances have been made in quantifying non-market-based ecosystem services, their loss or alteration by invasive species are often overlooked or under appreciated.

Ecosystem services are the benefits provided to human society by natural ecosystems, or more broadly put, the ecosystem processes by which human life is maintained. The concept of ecosystem services is not new and there have been multiple attempts to list and/or categorize these services, especially as the existence of additional services has been recognized.

There are different tree species introduced in Uganda, for example, eucalyptus. The term eucalyptus has been derived from two Greek words i.e. "Eu" means "well" and

Kalypta" means "cover" and is generally termed as "well cover". The name eucalyptus ıormally refers to the little cap (operculum) covering the unopened flower. Sohail and ;ulaiman (1999) have contributed a lot to the study of the plant species and they found ıut that as eucalyptus generally evaporates a high ratio of groundwater to atmosphere ınd lowers the water table, the French introduced it in waterlogged and saline areas. In ʾakistan, it is mostly planted on mountain slopes having humid and sub-humid climates. ˉherefore, it is more important to evaluate the impact of eucalyptus on mountain slopes ȷround water and its contribution in the lowering of the water table. There are however ›thers in the field of agro forestry who say that the problem with eucalyptus is with the vay the various species have been planted indiscriminately, such as on river banks, gnoring the dangers the trees can cause on those specific ecosystems (Marks *et al.*, .994).

There exists the possibility that human induced climate change in the form of ȷreenhouse effect may result in an alteration of the structure and function of savannas. Some authors have suggested that savannas and grasslands may become even more ;usceptible to woody plant encroachment as a result of greenhouse induced climate :hange (Chappendal, 1973). There is an increasing concern among foresters, ecologists, botanists, conservationists and policy makers about the threat of ıncontrolled introduction of aggressive tree species in plantation programs (Baker *et* *al.*, 2002). Invasion of exotics may cause major loss of biodiversity and species extinction either due to direct replacement by exotics or indirect effects on the ecosystem. Concern also exists on the degradation of the environment, for example. :he controversial effect of eucalypts on the environment.

CHAPTER THREE

MATERIALS AND METHODS

Description of the study area

Location

The Namwasa Central Forest Reserve is situated in the sub counties of Bukuya, Madudu and Kassanda in Buwekula and Kassanda North counties of Mubende District. Namwasa is situated about 30 km east of Mubende town. Mubende district boaders the districts of Mpigi and Luweero in the East, Kiboga in the North, Sembabule in the South, and Kabarole and Kibale in the West. The Forest Reserve occupies a series of hills in the Central part of Mubende District locally known as "Singo Hills". It is 8958 hectares in extent and is owned by the Government of Uganda (GoU). The whole reserve occurs at mid altitude, ranging from 1,234 to 1,444 meters. Rainfall trends for the reserve are shown in Fig:2

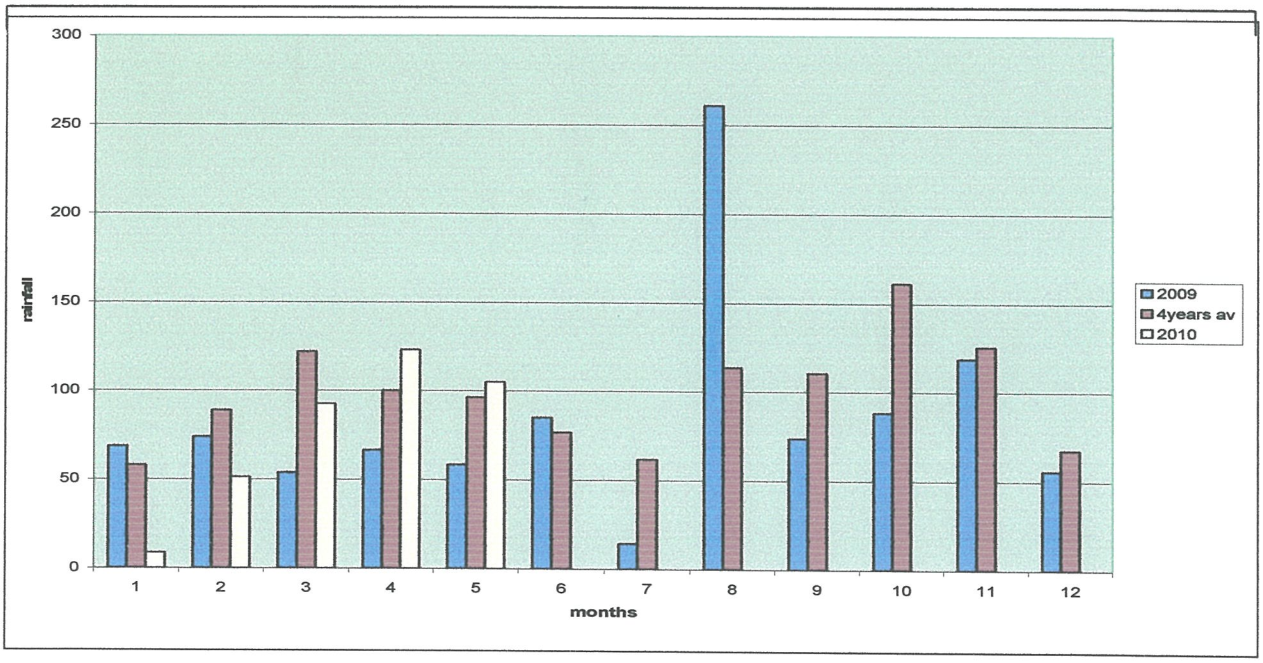


Figure 2: Rainfall Trends in Namwasa (mm)

Source: *Clean Development Project Design Document for aforestation and reforestation Project activities (CDM-AR-PDD) 2009/2010*

Namwasa CFR lies approximately between 341,000 and 360,000 on the x-axis and between 65,000 and 79,000 on the y-axis in UTM Zone 36. Altitudes range from 1135 to 1540 meters.

Latitudes and longitudes for compartments sampled were marked with the following coordinates:

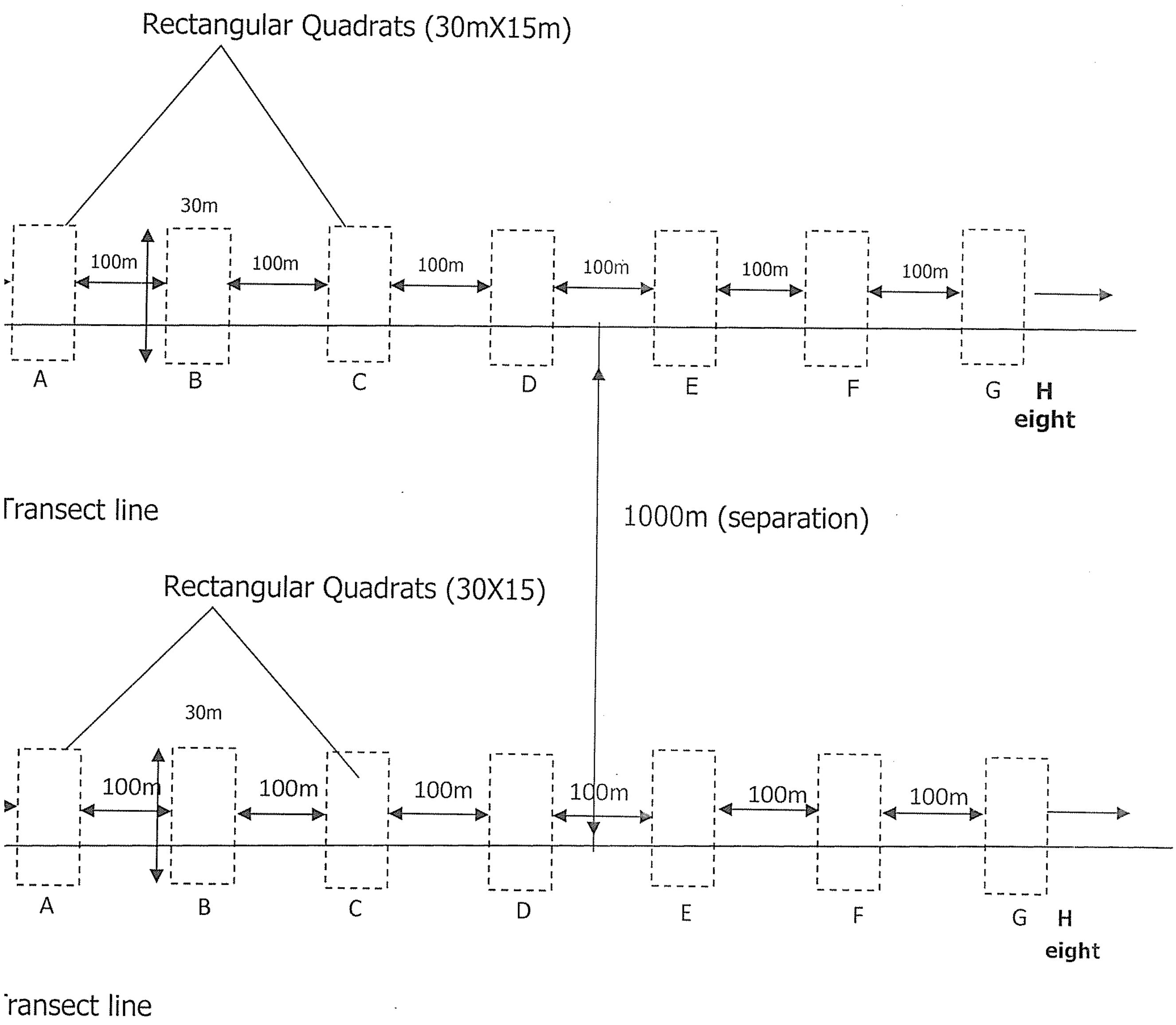
GPS Readings for compartments sampled

Code	GPS Readings		Tree species
	Easting	Northing	
CO 1	0350272	0066741	Eucalyptus grandis
CO 2	0349501	0065541	Pinus caribaea
E0 7	0351288	0069340	Eucalyptus urophylla
Z 22	0350664	066779	Natural forest
B 20	0354119	0070006	Pinus orcarpa

Sampling Procedure

Tree species

Transects and study plots within the forest were used. Transects were made into 5 compartments of the forest. These were compartments C1, C2, E7b, Z 22, and B 20. Each transect line was 1000m, with small plots of 30m by 15m in area along the main transect line, separated by a distance of 100m from one plot to another and the plots were used to census tree diameter at breast height (dbh). A digitech electronic caliper was used to measure tree diameters and a vertex hypsometer was used to measure tree heights. This was done with the help of three technical foresters of the New Forests Company. Stems in the plots were categorized in different size classes according to dbh. Strangler figs with multiple closely spaced trunks were measured by passing a measuring tape around the periphery of all the anastomosed roots. For buttressed trees, measurements were made above the buttresses. Snags (snapped and dead standing trees) were not measured for dbh.



igure 3: Transect line

. total of 48 rectangular plots, covering 21,600m^2 or 21.6km^2 were established and at egular intervals, a distance of 1000m was taken from one transect to another and a iPS unit used to locate the coordinates of the demarcated tree plots in each site. The rea surveyed was big enough to enable production of unbiased data on abundance, istribution of introduced tree species and to compare them with the indigenous tree pecies.

he radius of each plot was measured by a string stretched from the centre of the plot. oung trees were recorded as saplings if their diameters where less than 2.5 cm at breast height (dbh). Trees above 2.5 cm dbh were recorded in classes of 2.5-4.9 cm, 5-9.9 cm, 10-29.9 cm, 30-49.9cm and >50 cm. Liannas whose diameters were greater than 1 cm at 1 meter above the ground were recorded as present or absent whenever encountered in the plot. All climbing plants, woody or herbaceous, were recorded as liannas whenever they were seen to climb, entangle, or scramble on other plants within the plot.

Plots could give fairly good data on distribution and abundance, but could not give the total number of different species in an area, as there were plants that were only encountered outside the plots. Opportunistic records were used to record any new species seen or encountered for the first time in a site. The canopy estimates of all the trees was used in the estimation of canopy cover for each compartment to have a relative estimate of the comparison of the indigenous and introduced tree canopy cover . A pilot study was conducted to gather a general understanding about the ecological and economic benefits of the forest. Following the pilot study, a detailed survey during face-to-face interviews was conducted in the local language "*Luganda*" The interviews were supplemented by walks and direct observations.

Soils

Five random soil cores (8 cm diameter x 15 cm height) were collected using a trowel around the targeted tree plots belonging to five compartments. The soil samples were then placed in a Ziploc bag (Campbell, 2001). The trowel was washed with a detergent solution, rinsed and dried to minimize the possibility of contamination. Samples were then transported to the laboratory in an ice box. The samples were air-dried and sieved using a 2mm sieve.

Sample analysis

Soils

Soil texture was determined using the hydrometer method. Bulk density was determined by the soil infill method. The soil bulk density was calculated using the

Assessment of species richness and diversity

Species richness refers to the total number of plant species found within a plant community. Species richness was obtained by summing up the different species found in all transects (Musinguzi, 2010). When data from a sufficient number of transects was collected, quantitative estimates were obtained

$$\text{Density of species} = \frac{\text{Number of individuals of species}}{\text{Total area sampled}}$$

$$\text{Relative Density of species} = \frac{\text{Density of species}}{\text{Density of all species sampled}} \times 100$$

$$\text{Dominance of species} = \frac{\text{Total basal area/canopy cover of species}}{\text{Total area sampled}} \times 100$$

Where Basal area (m^2) = (DBH/Total number of trees in a plot) ^{2} x 3.142

And canopy cover= π d or πr^2, where d is the diameter of the canopy cover, if assumed to be circular. Canopy cover was calculated as a proportion for both introduced and indigenous tree species in each compartment. Canopy diameter (length in meters) was measured for all trees encountered within the circular plots. This information was used to compute canopy cover per plot and in turn the percentage canopy covers per compartment as per the formula below.

$$\text{Percentage canopy cover } (C_i) = \frac{\sum P_i}{\sum A_i} \times 100$$

Where P_i = Canopy diameter (length in meters) per plot in compartment i

A_i = Total plot diameter (length in meters) in compartment i

$$\text{Relative Dominance of species} = \frac{\text{Dominance of species}}{\text{Total number of plots sampled}} \times 100$$

$$\text{Relative Frequency of species} = \frac{\text{Frequency of species}}{\text{Total frequency of all species}} \times 100$$

The frequency of a species in each transect was shown by the number of times a given species could exist in various sample plots.

Important Value Index of species = Rel. Density + Rel. Frequency + Rel. Dominance

Species Diversity

Species diversity was assessed using the Shannon wiener index (H). This index was developed on the basis of the information theory and the concept of "uncertainity." In a community of low diversity, there is a high probability of predicting the identity of a randomly selected individual because of the few species represented. Conversely, this probability is low in a community of high diversity. Thus, high diversity is associated with high uncertainity and low diversity is associated with low uncertainty. Diversity indices reflect the manner in which abundance is distributed among the different plant species constituting the population (Clémentine *et al.*, 1998).

The Shannon index is given as **H= - _ (*ni*/ *N*) log2(*ni*/ *N*),**

Where ***ni*** = the number of individuals of species I which are observed

N = the total number of all individual species observed in the study area

Assessment of the effect of introduced tree species on soils

Soil samples were collected using a soil trowel from the base or/and around the targeted tree species randomly selected in transects around the targeted tree species. Soil samples were 5 in total, one from compartment C2 (Pinus caribaea), one from Compartment E7b (Eucalyptus urophylla), Compartment Z 22 (natural forest), and compartment C 1(Eucalyptus grandis), and Compartment B 20 (Pine oocarpa). Samples were then placed in a Ziploc bag (Campbell, 2001). Samples were then transported to the laboratory at the Government laboratory in Wandegeya in an ice box (Sekabira 2010).

Some selected soil characteristics under the natural forest (which was used as a control) were compared with those under the introduced tree species so as to determine whether there were positive or negative effects on the soil parameters.

Statistical analyses

Species Diversity Indices (SDI)

A diversity index is a statistic which is used to measure the diversity of a set consisting of various types of abundance of the different types of plant species. Species richness (s) which is the number of species present in an ecosystem; and species evenness E_H1, which is the relative abundance or proportion of individuals among species, were determined using an important diversity index;-

Shannon Weiner diversity index (H')

$$H' = -\sum_{i=1}^{s}(p_i \ln p_i)$$

Where

ni= the number of individual of species I which are observed

N = the total number of all individual species observed in the study area

S = the species richness or species diversity

Pi = n/N, is the fraction of individuals belonging to the i^{th} species

The values obtained were interpreted in the range 0 $\leq H' \geq 1$, with values near zero corresponding to a perfectly homogeneous diversity index and those whose diversity index score is near 1, corresponding to a perfectly heterogeneous or highly diverse community. Other Shannon measurements which were used were "S" which is the number of species present in the sample area, and E_H which is the evenness of those species. If the E_H value is 1, the species are equally present in the habitat. The formula to find E was: $E_H = H' \text{In} S$

Soils

Analysis Of Variance (ANOVA) was performed to determine whether groups of variables have the same means on data that are continuous or normally distributed and with homogeneous variance. Additionally, it was employed to assess the relationship between the different selected soil parameters. Data was analyzed using the SPSS (Statistical package for social Sciences) Statistical software (SPSS, 1999)

Correlation analysis: Pearson correlation coefficient analysis was performed to analyze and establish correlation between the selected soil parameters for introduced tree species.

CHAPTER FOUR

FINDINGS AND DISCUSSIONS

Ecological and economic benefits of introduced tree species

A pilot study was conducted at the beginning of the study to gather a general understanding about the ecological and economic benefits of the forest. Following the pilot study, a detailed survey using face to face interviews were conducted in the local language *"Luganda"* The interviews were supplemented by walks and direct observations and results are explained below:-

Table 1: Tree species identified in Namwasa Central forest Reserve

Local name	Botanical name
Pine caribaea	*Pinus caribaea*
Pine Ocarpa	*Pinus Ocarpa*
Kalitunsi	*Eucalyptus grandis*
Kalitunsi	*Eucalyptus urophylla*
Kapanga	*Lantana camara*
Nongo	*Albizia gummifera*
Palm trees*	*Elaies guineenis*
Mahogany	*Kyaya anthotheca*
Mvule	*Milicia excels*
Musizi*	*Maesopsis eminii*
Ffene	*Artocapus heterophylus*
Nkoba	*Lovoa trichiliodes*
Mukusu	*Entandophragma angolense*
Mutuba	*Ficus natalensis*
Muyembe	*Mangifera indica*
Mumwanyi*	*Coffea robusta*
Nkuzanyana	*Blighia Unijugata*
Munaba	*Pycnanthus angolensis*
Musambya*	*Markhamia lutea*
Muwafu	*Canarium schweinfurthii*
Muyovu	*Uapaca guineense*
Mwasa	*Beilschiedia ugandensis*
Podo	*Podocarpus latifolius*
Nkago	*Funtumia elastic*

*Represent trees which existed in both Plots for Introduced and native tree species

Mammals which are known to scatter seeds and to improve their germination were in eucalyptus and pine plantations. In the time available for the study, presence or signs of presence of mammals were noticed. Tracks of side stripped jackals, *Canis adustus,* which eat fruits, were seen, and individuals were observed several times during field trips. Tracks of civet, *Civectictis civetta,* which is known to be efficient in scattering seeds (Pendge., 1994), were seen in the plantation. Black-and-White Colobus Monkey, *Colobus quereza* was identified in pine plantation.

Exotic timber plantations initiated an important floristic change from the grass-dominated vegetation of native savanna toward undergrowth characterized by the importance of woody plants. The changing rate of the vegetation was slowed down by management practices or accelerated by high plantation density or by forest proximity. The basal area of undergrowth was low in all the studied plots, and far less than that of the planted trees. Floristic change was characterized by the increase of total species number and the proportion of forest-preferring species with increasing plots and an increase in the number of species with plantation was a common observation (Abbasi and Vinithan., 1990).

The forest reserve created employment opportunities for people both nationally and internationally. They fall in the category of casual laborers to professionals. Some work in Nurseries of the reserve, Enumeration team who measure trees at breast height (Dbh), count the survival of trees, do the pruning and thinning, and the top management who provide managerial skills. Nurseries are chosen for their location near sustainable water supplies and centrality to plantation operations. Nursery Manager keeps a number of records which include; Daily rainfall figures, Daily fuel/chemical stock levels, Seedlings dispatches, Seed stock balances and Daily labor attendance, Daily productivity, Instructions and guidelines, Plans/budget requisitions, Fertilizer, herbicide and pesticide usage register.

Weeding is practiced regularly, as the ecological conditions are highly conducive to rapid weed regeneration. Attention is given to completely removing the weeds' root systems to prevent re growth, using hoes or picks. Efforts are made to rely primarily on manual provisions of the Forest Stewardship Council's principles, strictly monitored herbicide applications are reverted to when necessary

Individuals with land- holdings exceeding 25 hectares are considered commercial out growers. They receive seedlings at a subsidized cost, and can sell timber to NFC at the time of harvest. Not confined to the plantation buffer zones (of 50 km), interested individuals can be located as far as 150 km from Namwasa
The tree-farming license extended to NFC authorizes the company to develop a commercial timber plantation for duration of 50 years, commencing in April of 2005. Production of timber from pine and eucalyptus will increase in production of timber products like furniture in the country and internationally

Some bird species were observed in the plantations. Among the species observed, *Nectarinia cuprea* and *Pycnonotus barbatus*, were common in the compartments. Species which were the most adaptable in plantations were those which were geographically widespread, whereas endemic African species were not seen in the plantations. The plant association most occupied by birds combined *Psychotria* sp., *Alchornea cordifolia, Maprounea* and *Canthium* spp. *Psychotria* flowers, as well as those of another pioneer plant, *Anthocleista* sp., provide food for most nectarivorous souimanga, whereas the other three fruiting species provide food for the bulbul *Pycnonotus barbatus* and the genera *Pogoniulus* and *Turtur*. The only species that built their nests in eucalyptus trees were souimangas, while some undergrowth trees, like *Maprounea* and *Macaranga* spp., were used for nesting by several species. The number of migratory bird species and individuals from palearctic countries was relatively high. Seven species were observed two of which were present at fairly high densities. First, these birds prefer vegetation which is physionomically similar to their native environment (Brosset and Erard., 1986), and secondly, tropical forests are generally saturated with local sedentary species. However migratory birds were encountered in transects where the understorey vegetation was thick and varied.

Plantations Improve Soil Organic Matter Status(Table:5) There is litter accumulation and quality, and the resulting soil organic matter accumulation and quality, were among the main ecological changes in areas planted with introduced trees especially soils under Eucalyptus grandis and pinus oocarpa, and determined the development of undergrowth and changes in soil characteristics (Wardle and Lavelle., 1997). Vegetation was mainly affected by the type of habitat. Heal and Dighton., (1985) observed that the increasing importance of fauna and the increasing dominance of macro fauna were related to the improvement of the quality of primary production residues.

The ecological effects of introduced tree species vary widely depending on sites (climate, soil, topography) and the benefits from Eucalyptus and Pines vary depending on the needs of respective communities. It should be noted that each site where Eucalyptus and pine may be planted has its own peculiarities and buffering mechanisms and the response to introduced tree species growing by each site should be judged separately. This means that decisions as to Eucalyptus and pine planting must be specific to each case and should be based on adequate assessment of physical, biological and society factors. Eucalyptus is increasing in importance in the world because many species have the ability to improve conditions in treeless areas. These results are in consistent with FAO, 1988. In many places Eucalyptus have helped to raise people's living standards by providing building materials, fuel wood, poles and farm timber.

Distribution, abundance and diversity of introduced tree species in Namwasa CFR

Table 2: Frequency of distribution of tree species in Namwasa Central Forest Reserve (f = 1483)

Botanical Name	Frequencies of species per transect						TOTAL
	TD1	TD2	TD3	TD4	TD5	TD6	
Pinus caribaea	360	0	0	0	0	0	3 6 0
Pinus Ocarpa	0	0	0	0	360	0	360
Eucalyptus grandis	0	384	0	0	0	0	384
Eucalyptus urophylla	0	0	0	0	348	0	348
Lantana camara	0	0	1	0	0	0	1
Albizia gummifera	0	0	1	0	0	0	1
Elaies guineenis	1	0	1	0	0	5	7
Kyaya anthotheca	0	0	0	0	0	1	1
Milicia excels	0	0	0	0	0	1	1
Maesopsis eminii	0	0	0	0	0	3	3
Artocapus heterophylus Lovoa trichiliodes	0	0	0	1	0	0	1
Entandophragmaangolensi Ficus natalensis	0	0	0	0	1	0	1
Mangifera indica	0	0	1	0	0	0	1
Coffea robusta	0	0	1	0	0	0	1
Blighia Unijugata	0	0	1	0	0	0	1
Pycnanthus angolensis Markhamia lutea	0	0	1	0	0	0	1
Canarium schweinfurthii	0	0	1	0	0	0	1
Uapaca guineense	0	0	1	0	0	3	4
Beilschiedia ugandensis	0	0	1	0	0	0	1
Podocarpus latifolius	0	0	1	0	0	0	1
Funtumia elastic	0	0	1	0	0	0	1
							F=1483

Key: Transect name ***TD1*** = *Eucalyptus grandis transect* ***TD2*** = *Pinus caribaea transect* ***TD3*** = *Indigenous tree species*

*Transect **TD4** Pinus Oocarpa transect **TD5** = Eucalyptus Urophylla transect **TD6** = Indigenous tree species transect 2*

Four introduced tree species and twenty indigenous tree species (Table 1) were documented and identified in the study area. The frequency of distribution of introduced and native tree species is presented (Table 2). These were grouped into pairs transects for analysis, that is to say, transect TD1 and TD2, transect TD3 and TD4, transect TD5 and TD6. Introduced tree species had a lower diameter at breast height (Dbh) compared to the native tree species. Eucalypyus grandis was the most frequent tree species with 384 stands in transect two (TD2), Pinus caribaea and Pinus orcapa with 360 (TD1 and TD5) followed respectively. Eucalyptus urophylla had 348 stands in TD5. The frequency of distribution of the natural forest ranged from 1-7 tree stands in all transects (Table 2). Trees species abundance, density and diameter size classes (Dbh) is presented (Table 3). Species abundance was 24.2%, 24.2%, 25.8% and 23.4%, species density was 1.66, 1.66, 1.77, 1.61, Diameter at breast height was 14.5cm to 16.4cm for pinus caribaea, pinus ocarparpa, Eucalyptus grandis and Eucalyptus urophylla respectively.

Indigenous tree species aboundance ranged from 0.067% to 0.47%, species density was 0.0046 to 0.034, Dbh was between 12.2cm to 180cm (Table 3).

Table 3: Tree species' abundance percentages, density and diameter size classes (Dbh) observed (n = 24)

Botanical name	Species (%)	Sp.density	Dbh/cm	Frequency (F)
Pinus caribaea	24.2	1.66	16.4	360
Pinus Ocarpa	24.2	1.66	14.3	360
Eucalyptus grandis	25.8	1.77	17.5	384
Eucalyptus Urophylla	23.4	1.61	14.5	348
Lantana camara	0.067	0.0046	-	1
Albizia gummifera	0.067	0.0046	142.6	1
Elaies guineenis	0.47	0.034	133.7	7
Kyaya anthotheca	0.067	0.0046	175.2	1
Milicia excels	0.067	0.0046	180.4	1
Maesopsis eminii	0.2	0.0138	130.2	3
Artocapus heterophylus	0.067	0.0046	41.3	1
Lovoa trichiliodes	0.067	0.0046	24.3	1
Entandophragma angolensis	0.067	0.0046	29.4	1
Ficus natalensis	0.067	0.0046	73.2	1
Mangifera indica	0.067	0.0046	164.4	1
Coffea robusta	0.067	0.0046	12.2	1
Blighia Unijugata	0.067	0.0046	27.1	1
Pycnanthus angolensis	0.067	0.0046	33.5	1
Markhamia lutea	0.269	0.0185	37.8	4
Canarium schweinfurthii	0.067	0.0046	47.6	1
Uapaca guineense	0.067	0.0046	34.9	1
Beilschiedia ugandensis	0.067	0.0046	45,0	1
Podocarpus latifolius	0.067	0.0046	31.2	1
Funtumia elastic	0.067	0.0046	30.7	1

The distribution and abundance or diversity of four introduced tree species in Namwasa Central forest Reserve, were obtained using transects. Six transects of 100m were made basing on each compartment, Compartment 1, Compartment 2, Compartment Z 22, Compartment E 07), and Compartment B 20, with codes; **TD1, TD2, TD3, TD4, TD5** and **TD6** respectively. A total of eight rectangular sample plots were designed along each main transects line. The plots were separated from each other by a distance of 100m; and had dimensions (30 x $15m^2$), (Kent and cooker, 1996), the sample plots boundaries were marked with crayons/colored tapes to ease their identification. Therefore, six transects had 48 rectangular plots of (30 x $15m^2$), making a total area under study to (450 x48) m^2 or $21.6km^2$.

Five diameter size classes were used to group these introduced tree species; 2.5-4.9 cm, 5-9.9 cm, 10-29.9 cm, 30-49.9cm and >50 cm Ssegawa P, et al., (2004). (Table 3). The canopy of introduced tree species was obtained by plumbing vertical lines to the ground from the two edges of the canopy, measuring the distance between the two points on the ground and using this as the diameter of the canopy. The canopy could be assumed to be circular, therefore the circumference (C) was calculated from the expression ($C = \pi d$) to establish the canopy cover. Data obtained from 48 rectangular sample plots was quantitatively analyzed using descriptive statistics. Shannon Weiner's diversity index was used to determine species richness (S) and Species evenness (E_H). The value 0 was treated bas no relationship while 1 or near 1 was a perfect relationship, Bishop et al., 1975).

Table 4: Shannon Weiner index (H'), Species richness (S) and Species evenness (EH) (n = 24)

Botanical name	TDI	TD2	TD3	TD4	TD5	TD6	Total	Pi	LnPi	PiLnPi
Pinus caribaea	360	0	0	0	0	0	360	0.2427512	-1.41571831	-0.34366729
Pinus Ocarpa	0	0	0	0	360	0	360	0.2427512	-1.41571831	-0.34366729
Eucalyptus grandis	0	384	0	0	0	0	384	0.2589346	-1.35117979	-0.34986719
Eucalyptus Urophylla	0	0	0	0	348	0	348	0.2346595	-1.44961986	-0.34016703
Lantana camara	0	0	1	0	0	0	1	0.0006743	-7.30182234	-0.00492368
Albizia gummifera	0	0	1	0	0	0	1	0.0006743	-7.30182234	-0.00492368
Elaies guineenis	1	0	1	0	0	5	7	0.0047202	-5.35591219	-0.02528077
Kyaya anthotheca	0	0	0	0	0	1	1	0.0006743	-7.30182234	-0.00492368
Milicia excels	0	0	0	0	0	1	1	0.0006743	-7.30182234	-0.00492368
Maesopsis eminii	0	0	0	0	0	3	3	0.0020229	-6.20321005	-0.01254864
Artocapus heterophylus	0	0	0	1	0	0	1	0.0006743	-7.30182234	-0.00492368
Lovoa trichiliodes	0	0	0	0	1	0	1	0.0006743	-7.30182234	-0.00492368
Entandophragmaangolensi	0	0	1	0	0	0	1	0.0006743	-7.30182234	-0.00492368
Ficus natalensis	0	0	1	0	0	0	1	0.0006743	-7.30182234	-0.00492368
Mangiferaindica	0	0	1	0	0	0	1	0.0006743	-7.30182234	-0.00492368
Coffea robusta	0	0	1	0	0	0	1	0.0006743	-7.30182234	-0.00492368
Blighia Unijugata	0	0	1	0	0	0	1	0.0006743	-7.30182234	-0.00492368
Pycnanthus angolensis	0	0	1	0	0	0	1	0.0006743	-7.30182234	-0.00492368
Markhamia lutea	0	0	1	0	0	3	4	0.0026972	-5.91552798	-0.01595557
Canarium schweinfurthii	0	0	1	0	0	0	1	0.0006743	-7.30182234	-0.00492368
Uapaca guineense	0	0	1	0	0	0	1	0.0006743	-7.30182234	-0.00492368
Beilschiedia ugandensis	0	0	0	0	0	1	1	0.0006743	-7.30182234	-0.00492368
Podocarpus latifolius	0	0	0	0	0	1	1	0.0006743	-7.30182234	-0.00492368
Funtumia elastic	0	0	0	0	0	1	1	0.0006743	-7.30182234	-0.00492368
Shannon Wiener Index	(H')									-1.5148564
Species richness	24									
Species evenness	(EH = H'/InS)									0.477

Shannon weiner index (H'), Species richness (s) and Species evenness (EH) is presented (Table 4).

Shannon weiner index (H') = -1.514, Species richness (S) = 24 and Species evenness (EH) = 0.477 (Table 4). The values obtained were interpreted in the range of 0 ≤H'≥, with values near zero corresponding to homogenous diversity index and those whose diversity index score is near 1 corresponding to a perfectly heterogeneous or moderately diverse community.

Soil characteristics such as pH and altitude are important in influencing species abundances and distributions in western part of the central region of Uganda forests. These results are consistent with Eilu et al., 2004b. Studies elsewhere in the tropics indicate that climatic factors such as rainfall and soil properties (for example pH, N & P) are important in influencing the diversity and distribution of plant species and results obtained are consisted with Markhabu et al., 2002. Human induced disturbances and land-use histories (Foster, 1992) are as important as other biophysical variables in influencing the tree species distribution. Results obtained (Table 5) agree with above Foster, 1992.

Woody plants contribute most of the structure and biomass to a rainforest and are surely the single most fundamental rainforest component. Information on the distribution and abundance of tree species is of primary importance in the planning and implementation of biodiversity conservation (Eilu *et al.*, 2004a; Duivenvoorden, 1996). This study documents the diversity and distribution of vascular plants, particularly, tree species in in Namwasa Central forest reserve and agree with Condit et al., 1996 about the Tropical forests which are well know for being the most species rich ecosystems on earth.

Effect of introduced tree species on some selected soil properties

Table 5: Laboratory results for Selected soil Properties in Namwasa Forest Reserve

Parameter	**Eucalyptus Urophylla**	**Natural forest Z 22**	**Pine caribaea Compartment 2**	**Eucalyptus Grandis Co1**	**Pine Oocarpa Compartment B 20**
PH	5.2	4.8	5.8	5.3	5.6
Conductivity[µs/cm]	564.0	502.0	496.0	522.0	482.0
NO_3 [mg/kg]	68.0	60.5	59.8	69.9	58.1
Ca [mg/kg]	98.0	87.2	86.2	90.7	83.8
Mn [mg/kg]	2.1	1.9	1.8	1.9	1.8
CI [mg/kg]	80.0	71.2	70.4	74.0	68.4
Cu [mg/kg]	0.10	0.1	0.1	0.1	0.1
SO_4 [mg/kg]	60.0	53.4	52.8	55.5	51.3
PO_4 [mg/kg]	54.0	48.1	47.5	50.0	46.1
Fe [mg/kg]	4.0	3.6	3.5	3.7	3.4
Pb [mg/kg]	<0.001	<0.001	<0.001	<0.001	0.001
NH_3 [mg/kg]	48.0	42.7	42.2	44.4	41.0
Mg [mg/kg]	128.0	113.9	112.6	118.5	109.4
Na [mg/kg]	52.0	46.3	45.7	48.1	44.4
K [mg/kg]	40.0	35.6	35.2	37.0	34.2
Ni [mg/kg]	<0.001	<0.001	<0.001	<0.001	<0.001
Zn [mg/kg]	0.54	0.48	0.47	0.50	0.46
Bulk Density [g/cm^3]	2.12	1.89	1.86	1.96	1.81
Organic matter	3.0	8.9	3.6	8.5	4.0
% Sand distribution in the soil	28	25	28	26	24
% Silt distribution in the soil	60	53	53	59	51
% Clay distribution in the soil	12	22	19	15	25
Soil texture class	Loam – silt	Loam soil	Loam soil	Loam soil	Loam soil
Soil Structure	Mixed prismatic & granular	Blocky	Blocky	Mixed prismatic	Blocky

PH under pine caribaea was 5.8 pine oocarpa 5.6, Eucalyptus grandis 5.3, and ucalyptus urophylla 5.2 (Table 5). In the natural forest, the pH of 4.8 was compared ith the introduced tree species. Conductivity [µs/cm] was 564.0, 502.0, 496.0, 522.0 nd 482.0 for Eucalyptus urophylla (Table 5), natural forest, pinus caribaea, Eucalyptus randis and pinus oocarpa respectively. Bulk density was 2.12g/cm^3, 1.89g/cm^3, 86g/cm^3, 1.96g/cm^3 and 1.81g/cm^3 for Eucalyptus urophylla, natural forest, pine ribaea, Eucalyptus grandis and pine oocarpa respectively (Table 5). Exchangeable Ca and Mg concentrations in the soils under natural forest 87.2 and 113.9 mg/kg, respectively, were lower than soils under Eucalyptus urophylla and Eucalyptus grandis with Ca 98.0, Mg 128.0 and Ca 90.7, Mg 118.5 respectively (Table 5). In contrast, Ca and Mg (Table 5) concentrations in soils under pinus caribaea and pinus oocarpa, 86.2 and 112.mg/kg and 83.8, 109.4 respectively were lower compared to Eucalyptus urophylla, Eucalyptus grandis and the natural forest, soil texture class (Table 5) for soils under Ucalyptus urophylla was loam – silt soil and loam soil for Eucalyptus grandis, natural forest, pinus caribaea and pinus oocarpa respectively. Soil structure (Table 5) was mixed prismatic and granular for Eucalyptus urophylla and Eucalyptus grandis. However, soil structure (Table 5) for soils under the natural forest, pinus oocarpa and pinus caribaea was blocky. Organic matter (Table 5) was 3.0%, 8.9%, 3.6%, 8.5%, and 4.0 for soils under Eucalyptus urophylla, natural forest, pinus caribaea, Eucalyptus grandis and pinus oocarpa respectively. Pb [mg/kg] and Ni [mg/kg] for all soils were <0.001 and <0.001 respectively implying "below detection limit".

% sand distribution (Table 5) in the soil under Eucalyptus Urophylla was 28%, 28% for Pine caribaea, 26% for Eucalyptus grandis, 24% for Pine oocarpa and 25% for natural forest. % silt (Table 5) was 60%, 53%, 53%, 59% and 51% for Eucalyptus Urophylla, natural forest, Pine caribaea, Eucalyptus grandis and Pine oocarpa respectively while % clay distribution (Table 5) in the soil was 12%, 22%, 19%, 15% and 25% for Eucalyptus Urophylla, natural forest, Pine caribaea, Eucalyptus grandis and Pine Oocarpa respectively (Table 5). Potential C mineralization, on grams of C basis, differed among species (Table 5), indicating that the quality of the SOC differed among species.

Table 6 A: ANOVA

	Sum of Squares	Df	Mean Square	R^2	F	Sig.
Regression	232174.492	3	77391.497	0.782	146792.336	0.000
Residual	9.490	18	.527			
Total	**232183.982**	**21**				

ANOVA results (Table 6) indicated that the introduced tree species all together significantly affect the selected soil properties (F =146792.336, sig. =0.000). The adjusted r squared (Table 6) indicated that the introduced tree species involved in this test, account for over 78% in variations in selected soil properties.

Table 7 B: Coefficients

Tree Species	Unstandardized Coefficients		Standardized Coefficients	t statistic	Sig.
	B	Std. Error	Beta		
(Constant)	-0.079	0.189		0.426	0.682
Eucalyptus Urophylla	-0.242	0.094	-0.273	-2.573	0.019
Eucalyptus Grandis	0.662	0.119	0.689	5.557	0.000
Pinus Oocarpa	0.608	0.059	0.584	10.245	0.000

The coefficient table (Table 7) indicates that the three tree species introduced have a significant effect on the selected soil properties. These include Eucalyptus Urophylla (Beta = -0.273, sig. = 0.019) Eucalyptus Grandis (Beta = 0689, sig. = 0.000) and

Eucalyptus urophylla (Beta = 0.584, sig. = 0.000) (Table 7). It is also indicated that of the three tree species, Eucalyptus Grandis Co 1 has the biggest effect on soil properties, accounting for over 69% in variations of the soil properties in question, followed by Compartment B 20 accounting for over 58% in variations of the soil properties in question, other tree species held constant, while Eucalyptus Urophylla negatively affects the soil properties in question with a percentage of over 27% (Table 7).

Table [illegible] Pearson Correlation Coefficient matrix (r) for some Selected Soil Properties of Introduced Tree Species of Namwasa Central Forest Reserve in Mubende District (n= 14)

	PH	cond	No3	Ca	Mn	Cl	SO4	Po4	Fe	NH3	Mg	Na	K
PH													
cond	-0.356												
No3	-0.290	0.814											
Ca	-0.353	1.000**	0.814										
Mn	-0.531	0.962**	0.696	0.962**									
Cl	-0.352	1.000**	0.811	1.000**	0.962**								
SO4	-0.352	1.000**	0.811	1.000**	0.962**								
Po4	-0.361	1.000**	0.816	1.000**	0.962**	1.000**	1.000**						
Fe	-0.446	0.995**	0.805	0.994**	0.975**	0.994**	0.994**	0.995**					
NH3	-0.355	1.000**	0.813	1.000**	0.962**	1.000**	1.000**	1.000**	0.995**				
Mg	-0.353	1.000**	0.816	1.000**	0.962**	1.000**	1.000**	1.000**	0.995**	1.000**			
Na	-0.362	1.000**	0.813	1.000**	0.963**	1.000**	1.000**	1.000**	0.995**	1.000**	1.000**		
K	-0.352	1.000**	0.811	1.000**	0.962**	1.000**	1.000**	1.000**	0.995**	1.000**	1.000**	1.000**	
Zn	-0.390	0.998**	0.826	0.998**	0.968**	0.998**	0.998**	0.998**	0.996**	0.998**	0.998**	0.999**	0.998**

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

Correlation results in (table 8) indicated that PH is negatively correlated with all other soil properties ($r<0$) however the relationship with all soil properties is not significant (all sigs >0.05), these results are consistent with Krishnaswamy and Richter, 2002. Implying that much as PH reduces all other soil properties, the reduction or the impact is not significant. Conductivity in all cases (Table 8) is positively and significantly correlated with other soil properties (all sigs. <0.05); it is however perfectly correlated with most of the soil properties like NO_3, Ca, Cl, SO_4, PO_4, NH_3, Mg, Na and Zn (all their corresponding r-values $=1.0$, and all sigs. $=0.000$) (Table 8). Bulk density differed significantly among soil parameters. This suggested that biological activity could have as much or more of an effect on bulk density than the addition of detritus. These results are consistent with Fisher, 1995

The same significant and positive correlations with all other soil properties were found for NO_3 (all r-values >0 and sigs. <0.05). The same applies to the rest of the properties in table 8.

CHARPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

This chapter presents the conclusions and recommendations following the study objectives. The areas for further research are also suggested here.

CONCLUSIONS

Introduced tree species which were identified have both ecological and economic benefits and they have effect on the soil the selected soil properties of Namwasa Central forest Reserve. In Uganda more than 90% of the rural communities depend on fuel wood for heating and lighting and there are no other energy alternatives that can out stand fuel wood. Further construction materials in the rural areas depend on wood from small holder forestry woodlots with no much alternative from natural forests/woodlands. Therefore, there is need to establish a monitoring and sensitization team to educate residents of Namwasa CFR to stop setting fires in the forest reserve since they destroy plantations.

Results showed a moderate species distribution and abundance of trees in the forest, but native trees showed unevenness. This could have been either due to low levels of reproduction or inability of dispersal mechanisms and habitat encroachment by mans (Table 2). Introduced tree species for example Eucalyptus grandis and Pine caribea had Diameter at breast height (Dbh) size classes 10-29.9cm and indigenous tree species had Diameter at breast size classes >50cm. This is because introduced trees commenced plantation in 2005 and thus they are still small but native tree species had existed for along period of time that why their Diameter at breast height size classes were >50cm. The distributions and frequency of indigenous tree species was low implying that activities of man's encroachment on the forest for fuel wood, grazing and timber could have in most cases caused depletion or disappearance of these species from the forest as burnt areas were identified. (Peters,1994).

Poor management practices likely to decrease inputs such as burning of harvest residues and charcoal burning should be stopped immediately and government need to sensitize more local people about the importance of forests.

Tree species effect on soil properties persist beyond the early rapid-growth phase following plantation initiation. Long-term studies in temperate-zone forests support this idea and differences among species in soil properties are confined to the surface soil. Results demonstrate that trees can influence deep soil by various mechanisms including organic acid production and pumping of nutrients from deep soil .soil samples differed in the quantity of SOC as a result of differences in the amount of fertilizers and herbicides that are added to the forest soils.

RECOMMENDATIONS

This section deals with recommendations arising from the pertinent findings and conclusions of this study, following the study objectives;

Basing on the findings of the objectives, the researcher recommends that the effect of introduced tree species on the soils of Namwasa CFR should be addressed in the following ways;

The controversies surrounding ecological and economic benefits of introduced tree plantations in Uganda and the world in general seem to be a matter of management (understanding relevant species or species choice, where and how to plant) and not a problem inherent in any particular species characteristics. Meanwhile given the dynamics of water use by different tree species and the water consumptive capacity of fast growing species like Eucalyptus, it would be advised against planting of Eucalyptus in water sources/catchments, riparian areas or as gap planting species in catchment forests especially in arid areas.

All management practices likely to decrease inputs, such as the burning of harvest residues, charcoal burning, harvest of twigs and leaves for fuel which affect the distribution, abundance and diversity of introduced tree species need to be stopped by sensitizing local people who are neighbors of the forest reserve about the importance of forests.

Although eucalyptus are among the less efficient species for improving soil nutrient status, when they are grown on the poor savanna soils, their litter contributes to soil fertility increase after 6 to 7 years of plantations so it is recommended that there is need to ensure proper management of exotic plantations since litter contributes to soil fertility increase after 6 to 7 years.

Further research

A good understanding of the complexity of forest/vegetation processes requires long term monitoring of vegetation change in Namwasa CFR so further studies are needed. They could be focused on seed dispersion mechanisms, including biotic factors and a biotic factors (for example wind), and on specific heterogeneity of undergrowth with the presence of dense diversity patches. More attention has to be paid to the variability of the floristic composition and densities in the undergrowth of the natural forest which might affect undergrowth composition of introduced tree species plantations and management practices.

Further research is also needed on the cumulative effect of silvicultural practices involved in short rotation forestry and its relation with soil properties

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APPENDICES

Appendices1: Transmittal letter

KAMPALA INTERNATIONAL UNIVERSITY

EXPLORING THE HEIGHTS

Ggaba Road - Kansanga
P.O. Box 20000, Kampala, Uganda
Tel: +256- 41- 266813 / +256- 41-267634
Fax: +256- 41- 501974
E- mail: admin@kiu.ac.ug,
Website: www.kiu.ac.ug

OFFICE OF THE ASSOCAIOTE DEAN, SOCIAL SCIENCE
SCHOOL OF POSTGRADUATE STUDIES AND RESEARCH (SPGSR)

MARCH 11, 2011
GENERAL MANAGER
OF THE NEW FORESTS COMPANY (NFC)

Dear Sir/Madam,

RE: REQUEST FOR MUNUBI ABDALLAH MEM/40277/91/DU TO CONDUCT RESEARCH IN YOUR ORGANIZATION

The above mentioned is a bonafide student of Kampala International University pursuing a Masters of Science in environmental Management and development.
He is currently conducting a field research of which the title is **"The effect of Introduced Tree Species on the Soils of Namwasa Forests Reserve, Mubende."** As part of his research work; he has to collect relevant information through questionnaires, interviews and other relevant reading materials.

Your organization has been identified as a valuable source of information pertaining to his research project. The purpose of this letter is to request you to avail him with the pertinent information he may need.

Any information shared with him from your organization shall be treated with utmost confidentiality.

Any assistance rendered to him will be highly appreciated.

Yours truly,

KAMPALA INTERNATIONAL UNIVERSITY
SCHOOL OF POST GRADUATE STUDIES
BOX 20000 KAMPALA

Dr. Roseann Mwaniki
Associate Dean Social Sciences, (SPGSR)

"Exploring the Heights"

Appendix 2: Data sheet (for researcher)

KAMPALA INTERNATIONAL UNIVERSITY

SCHOOL OF POST GRADUATE STUDIES AND RESEARCH (SPGS)

Date of sheet number...

Date...

Forest...

Transcect walk from...............................to..

Plot number...canopy cover..............................

Voucher specimen Number	**Dbh size class distribution (centimeters)**				
	<2.5-4.9	5-9.9	10-29.9	30-49.9	>50

Notes about the tree species characteristics and number of lianas observed

....

....

....

Interactions from;

Technical Foresters..

Appendix 3: Researcher's Curriculum Vitae

CURRICULUM VITAE

Name: Munubi Abdallah

Profession: Environmentalist

Date of birth: 10th October 1984

Nationality: Ugandan

Marital status: Single

Address: Tel: +256776485230

P.o Box 915, Jinja, Uganda

Email munubibob@yahoo.com

Key Qualifications

Bsc Environmental Management, Kampala International University (2009)

Certificate Uganda advanced certificate of education (UACE), Jinja Secondary School (2003)

Certificate Uganda certificate of education (UCE), Kamuli Progressive College (2001)

Other Qualifications

Certificate Strategic Environmental Impact Assessment (SEA) 2011

Certificate Environmental Impact Assessment Methodology (2011)

Certificate Agro forestry Systems and Practices, Fuel wood Conservation, soil and water Conservation practices and participatory rural Appraisal, Kabale district local government in conjunction with Kampala International University (2008)

Munubi Abdallah is a Registered/Certified Environmental Practitioner by National Environment Management Authority (NEMA). He is a member of Uganda Association for Impact Assessment (UAIA) and holds a bachelor of science in Environmental management from Kampala International University. He is a self –propelling, disciplined, and hard working person who is devoted to his work and ready to find a position in the Environment sector and competence in all that concerns the same using the learnt knowledge, experience, skills and all that shall be acquired in the field. A person with commitment to career development, able to get the best from the least (synergy) and with ability to work towards delivery of expected results.

Carrier Objective

To excel in all that pertains mitigating Environment Impacts. Steering our country as well as the east African region into same great and diverse heights as the rest of the world and environmentally and to utilize full potential with a view to remaining relevant to tackle the ever growing changes, challenges and demands facing today's environment.

Summary of Relevant Assignments

2011	Team member (GEO-TAXON CONSULT LTD) for Environmental audits for shell

	petrol stations in Uganda to ascertain whether they comply with environmental laws and to recommend mitigation measures. Team member (GEO-TAXON CONSULT LTD) for Environmental impact assessment for Sure Telecom mask in Kawempe division, Kampala district. Team member (GEO-TAXON CONSULT LTD) for Environmental Impact Assessment (EIA) of the proposed construction of Blisk petrol station in Ambarcot, Jinja Municipal council. Team member (GEO-TAXON CONSULT LTD) for Environmental audit of Jomayi quarry in Mbalala, Mukono district. Team member (GEO-TAXON CONSULT LTD) for EIA of Hared Petrol station in Lugazi, Bwikwe district Team member (GEO-TAXON CONSULT LTD) for EIA of the construction of MIG ware houses in Kikubanpanga Village, Kakiri, Wakiso district Team member (GEO-TAXON CONSULT LTD) for EIA of the construction of Broad band company mast in Kawempe, Kampala district Team member (GEO-TAXON CONSULT LTD) for EIA of the construction of Bliss factory in Masese, Jinja Municipal Council.
2010	Team member (GEO-TAXON CONSULT LTD) for EIA for the construction of the Aluminium factory in Walukuba, Jinja Municipal Council, Team member (GEO-TAXON CONSULT LTD) for Environmental Audits process Tobacco Leaf Factory, Kireka. To ascertain the impacts of tobacco processing activities and assessment of impacts as a result of the operations of the

	factory and recommend mitigation measures for the operations. Team member (WINSJET ASSOCIATES) for EIA Albert Developments limited stone quarry in Kibaale district. Team member (WINSJET ASSOCIATES) for EIA of Casco petroleum overseas limited vessel assembling and repairing yard in Wakiso district. Team member (WINSJET ASSOCIATES) for EIA of Kalisizo stone quarry in Kiruhura district. Team member (WINSJET ASSOCIATES) for EIA for construction of Mukama service station in Ibanda district. Team member (WINSJET ASSOCIATES) for EIA for the construction of Lakeland service station in Kabale district.
2009	Team member (GEO-TAXON CONSULT LTD) for EIA of White sands ecolodge and ecotourism project at Kyewaga forest reserve and lake Victoria shoreline in Kitinda Village, Nkumba parish, Wakiso district Team member (GEO-TAXON CONSULT LTD) in the follow up study on pollution management and ecological restoration of lake George. Team member (GEO-TAXON CONSULT LTD) in the monitoring of the off site socio and economic impacts of Bujagali hydro power project like negative impacts of blasting on the neighboring communities (cracking houses) in Kyabirwa and Namizi in Budondo sub county in Jinja district Team member (GEO-TAXON CONSULT LTD) for EIA of the construction of Orange telecom mast in Buwenge town council, Jinja district

2008	Team member (GEO-TAXON CONSULT LTD) for EIA for the proposed fuelex service station on Mukabya road, Nakawa division, Kampala City council Team member (GEO-TAXON CONSULT LTD) for Environment Impact Assessment of proposed Nile plastics recycling plant in Masese, Jinja district Team Member (Jinja district environment department) in the follow up study of the proposed development in Kalagala falls, Kayunga district

REFEREES

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