ASSESSING THE POTENTIAL FOR FOREST CONCESSION AS A PLANTATION MANAGEMENT TOOL: CASE OF KOIBATEK AND MAJI-MAZURI FORESTS, KENYA

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented in this university or any other for the award of a degree.

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Recommendation by supervisors

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DEDICATION

I dedicate this thesis to my family and siblings, wife, sons Babu, Terah and the only daughter Ada

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ABSTRACT

Public forests all over the world are managed in different ways. Forest concession policy concerns all matters pertaining to the award and management of forest concession and, therefore, influences the achievement of the goal of sustainable forest management. Even though the Forest Conservation Management Act (2017); which is currently used in the management of public forests in Kenya recognizes management of plantations through a license, concession, contract and joint agreement, no efforts have been attempted on any of these management scenarios. The objective of the study is to evaluate and assess the potentiality of adopting forest concession as a management tool in forest plantations using Koibatek and Maji-Mazuri forests as case study. In particular, the research derived the relationship between the various tree attributes for purposes of volume projection. Systematic sampling method using the plot line method was used. This has given the categorization of timber-based industries that the study area can support. Regression analysis was used in deriving the r values. The study determined the long run sustainable yield based on volume projections and industrial capacities that can qualify for concession. Volumes were determined following the method used by the Kenya Forest Service inventory section for comparability. Due to poor management practices, poaching activities led to lower volumes in high rotations. The long run sustained yields show variations in the volume attribute to difference in the stand attributes, based on area and height. The study concludes that the area-based method of categorization of the number of firms to be supported in the study area is quite higher than when volume-based method is used and therefore the volume-based method is more effective and efficient. Finally, the study recommends that there is a need to pilot concession as a forest management tool to rectify the problems encountered in the current scenario to be able to determine the maximum number of timber-based industries that can be supported by a given forest area.

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LIST OF ABBREVIATIONS AND ACRONYMS

CAP	Chapter.
DBH	Diameter at Breast Height.
EIA	Environmental Impact Assessment
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EMCA	Environmental Management and Co-ordination Act.
FAO	Food and Agriculture Organization.
FML	Forest Management License.
FSGO	Forest Service General Order.
IMF	International Monetary Fund.
KFS	Kenya Forest Service.
KNCHR	Kenya National Commission on Human Rights.
LEV	Land Expectation Value.
PELIS	Plantation Establishment and Livelihood Improvement Scheme.
REDD	Reducing Emissions from Deforestation and forest Degradation.
SAP	Structural Adjustment Program.
SDGs	Sustainable Development Goals
TL	Timber License.
UNDP	United Nations Development Program.
UNEP	United Nations Environment Program.

CHAPTER ONE
INTRODUCTION

1.1 Background information

Forest concessions are written mutual agreements enforceable by law, between two or more parties that something shall be done by one or both (FAO, 2001, p.24). Forest concessions are a significant instrument used for allocating public forests to a private individual. According Karsenty *et al*. (2008) concessions refers to the stewardship and use of forests and forest lands in a way, and at a rate that maintains the biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems. There are two classes of concessions that are used in administration of public forestland. These are resource utilization and procurement concessions. In the procurement concessions, agreements are made with other parties to provide goods and services for the management and administration of public forests such as forest certification, tree planting and fire protection. Resource utilization on the other hand involves making agreements to use a particular resource for harvesting, honey harvesting and quarrying activities from the forest (FAO, 2001). In Kenya, the type of concession envisaged is neither procurement nor resource utilization. Currently, license arrangement is used where conditions are given for exploiting mature plantations upon payment of royalty that is determined by the Kenya Forest Service inventory section.

The Forest Conservation Management Act, 2017, laws currently used to govern forestry, defines "concession agreement” as authorization which is a long-term agreement issued by the Service for the management of a specified forest area at a price determined after forest valuation and bidding. Specifically, it defines "forest concession" as the right of use granted to an individual or organization in respect to a specific area in a national or county forest by means of a long-term contract for the purpose of commercial forest management and utilization.

Forest management objectives generally imply desired forest organization outcomes. According to Leuschner (1984, p.32) “these outcomes are always the goods or services produced by the forest as the objects of forest management”. The stratification of the forest management objective is a challenge based on the different users’ group. Mills want timber, hunters want game and backpackers want undisturbed wilderness. The objectives can change depending on which user group becomes dominant over time. Therefore, management objectives are a mixture of several management objectives. This depends on the owner's objectives and the relative importance placed on them. Assigning relative importance is one reason for valuation (Leuschner, 1984). This therefore calls for a clear understanding of the objectives behind any forest establishment to avoid conflicts of interests in future. In Kenya, the concessions are signed at the time and when the authority deems necessary, thus creating conflicts. In the Agenda 2030 and its 17 Sustainable Development Goals (SDGs) have globally brought about the political devotion to forests and their sustainable management. Forest concessions being a predominant tool for the sustainable management of public production natural forests in the tropics, there is a poor relationship between the SDGs and forest concessions (Tegegne *et al*., 2019). However, Forest concessions have improved the livelihoods, health and education of local communities and have contributed to forest conservation and helped build public infrastructure in remote areas (Belcher, 2005).

It is on this premise that this study was conceptualized to assess the possibility of adopting forest concession as a management tool in Kenya. In particular, the relationship between the various trees' attributes such as basal area, tree height and diameter at breast height has been used for purposes of volume projections. This has been used to determine the long run sustainable yield based on the volume projections of the total area. Consequently, timber-based industry that the study area can support given its resource has been categorized.

1.2 Statement of the problem

The FMCA (2017, p.19) stipulates the conditions for forest concession requirement. It gives the conditions in which an agreement can be made or terminated. However, it is interesting that despite this legal stipulation, no piloting or research of concessions has been done in any of the forests in Kenya. Since the introduction of plantations in Kenya, forest management strove to create a fully regulated forest that optimized financial returns from the overall land base. Harvest planning tools were to be used to predict the financial returns from alternative silvicultural regimes that improved plantation growth.

However, despite the revision of the original harvest scheduling models caused by human based activities such as poaching, encroachment and natural calamities such as diseases and forest fires, the technological developments of mathematical programming methods to solve realistically sized forest harvesting scheduling have not been embraced. Instead, the traditional stand volume tables of *Pinus patula* (developed for Timboroa area) *Pinus radiata* and *Cupressus lusitanica* (general) species developed decades ago are still in use (Mathu, 1983). This therefore has triggered the need to look at other alternative mathematical programming techniques that will assist in harvest scheduling for such a study area.

The result of the irregular excisions and illegal logging has reduced the forestland and forest cover since independence. This is both ecologically and hydrologically unsustainable, and falls short of the internationally recommended minimum of 10% forest cover. Meanwhile, the current backlogs in the forests have not been addressed adequately. This study is therefore, concentrated on the assessment of the significance of concessions for forest plantations sustainable utilization and effective management.

1.3 Objectives

1.3.1 Broad objective

To assess the significance of adopting forest concessions as a plantation management tool in Kenyan forests.

1.3.2 Specific objectives

i. To assess the best forest attributes for volume projections for effective management and sustainable utilization of the forests.
ii. To determine if the long run sustainable yield can be projected using tree volume of the total area.
iii. To evaluate the various types of timber-based industry that can be supported on long run sustained yield basis within the study area.

1.4 Hypothesis

i. Tree height and diameter are not the best forest attributes for volume projections for effective management and sustainable utilization of the forests.
ii. The long run sustainable yield cannot be projected using tree volume of the total area.
iii. There is no timber-based industry that can be supported on long run sustained yield basis within the study area.

1.5 Justification

The major problem affecting forest ecosystem in Kenya does not stop with demonstrating that they have a high economic value. Despite many studies attempting to value the benefits of forests, forest valuation remains a purely academic exercise. Yet, however high the value of forest environmental benefits is demonstrated to be in theory; it has little meaning unless it actually translates into real returns, rewards and profits for the groups who are responsible for sustainable forest management. Therefore, overcoming the information gaps about the value of forest ecosystem is only a first step in a much longer process. This has triggered the need to understand the actual value of the plantations in the study area and capturing forest benefits as real values that are involved in sustainable forest management.

In the recent times, United Nations conventions on the climatic change has been revolving around the need to improve the forest cover, reduce carbon emissions and who to fund what on limiting environmental degradation. The way forward on increasing forest cover lies on the management formula applied. In 1997, for instance, the Kyoto protocol accord recognized the need to increase the forest cover in all countries to 10%. Fourteen years later no formula has been found on how this can be achieved. This is in addition to curbing of illegal logging and poaching, which has been rampant. Instead, a ban on logging is in place on a resource, which is not only on demand, but also a resource, which is perishable and can be managed sustainably.

The end of 2009 also saw the United Nations Climate Convention Summit in the Danish capital in which countries agreed to ‘take note’ of a document entitled the “Copenhagen Accord”. The Accord recognized the crucial role of forests in addressing climate change, stating that there was a need to recognize reduced emissions from deforestation and forest degradation (REDD) via the immediate establishment of a mechanism to enable the mobilization of financial resources from developed countries (FAO, 2001, p. 20). The summit is to seal a final deal by the end of December 2011 for it to succeed the Kyoto protocol (Schmithusen, 1995, p.23).

The concerns raised in the climatic conventions therefore have provoked the need to look at other alternative options in the management of forests in Kenya (GoK, 2005, p.33). This is clear from the trend of traditional forest management system in Kenya coupled by now the need for collaborative approach in management of forest resources. Could forest concessions be one of the best options to remedy Kenya’s situation?

Furthermore, according to the Forest Conservation and Management Act 43 (2), gives the forest service the powers to enter into any forestry management agreement. Specifically, the act allows for forest concession as a management option in Section 44 (1). It is in this regard that there is need to assess its potential (GoK, 2005, p.33). Concurrently, the Kenyan

Constitution in chapter 5, part 71(1), recognizes management of natural resources through agreements and concession subject to ratification by an act of parliament. As the process of the implementation of the new constitution continues, the need to engage on the study of frameworks of natural resource agreements and issues involved in forest concession is wanting (GoK, 2005, p.34).

The great question asked by Clawson (1975, p.9) “Forests for whom and for what?” triggered the need of this study if the answer could be the same for all forests everywhere; especially in Kenya. This is due to the current knowledge of what is needed to sustain the regenerative capacity of forest ecosystem to meet current and anticipated needs. To date, very little empirical research has been done on the subject, particularly on its impacts on forest management. Past research has focused mainly on the determination and distribution of stumpage.

1.6 Assumptions/Scope and Limitations

The research was carried out in Koibatek and Maji-Mazuri Forest stations as case studies. Additionally, it was due to the vast areas of plantation in the forests and possesses plantations that are facing mixed management and utilization goals from the different stakeholders. The forests have up to a total of 6,442.9 hectares of plantation area. Considering the Teel (1984) classification of climatic zones in Kenya, Koibatek and Maji-Mazuri forests fall under the Afro-Montaine forests classification with cool wet areas. Rainfall patterns are between March to June, for long rains and October to December for short rains. This makes it suitable for plantation establishment. This could be used entirely for commercial forestry for the purposes of the existing timber industries.

The zoning of the forest is such that plantation areas are mixed up with pockets of natural forests. However, the study entirely concentrated on the plantation area only. The study did not look at the viability of forest concession in the natural forests with focus on its contribution to services such as eco-tourism, water resources and wildlife habitat, which has contributory monetary value to the forest. Therefore, the first step was meant towards regulating the forest.

1.7 Definition of Terms

Annual Growth Refers to the yearly growth of a tree or forest stand. It is expressed as increase in basal area and average tree diameter.

Canopy	The top layer or cover in a forest made up of tree’s crowns.
Diameter at Breast Height	The point on the trunk of a tree that is 1.3 meters above the ground level.
Forest Act	The government legislation designed to protect the forests from undesirable activities.
Forest regulation	This is the process of converting a forest with an unbalanced age class distribution into a regulated forest.
Regulated forest	A regulated forest is one with an equal number of acres in each age class.
Stand Density	A quantitative expression of stand stocking, expressed in number of trees per hectare.
Stumpage fee	The monetary value of a tree.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The decision to award forest concession areas to individuals or private timber companies is influenced by the objectives for awarding such areas. These objectives include the need to develop forest industries, stabilization or improvement of these industries, introduction or improvement of forest management, and the preservation of forestlands (Schmithusen, 1995, p.3). The guiding principle should be that a forest concession area should be awarded to a party who has interest and capability to manage the forests perpetually. To ensure this, the concessions need to be evaluated to determine that the end users of the forests' resources are utilizing them in a sustainable basis, hence the need for the assessment.

The relationship between the forest concession holder and the government is controlled by a contract known as a forest utilization contract or agreement. The main purpose of the contract is to recognize and legalize the rights and responsibilities of the concession holder and the government in the management of forest within the concession area. Such contract incorporates many elements which include rights and obligations of the concession holder, contract duration, extent of forest area, forest management planning, and determination of forest fees (FAO, 2001, p.21).

Another important element is the extent and type of the forest area that is awarded to the concession holder. Theoretically, the size of the area should be determined based on the potential of the concession holder because the area size influences the management efforts required. In order to facilitate enforcement of any contract, the boundaries of the concession area should be demarcated on the concession map as well as on the ground (FAO, 2005, p.24). Nevertheless, this is not the case in Koibatek and Maji-Mazuri forests. Why?

A recent report by the World Wildlife Fund (WWF) suggests that a significant expansion of the area of intensively-managed forest plantations could allow the world's major forest products companies to meet a substantial share of the global demand for industrial round wood from a relatively small proportion of the world's forest area, and open up new opportunities to provide outright protection to high conservation value forests, particularly those with globally-significant biodiversity values (Howard & Stead, 2001, p.11). Unfortunately, this is not the case in Koibatek and Maji-Mazuri forests.

World-Wide Fund for nature is so convinced of the value of this approach that they have called upon the world's ten largest forest products companies to collectively increase the area of intensively-managed forest plantations by 5 million hectares per year—for the next 50 years, through concessions (WWF, 2001, p.22). With this level of investment, WWF estimates that as much as 80 percent of the world demand for industrial round wood in 2050 can be met from less than 20 percent of the world's forests. Forest concessioning is therefore adapted as a management method to ensure the availability of the demand for round wood. This is applicable for plantation management purposes. Natural forests can also be managed in the same way for conservation purposes.

2.2 Legislation and contracts

Legislative frameworks in many jurisdictions establish the basis for policies that directly or indirectly affect the management and use of forests on public land. In many countries, the constitution defines the ownership and legislative authority over natural resources, and therefore impacts directly on the design and the implication of procurement and resource utilization contracts. For example, the Mexican Constitution states that, regardless of their land tenure, all forests belong to the nation (Castilleja, 1993, p.48).

Other countries, such as Kenya, have a similar legislation. Therefore, it is important that the national constitution establish an enabling environment for the sustainable use and management of public forestlands (Schmithusen, 1995, p.27). It is prudent to think that the availability of the constitution, the legislative framework and the forest concession is an opportunity for judicious forest resources management. However, this is not the case in Koibatek and Maji-Mazuri forests.

Weak legislations inherited from the Colonial Administration, which ignored joint forest management together with laxity among the implementing personnel in the then Forest Department resulted into encroachment and excisions leading to reduction of forest cover to dangerous levels (Aywaa & Oloo, 2001, p.40). This is ecologically and hydrologically unsustainable. One of the major faults in this scenario was non-involvement of the adjacent communities into the conservation of the forests.

Limited facilitation and support by the government agencies and departments in terms of enumeration and the working infrastructure has been prominent. Consequently, the staff becomes less motivated thus reducing the performance levels. Massive and wanton excisions have been experienced within these regions which can be attributed to political influence and weak legislation. Some excisions went on even after the enactment of Environmental Management and Co-ordination Act of 1999 (KNCHR, 2007, p.21) which subjects any changes in land use to an Environmental Impact Assessment. In some cases, forest areas were left for issuance of selective title deeds such as Karura and Ngong' Forests.

A majority of the forests in tropical region are owned by the government and managed by government departs or agencies. The effective management and sustainable utilization of forests therefore will depend on the nature of government policies. Policies outside the forestry sector include those that relate to agricultural settlements, industrialization incentives, land tenure, concentration of land holdings, and overvaluation of local currency. The challenges within the current management strategies includes neglecting for non-timber resources, timber cutting rights, undifferentiated timber charges and poorly drafted policies and regulations (Repetto & Gillis, 1988, p.16).

Historically, many countries have chosen public sector management, public institution and government command and control as a means of providing public goods, remedying market failures, resolving environmental issues and influencing the distribution of income and wealth (Shirley & Nellis, 1991). In particular and more specifically, the forest sector in Kenya has been heavily dependent on public sector management by public institutions (Ljungman, 1994, p.15).

In the early 1980's conservative governments in the United States and the United Kingdom began what became a worldwide trend towards government down-sizing, reversing the policy of government production and privatizing many traditionally public sector functions. This included the increased use of contracts with the private sector. Primarily driven by Structural Adjustment Programmes (SAP) of international lending institutions such as the World Bank and the IMF, the trend spread to many developing countries in mid-1980's, to the agriculture and forestry sectors as well (Morell & Paveri, 1994, p.17).

Forest concession contracts, which predated this trend, have been an instrument of forest policy in many countries from the 1980's. Grut *et al*. (1991, p.9) stipulated that "to achieve success with forest contracts, governments must first strengthen their administrative capacities in the design, allocation, supervision and enforcements of forest contracts".

Decentralization is one of the public policy reforms that many governments have aggressively applied in recent years as part of domestic processes to democratize their country's political system, or in response to pressure from international agencies or both. Although decentralization has focused mainly on the provision of social services, numerous countries have begun to give local governments more rights and responsibilities over their natural resources, including forests. Some studies show that decentralization has diverse and sometimes contradictory results in practice, depending on variables such as the political economy of the municipalities, the composition of their government and the importance of forest resources to their economy, among others (Anderson, 2002, p.42).

Ribot (2001, p. 18) indicated that decentralization is a process that brings with it both opportunities and threats. The important thing is to recognize both and make this process contribute more efficiently to improving the distribution of forest resources and, facilitate more democratic decision-making and forest conservation. It is for this reason that brings the importance of evaluating the country's decentralization model and its implications, in association with other factors such as the system of existing stakeholders' participation and the existing forestry regulations within which the Kenya Forest Service is mandated. Currently, annual felling plans are drawn for every ecosystem conservancy managed by the KFS.

The core functions associated with the management, utilization and conservation of public forests can be assigned to one or more organizations or groups in any administrative structure (Ross, 1988, p.11). Further, forest management contracts alter who are the producers of forest outputs, forestry inputs or services. Forest management contracts out producer activities such as forest inventory, forest management planning, and silviculture, reforestation and fire protection. Consequently, procurement contracts include obligations by the contractor to provide goods and services for public forests, for services such as road construction or maintenance, forest protection, forest monitoring (FAO, 2001, p.21). Both types of contracts may be combined in a single contract that includes both rights and obligations. Forest management concessions, combine forest utilization of goods and services procurement contracts. They provide rights to timber, but require the concessionaire to undertake a variety of forest management activities.

In Kenya Robinson (2010) designed a model timber concession agreement which is a typical of a forest agreement that can be adapted by the Kenya Forest Service, the custodians of Kenya gazetted forest. As well, other agencies like Kenya Water Towers could adopt similar agreements for purposes of conservation of natural forests. This is referred to in appendix D.

2.3 Forest protection

A study of tropical forest management undertaken for the International Tropical Timber Organization, found that less than 1 % of natural tropical forests (under 1 million hectares) were under sustainable forest management (Poore *et al.*, 1989, p.27). A number of people have challenged the viability of sustainable forest management of tropical, temperate or boreal natural forests. One argument is that forests can only be conserved in protected areas free from logging (Bowles *et al.*, 1998, p.15). Another view is that it is not possible to control logging, therefore, under certain circumstances; areas should be set aside after logging and protected from incursion or relogging (Rice *et al.*, 1999, p.33).

However, given pressures for land and resources in most countries, protection alone is likely to be of limited success. The costs of protection and enforcement, the lack of resources available for protection, and the domestic needs of countries for forest products mean that a policy of protection is unlikely to succeed. Protection following logging is also likely to be of limited success given the pressures on land in many countries.

Agricultural incursions following logging are common to many tropical countries (Angelsen, 1999, p.12). Community Forest Association were formed for purposes of not only establishment of plantation, but also maintenance and protection of the forests. However, it has been noted that a few of the CFA'S do contrary to the agreements by serving their interests, especially the officials (KFS, 2001, p.14).

2.4 Forest concession around the world

2.4.1 Forest concessions West and Central Africa

Concessions are covering nearly 56 million ha in West and Central Africa (50 million ha for Central Africa. It has also provided direct employment for at least 135,000 workers in countries of West (Liberia, Ghana, Côte d'Ivoire) and Central Africa (Cameroon, Congo, Gabon, DRC, CAR and Equatorial Guinea) (Karsenty, 2016). The informal sector is likely to provide many more jobs in populated countries such as Côte d'Ivoire, DRC, Ghana, and Cameroon, according to estimates. In Cameroon, more than 100,000 jobs are created and 15,000 permanent jobs. Additionally, it is estimated that one permanent job in Central Africa sustains the livelihood of 10-12 relative (Karsenty, 2016). Forest concessions of various types are the dominant form of forest tenure in almost all the forest countries of West and Central Africa: Liberia, Cote d'Ivoire, Ghana, Cameroon, Gabon Congo, the Democratic Republic of the Congo, and the Central African Republic (Grut *et al.*, 1991, p.10). In Gabon logging concessions cover 11.9 million hectares, 56 percent of the forest area of the country (World Resources Institute, 2000, p.3). In Cameroon logging concessions cover 17.3 million hectares, 76 percent of the forest area, with over half of the area in abandoned concessions (World Resources Institute, 2000, p.3).

2.4.2 Forest concessions South-East Asia

Forest concessions are the dominant forest tenure in Malaysia (Peninsular Malaysia, Sabah and Sarawak), Indonesia, Papua New Guinea, and Cambodia. In Indonesia the 427 forest concessions active in 1998 covered 52.3 million hectares and logged 15.6 million cubic meters of wood, logs, 53 percent of the total official harvest (World Bank, Operations Evaluation Department, 2000, p.28). Another 34 percent, 10 million cubic meters of the official harvest came from land clearing. Cambodia has 24 concessions, covering 4.6 million hectares, about 44 percent of Cambodia's 10.5 million hectares of forest (Fraser *et al.*, 2000, p. 19). A further 12 concessions, covering an additional 2.3 million hectares were cancelled in 1999.

2.4.3 Forest concessions Latin America

Forest concessions are dominant forest tenure in Suriname, Guyana, Venezuela, Bolivia, and Nicaragua. In Suriname for example the 32 concessions cover 712,000 hectares, expired concessions 560,000 hectares, Incidental Cutting Licenses (shorter-term concessions that do not require a management plan) 567,000 hectares, and exploration licenses for potential licenses a further 1.3milion hectares, a total of 3.2 million hectares, 22 percent of the total forest area of Suriname (Mitchell, 1998, p.18).

Other Latin American countries have also had experience with forest concessions. Guatemala has established 13 community and 2 industrial forest concessions in the Peten region (Carrera *et al.*, 2000, p.18). Peru has developed forest concession procedures and is planning to auction over 20 concessions in the Biabo Forest in the Amazon (Toledo, 2000, p.33). Brazil is moving towards adoption of a forest concession system and learning from the experience of other countries. Brazil recently experimented with auctioning a first concession in the Tapajos region of the Amazon.

2.4.4 Forest concessions North America

Canada has a variety of types of forest concessions, area based and volume based, tree farm licenses and other licenses, short- and long-term timber sales (World Resources Institute, 2000, p.19). These forest tenures differ among the 10 provinces and two territories

(Nunavut Territory is non-forested), each of which has its own forest legislation and administration, providing a diverse portfolio of forest management experiences. These tenures cover 220 million hectares, 77 percent of the commercial forest area (World Resource Institute, 2000 p. 19), they represent an annual allowable cut of approximately 180,000 cubic meters per year, 83 percent in long term tenures (Haley & Luckert, 1990, p.7).

2.4.5 Forest concessions challenges compared around the world

Many of the issues in management and operation of forest concessions stem from the complex nature of the forests. Other concession issues are social, institutional and administrative. These issues are shared among a large number of tropical forests developing countries, as well as with a number of forested temperate developed countries. The specifics of problems vary among countries, but the basic issues and problems are common. Thus, opportunities exist for countries to learn from their shared experiences.

Concession problems common to a number of developing counties involve biological issues related to the nature of the forests; environmental issues related to the non-timber outputs and environmental impacts of logging and forest management; social issues related to local community use, impacts and benefits; and administrative issues related to the supervision and control of logging and forest activities, setting forest fees and revenue collection.

2.4.6 Forest concession fees

There are various types of concession fees. These include initial fees, annual concession, and area-based and fixed price contract concession type of fees. The initial fees are paid up on a one basis upon application or the granting of a forest concession. FAO (2001) recognizes an initial license fee based on the productive forest area, or operating area, would require completion of the forest inventory. The initial fees have been used in a number of countries. In most jurisdictions, initial license fees on long-term timber supply agreements are very modest. For instance, Cameroon has levied initial concession fees based on the total license area.

Grut *et al*. (1991, p.24) defines annual fees as the amount paid yearly and based on the area of the concession. They recognize the fees as much more significant source of forest revenues. Annual concession fees are levied in a few of West and Central African countries; including Cameroon, Cote de Voire, Congo and Gabon. In most of these countries annual concessions are based on the total area of the concession. In Congo, it has been based on the annual allowable cut.

Usually, concession fees set at a reasonable level can serve a number of forest management functions. Concession fees can reflect the security value of a guaranteed timber supply provided by the contract and capture such values as revenues. Concession fees that put a price on this security value will help to reduce the speculative acquisition of large concession areas. Moreover, concession fees set to reflect the conservation and preservation values of forest areas, the alternative uses and the opportunity cost of logging an area, will further discourage the acquisition and retention of such areas (Boscolo &Vincent, 1998, p.16).

Minimum forest fees ensure those timber and forest contracts are not given away with little return to the country. They may be set to reflect the value of the timber or forest areas in other uses (environmental protection, wildlife, forest foods, watershed protection, and biodiversity). These non-timber benefits can be of a significant (Bishop, 1999, p.10).

Under a fixed price procurement contract, the government fixes a sum of money independent of other factors. The contract price is simply the amount of a firm's bid or negotiated contract price. It has been classified as the simplest method and common form of government contract in procuring goods and services (Cassidy, 1994, p.19). Palmer and Marshall (1996) indicates that, concession fees are much easier to collect than the volume-based stumpage fees, an important practical advantage in most countries. Concession fees have thus been recommended to replace or supplement difficult to collect, easily evaded volume-based stumpage fees in a number of countries.

Concessions are too often allocated in an arbitrary fashion, inviting corruption. Persons with little knowledge of the forest industry, or no intention of entering it, are sometimes awarded concessions that they then sell or contract out (World Resources Institute 2000a). Forest values, which should go the government, as owner of the forest, are dissipated elsewhere. When there is adequate competition, concessions should preferably be allocated through bidding, Concessions sold by bidding can also provide an indication of what should be charged on concessions where competition is not possible (Gray 1983; Gray & Hadi, 1989). Competitive allocation has advantages. It avoids administrative decisions to choose among competing applicants and reduces the potential for bribery and corruption. It allocates concession areas to those processors to whom they are most productive and valuable. Finally, it generates revenue to the forest owners, be they governments or local communities. Bidding has another advantage, the prices bid for concessions provides a market based indicator of whether forest fees on the timber harvested are at the right level. If forest fees are low, profits from harvesting timber will be large, concessions financially attractive, and the "bonus prices" bid for new concession will be high. On the other hand, if forest fees fully reflect the value of the standing timber on concessions, then the bids for concessions will reflect only the security of timber supply value of concessions.

Auctions and sealed tenders have been used to varying degrees in allocating forest concessions in Venezuela, a number of Peninsular Malaysian states, as well as in Sabah and Sarawak, Ghana, Côte d' Ivoire, and the Congo (Gillis 1992; Grut *et al*., 1991). Honduras has used auctions in the sale of pine timber under short term timber sales (Gray & Hãgerby, 1997; Rybum 1997). Cameroon has had a varied success with auctioning concessions starting in 1996 (World Bank Operations Evaluation Department 2000b). The uneven success was mainly the result of uncertainty and confusion of the sale conditions, an uncertain commitment by the government to the auction process, and not having fully specified the procedures and conditions (World Resources Institute 2000d). Changes have been made, procedures tightened, an independent observer appointed, all of which improved transparency and accountability (World Resources Institute 2000d). Cameroon's auction experience provides useful lessons for other counties in improving forest concession allocation. Brazil recently auctioned a first concession in the Amazon on a second attempt. Largely as a result of the newness of the process and uncertainty on the part of potential bidders there was only one bidder and the bid was low. Nevertheless Brazil gained experience in the process, and perhaps the advantages of proceeding slowly. Peru is planning the auction of managed forest concessions in the Biaba Permanent Forest in the Peruvian Amazon under the auspices of the World Bank and World Wide Fund Forest for Nature Forest Alliance.

The Biaba Forest project will bring 2.18 million hectares under management, over 1 million hectares as protected forest, and 631,000 hectares managed under the proposed forest concession system. Toe project includes the design of the proposed bidding and auction system, forest management supervision, inspections and monitoring procedures and capacities, management of protected areas and community participation in forest management and monitoring. In 1999 Indonesia announced its intention to auction 3 million ha of expired concessions (Reuters, 1999). However, this would require the procedures and conditions for auctions, performance bonds, etc. be put in place (World Resources Institute 2000d). As is apparent from the country experiences, auction procedures need to be clearly defined and adhered to and under tight control, to ensure that bidding is competitive and that concessions are awarded to the highest bidder, or to the highest ranking bidder where technical competence and other factors are considered. Bidding conditions can be tailored to the country's industrial strategy. For example, to prevent large companies from acquiring large areas, concessions could be auctioned in small but manageable units and small companies without concessions given bidding preferences. To ensure independence, concession allocation procedures might be entrusted to an independent auctioneer and monitored.

Forest concession fees are levied in only a few countries, but they generate little revenue. They are modest, even token fees, and generally from less than one per cent to at most levied per cent of forest revenues. Examples of initial concession fees are found in several West and Central African countries (Côte d' Ivoire, Cameroon, Gabon, and Central African Republic), Indonesia, and Nicargua (Gray & Hadi 1990; Grut *et al*., 1991; Gray & Hagerby, 1997). Annual concession fees are levied in a few West and Central African countries (Côte d'Ivoire, Cameroon, Gabon, Central African Republic, and Congo Indonesia, and Nicaragua, for example (Gray & Hadi 1990; Gray & Hãgerby 1997; Grut *et al*., 1991). Concession fees set at reasonable levies can serve a number of forest management functions (Gray & Hãgerby, 1997; Gillis, 1992; Hyde & Sedjo, 1992).

The level and structure of forests can have important incentive effects on concession performance, logging methods, adoption of low impact logging, compliance with diameter limits, utilization of species, etc. (Boscolo & Vincent 1998; Gray, 1983; Grut *et al*., 1991; Karscnty, 2000). Prepayment of forest fees will ensure that concessionaires are up-to-date with submission of their fees. Existing research suggests that forest taxation often generates low levels of revenues compared with the market value of the resource, and that certain groups and individuals with access to the resource earn large windfall profits (Gray 2002; Hansen & Lund, 2011). Moreover, benefit-sharing arrangements are often not transparent to forest-dependent people: they have little chance of knowing the revenues involved or in gaining a say in how and for what purposes such revenues should be used (Cerutti *et al*., 2010).

2.5 Harvest scheduling

Harvest scheduling determines the age distribution, forest structure and the flow of forest products; hence forest revenues and costs. Leuschner (1984) recognizes that it is one of the most complex decisions because the entire forest should be scheduled to obtain optimal productivity. Thus, harvest scheduling is a natural application for mathematical programming.

According to Leuschner (1984) amongst the earliest work on mathematical programming were done in 1966 by Kidd, Thomson and Hoepner. Ware and Clutter then followed in 1971. Since then, many models have been developed- for example (Tedder *et al*., 1980a, p.18). Many of these use linear programming techniques to optimize an objective function. Most of the linear programming harvest scheduling models follows the procedure in Ware and Clutter (1971, p.27).

2.6 Mathematical programming methods

According to Leuschner (1984, p.24) mathematical programs are techniques or specific algorithms that allocate resources to optimize a particular objective. Optimizing means either minimizing or maximizing the objective, which is stated as an objective function. There are many types of mathematical programs. Ware and Clutter (1971) notes that programs exist that may not precisely fit into a category or ambiguously defined.

As plantations replaced natural stands, foresters strove to create a fully regulated forest that optimized financial returns from the overall land base under management (Davis, 1966, p.11). The introduction of linear programming as a forest-planning tool in the 1960s was a major advance in this effort. Improvements in computers in the 1960s made it possible to use linear programming techniques to solve realistically sized forest harvest scheduling problems for the first time (Clutter *et al*., 1983, p.18).

Simulation model on the other hand is a computer model built of a real-world system using mathematical or logical relationships. This model is then used to perform experiments. Data generated by the experiments are analyzed, often using statistical techniques as in any other data analysis, and conclusions drawn about the real-world system (Leuschner, 1984, p.24).

Ware and Clutter (1971) recognizes that, there are many forestry examples in which experimentation is not possible. Perhaps growth and yield prediction are one of the best. Here, the time required to experiment with different plantation spacing or thinning regimes makes experimentation on the real-world system impossible. Computer models simulating the growth of forest stands, allow analysis of different spacing and thinning regimes in a matter of minutes rather than decades. Therefore, growth and yield simulations not only show

how a forest stand will behave through time but can also indicate the spacing necessary to optimize yield.

2.7 Exclusiveness in use of forest properties

Exclusiveness refers to the extent to which the holder of the property may claim and secure sole use rights to the property, to the exclusion of others. The feasibility and power to exclude others is a key dimension of property right, with important economic implications (FAO, 2001, p.20). The degree of exclusiveness can vary across a spectrum (Gray, 1997, p.17). At one extreme, traditional freehold tenure usually provides the owner with a strong legal right to protect his or her interests against any intrusion by others. At the other extreme, with open access resources, everyone has a right to use resource, and no one has any right to exclude anyone else. Common property is also another in which two or more people can hold right to the same resources.

Therefore, exclusiveness of rights is an important factor to consider in the design of contracts. The exclusiveness of users' rights can have a profound influence on the way contract owners use and manage resources. If users compete for the same resources, each is likely to exploit it inefficiently. In their effort to protect their own share or increase their share at the expense of others, they will tend to exploit the resources too rapidly. No one will have an incentive to conserve reserves for the future, or to invest in future growth and yields, because they cannot expect to capture the benefits of their efforts (FAO, 2001, p.20). The majority of tropical forests, including those in Indonesia, is state forest that is managed under concession or permit system (Karsenty *et al*., 2008). Forest permit system has become the primary form of forest tenure and forest management (Burgess *et al*., 2012; Gray 2002; Walker & Smith, 1993). Forest permit refers to a contract between a forest owner and another entity that permits the use and/or management of forest resources in a specified area at a definite time (Gray, 2002). Forest permit system has become the primary form of forest tenure and forest management (Burgess *et al*., 2012; Gray 2002; Walker & Smith, 1993). Forest permit refers to a contract between a forest owner and another entity that permits the use and/or management of forest resources in a specified area at a definite time (Gray, 2002). It may consist of utilization rights of forest resources (timber, non-timber, area and services) and management obligations/ responsibilities (for examples environmental protection and biodiversity conservation) embedded in that permit. The majority of forests in Indonesia is also state forest and managed under concession or permit system (Karsenty *et al*., 2008).

Forest permit system has become the primary form of forest tenure and forest management around the world (Burgess *et al*., 2012; Gray 2002; Walker & Smith, 1993).

2.8 Duration in a contract

The duration in a contract is the length of time over which the rights extend (Gray, 1997, p.19). It has important implications on the resource users' behavior. Private freehold ownership of land conveys rights in perpetuity. Leases and licenses normally have a shorter, finite term. The duration of property right is important because it determines the extent to which the holder will take account of the future impact of his/ her actions.

If the rights over a forest extend for a long period, the holder will consider the relative economic advantage of investment in silviculture and forest management that yields benefits over many years (FAO, 2001, p.18). But if the rights will expire over a brief period, they will disregard future benefits that they may not capture. There is some evidence from Indonesia that short-term tenures, renewable upon forest management performance, have provided a much stronger incentive for forest management than have long-term tenures (Gray & Hadi, 1997, p.26).

Therefore, for plantation forestry, because forest growth and silviculture yield return over a longer time, the duration of rights over forestland is especially important. Unless their rights extend over the full period needed to grow forest crops, those who harvest timber will lack adequate incentives for planting, reforestation and forest enhancement. In an empirical test simulating concessionaire behavior, Boscolo and Vincent (2000) demonstrate that under longer concessions loggers have little incentive to adopt reduced-impact logging, or to comply with minimum-diameter cutting limits.

However, for tropical natural forests and other slow growing forests managed under uneven-aged silviculture, shorter-term tenures, renewable against demonstration of sustainable forestry practices, may provide better incentives for forest management (Boscolo & Vincent, 2000, p.50). Where growth rates of tropical forests (in volume and value) are low, below rates of return on other investments, concessionaires have no incentive to manage the forests, even under long term, or secure tenure. Concessionaires will liquidate the forests and invest the proceeds elsewhere at a higher rate of return in an empirical test simulating concessionaire behaviour Boscolo and Vincent (1998) demonstrate that under longer concessions loggers have little incentive to adopt reduced-impact logging, or to comply with minimum-diameter cutting limits. In practice, under slow growth rates of tropical forests, short-term tenures may result in better forest management performance.

2.9 Concession size

Forest concessions can vary enormously in size among countries as well as varying greatly in size within countries, from a few hundred to tens of thousands of hectares (Grut *et al.*, 1991, p.45). In some countries concessions are too small to support viable silviculture, logging and transport units. More often concessions are too large; often well beyond the needs of concessionaires. In Cameroon the ten largest concession owners held 50 percent of the area, the 25 largest held 75 percent of the area. The largest concession holding was 650,000 hectares (World Resources Institute, 2000, p.33).

Concessionaires may often acquire large forest areas, more for future "insurance" purposes, or speculation, leaving large areas of forest locked-up and public forest resources idle. Large concessions with excess timber supply have little incentive to utilize the timber efficiently, or to practice more intensive forest management. High-grading and wasteful logging is encouraged. In addition, with excess forest area, concessionaires have little incentive to control agricultural or other types of encroachment. In Gabon the 12 largest concession owners, 5 per cent of the owners, held half of the concession area, equal to 21 per cent of Gabon's total forest cover. The remaining 209 concession owners held the rest. The largest holding was 699,000 hectares (World Resources Institute 2000a). In Indonesia, in 1989, with 557 concessions covering 58.8 million hectares, the top 4 concession owners held 9.87 rnillion hectares, 17 per cent of the total concession area, a high degree of concentration (Gray & Hadi, 1989). In Canada, in British Columbia, the biggest forest province, the top 10 forest companies hold 59 per cent of the annual allowable cut, a volume of 41.8 million cubic metres per year (World Resources Institute, 2000c).

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2.9.1 Environmental impact assessment in resources extraction

The most challenging thing in forestry globally erupts when integrating diverse forest values within policy and decision-making processes (Hanna & Raitio, 2011). The use of environmental impact assessment (EIA) provides potential for improving forest conservation and making sure that the responsible or forest custodians utilizes forest resources sustainably and reduce conflict of interests (Takoukam, 2011). Environmental impact assessment is a systematic, stepwise procedure, which gathers information and evaluates the likely impact of the change of circumstances that might result from implementation of a management programme. An important aspect in EIA is to ensure that adverse impacts of harvesting activities- road design and construction, cutting, extraction, landing and transport operations- are minimized. Bishop (1999) stipulates that, the maintenance of environmental values and services should be supported by revenue from wood production, except where forestland is located in places not zoned for production.

The environmental impact assessment is useful tool for any practical forest management. Minimizing the adverse environmental impacts in the planning and practical implementation of tropical forest operations is a basic principle of sustainable forest management. According to FAO (2000) at all stages in forest management, like wood harvesting, silvicultural operations, forest protection, harvesting of non-wood products or other activities, forest managers should safeguard the integrity of both land and forest through planning and sensitive implementation of forestry operation. The privatization of tropical forests is named as the first out of a list of nine key issues by Gray (2002) because "tropical natural forests have too many nonmarket, environmental, and non-timber public benefits" that would be ignored by the concessionaires as there is no revenue for them. "Privatization is appropriate only for fast growing forest plantations that produce few non-timber, environmental, and biodiversity benefits". The main concern, raised in numerous publications, is about the contribution of the concession systems and the actual activities of the concession businesses to reduced impact management and avoiding any destruction of tropical forests. Gray (2002) gives a critical assessment of the experience.

The privatization of tropical forests is named as the first out of a list of nine key issues by Gray (2002) because "tropical natural forests have too many nonmarket, environmental, and non-timber public benefits" that would be ignored by the concessionaires as there is no revenue for them. "Privatization is appropriate only for fast growing forest plantations that produce few non-timber, environmental, and biodiversity benefits" There are also ways to maintain public control of forest concessions, but to contract out to the private sector certain forestry activities; harvesting operations as well as regulatory functions, or services such as forest inventory, scaling and grading, inspection of concessions, forest nursery operations, tree planting, and other forest management operations. Activities privatized or contracted out will still need to be supervised and monitored for performance. Concession performance can be audited by independent organizations or autonomous inspection services. Greater use can be made of performance incentives, both positive and negative, including such things as, for example, refundable performance bonds, refundable at the end of each management plan upon demonstration of satisfactory performance.

Non-timber values vary greatly by forest type and location. Unlike timber values, which are realized only at harvest time, non-timber values are annual and continuing. Non-timber values can often equal to or exceed timber values. Non-timber benefits add to the value of the forest, making it easier to justify forest management, but they make forest management for multiple outputs complex. Forest concession legislation and concession agreements in most countries, tropical and temperate, are based on timber production, and concession agreements are operated primarily for timber production. The challenge is to redesign concession agreements to incorporate non-timber forest products and environmental values, to require concessionaires to manage the forest for non-timber and environmental values, and to provide incentives (both positive and negative) for concessionaires to manage the forest for these values. Suggestions for the redesign of concession agreements, forest management requirements and procedures, performance incentives, penalties, supervision and inspection procedures should be accounted for in any concession arrangement

2.10 Long run sustained yield

According to Cambridge dictionary, sustainability is defined as the ability to continue at a particular level for a period of time. Consequently, FAO (2005) explains that early forest managers developed an understanding of natural forestry productivity, and how it might be enhanced through silviculture to maintain a continuous supply of wood, game, and other products for human use and consumption. The concept was fundamentally driven by the desire to avoid the social and economic disruption associated with shortages timber, whether for local use or as the basis for a community export economy. Forest products clearly held the potential of being a perpetually renewable resource, and foresters undertook the responsibility of making this so.

The origins of sustained-yield forest management can be found in late-medieval Europe (Heske, 1938) the lack of well-developed systems for transportation and communication at this time resulted in a system of small, independent political units with high customs barriers that prevented any significant degree of regional trade (Waggener, 1977, p.67). Local consumption was almost entirely dependent on local production, and communities had to be largely self-sufficient. There was a distinct possibility of exhausting local timber resources unless collective use was strictly controlled, and the production and consumption of forest products became highly regulated. This applied not only to the cutting of timber and fuel wood, but to the gathering of leaf litter and grazing of livestock, both of which were understood to affect long-term soil productivity in forests.

It has been argued (Adams, 1993, p.24) that the concepts of secure land tenure for private property owners, mutual coercion by mutual consent under common law, and government intervention in free markets to protect the broader public interest; principles basic to the development of a constitutional democracies, had their origins in communities such as these, seeking to avoid a “tragedy of the commons” (Hardin, 1968, p.31). Perhaps because of the opportunities it afforded for stable employment and income in rural communities, this approach to sustained-yield forestry persisted long after improved transportation and communication systems had reduced the need for local self-sufficiency and turned wood into a widely traded economic commodity.

It is in this context that the concept of the "regulated forest" came into being. A regulated forest is one managed to yield a regular, periodic and sustainable harvests of timber. The objective of sustained-yield management by itself does not indicate a single specific harvest level, since a forest can be sustained at a range of different management intensities. However, the objective of *maximizing* the sustainable volume of the timber harvest does generate a unique result.

2.11 The regulated forest

A regulated forest is one with an equal number of acres in each age class. Forest regulation is the process of converting a forest with an unbalanced age class distribution into a regulated forest – one with an even distribution of acres in each age class. According to Davis and Johnson (1997) the essential requirements of a regulated forest are that age and size classes must be represented in such proportion and be consistently growing at such rates that an approximately equal annual or periodic yield of products of desired sizes and quality may be obtained in perpetuity. A progression of size and age classes must exist such that an approximately equal volume and size of harvestable trees are regularly available for cutting.

The primary purpose of regulating a forest is to achieve a state where an even flow of products can be produced in perpetuity. This is desirable for two fundamental reasons: sustainability and stability. The flow of products from a regulated forest will be sustainable as long as the basic structure of the regulated forest is maintained and the productivity of the soil itself is not degraded. Once a forest is regulated, the oldest age class can be harvested each year. Each age class will then grow one year older, and the acres that were harvested will be regenerated and replace the acres that grew out of the youngest age class. This process maintains the age-class distribution in a steady state where harvest and growth are balanced and the age-class distribution always remains the same at the end of each period (Parkash, 1985, p.45).

Since the age and the area of the harvested acres are the same each year, the harvest from a regulated forest is constant from year to year. This guarantees a consistent flow of products to wood processing facilities, which, in turn, allows them to provide a steady supply of wood products and employment. Thus, a regulated forest helps ensure stability in the wood products industry and in the economic sectors that use their products (Davis & Johnson, 1997, p.28).

A regulated forest also has desirable properties for wildlife habitat. In a regulated forest all age classes – up to the rotation age – are equally represented at all times. If a forest is not regulated, any gaps in the age-class distribution will result in shortages of the type of habitat provided by the age-classes that are under-represented. Even if an age-class gap currently exists in an age class that does not provide a critical type of habitat, as time passes the gap in the age class will inevitably move into older age classes.

Parkash (1985) recognizes that, at some time, the gap is bound to move into a more important age class. From a wildlife perspective, the biggest concern with regulation is whether the harvest age is set too young. Consequently, the optimal economic rotation can be quite short relative to the biological life cycles of forest communities. If an entire forest is regulated using an economic rotation age, it is likely that there will be no acres in the more mature age classes.

2.12 Allowable cut

The allowable cut is the amount of timber considered available for cutting during a specified time period, usually one year. It is the volume of trees one would consider to be removed and thus is a target or guideline that should be reached (Leuschner, 1984, p.19). Allowable cuts are usually developed for large geographical areas and for long time periods. Forests may be divided into compartments and the compartments into working circles. Allowable cuts are calculated for working circles and often calculated for the compartments. These are then aggregated for the forest or total ownership. Allowable cut, then, is a large area concept and infrequently applied to individual stands.

Allowable cuts are often calculated for long time periods. The length of the time periods depends on the organization’s planning horizon and can cover variable-length time periods. For example, allowable cut may be calculated annually or biannually for the first five years, in 5-year increments for the next 20 years, and in 10-year increments for the next 50 years. According to Leuschner (1984, p.40) allowable cut can be calculated with area control method, with volume control methods using specific formulae or with a combination area and volume control, with a bit more emphasis on area control, which is often found in practice.

When using the area control method, one gets the total area that can be harvested at a given specified period of time. However, for the volume control methods some various formulae are used. These include, Hundeshagen’s, Von Mantel’s, Austrian, Hanzlik, Kemp’s and Meyer’s Amortization Formulae. The formula to be applied normally depends on the data available, hence affecting the accuracy.

According to Parkash (1985) the formula methods should rarely be relied upon as the sole basis of yield regulation, as they are liable to inaccuracies even when applied to normal forests. In case of abnormal forests- as most of our forests are, they are dangerous, as they are based on abstract quantities and pay little or no attention to the distribution of age-classes and the condition of the crop. The fact that a certain forest has a certain volume, and a certain increment, does not indicate whether any part of the forest is of exploitable size and, if so, how much. The use of an area check therefore becomes very important.

In spite of their obvious defects, formula methods are widely used due to their convenience and the impossibility of applying a more suitable and accurate method. Their use is justified provided the yield so calculated is not prescribed blindly, but modified to suit the actual conditions in the forests and the yield re-calculated on the basis of measurements of the growing stock (Parkash, 1985, p.33). Forestry departments and ministries are often underfunded and ill equipped to supervise and monitor logging activities and forest management on forest concessions, with little field capability for on the ground inspection and monitoring (Grut *et al*., 1991; Hardner & Rice, 1999). Forestry agencies commonly do not have the vehicles or fuel to allow staff to go into the field. As a result, personnel are often dependent on concessionaires for transport, accommodation and support, jeopardizing their ability to supervise and monitor concession operations and independence. In the late 19801s the Cameroon Ministry of Environment and Forests was forced to sell most of its vehicles as a result of the economic crisis. It recently (1998) acquired new vehicles, but now has only five four-wheel-drive vehicles (one in each region), and 28 motor-bikes, for 793 "field agents" assigned to "Forestry monitoring and enforcement", most of whom remain "office bound" (World Resources lnstitute, 2000b). Maintenance of vehicles and fuel further limits field operations. In Gabon, the Ministry of Water and Forests now has nearly 100 vehicles, a substantial increase form 19 in 1997, but two-thirds of them are in the capital. Only 34 vehicles are available for provincial inspectors (World Resources Institute, 2000a).

To improve concession management, logging and forest management on concessions, it is important to strengthen the field capability of forestry agencies, provide incentives and training to staff for field work, and take steps to strengthen their independence so that they are less vulnerable to bribery. Contracting out of monitoring and supervision to independent (public or private) organizations is an alternative. Independent auditing of concession management, logging performance and forest management is proposed to strengthen performance incentives for concessionaires, and to provide performance incentives for forest agencies.

Walker and Smith (1993) used representative data from Indonesia and a decision model of logger or concessionaire behaviour to analyze the effect of different levels of inspection and detection probabilities on contract performance. With the logging costs, prices, revenues and forest conditions used, they show that with zero probabilities of detection, loggers are always motivated to employ liquidation harvesting, and to employ liquidation harvesting practices throughout the entire length of the contract."

Long term tenure (or privatization of forests) would likely result in "high grading" and "mining" the forest, leading to rapid depletion and abandonment of forest lands (Boscolo & Vincent, 1998). Boscolo and Vincent (1998) also demonstrate the performance based renewal conditions provide a strong incentive for loggers to comply with performance conditions. Combined with performance bonds renewal conditions provide very powerful performance incentives.

Wood volume estimation has been a central research topic in forest science, because accurate estimates of wood volume are essential in sustainable forest management and for trade in forest resources (Davis & Shaw, 2001). Understanding the volume of wood in forests and regions is fundamental for regional forest management planning, commercial harvest, and conservation. As well, jurisdictions are increasingly estimating the overall volume of their forest inventories, and these volume estimates will be valuable in the modeling of carbon budgets. The accuracy of wood volume estimation could influence sustainable forest management planning and decision-making on wood utilization (Leuschner, 1984). In market trade, better estimates of wood volumes could help ensure fair trades between sellers and buyers. However, the use of different formulas and models often causes confusion, as does the fact that there are different approaches and methods for estimating wood volume. As a consequence, it can be a challenge for forest managers and practitioners to find reliable methods of wood volume estimation that suit their purposes.

Wood volume is a cubic measure of the amount of usable wood present in an individual log, tree or group of trees and is used to assess economic value (FAO, 1997). Wood volume is generally estimated on the basis of the stem wood of standing softwood trees; branches may be included for hardwood tree species. From the perspective of the forest value chain, forest wood volume may be referred to as (1) standing wood volume, expressed either as stem volume or as merchantable volume (a stem volume that has been truncated according to a given utilization standard); (2) log volume, which is the merchantable volume that arrives at a mill's gates, reduced as a result of losses during harvest and transportation; or (3) product volume, which is the amount that can be sold in the market (including lumber, chips, sawdust, shavings, barks, plywood and veneer sheets, hog fuel for bioenergy, and chemical products), reduced as a result of mill operations. Figure 1 shows the relationships among these volumes and their influencing factors.

2.13 Volume equations comparison

Wood volume estimation is a crucial study area in forestry for the most accurate management and trading of forest resources (Davis & Shaw, 2001). Forest products and services should be measured as precisely as possible to reveal the value supplied by forests. The most precious property created from forests is logging, which is the most valuable sort of wood commodity (Şahin, 2015). The log volume can be computed relatively correctly in the factory using today's technologies, but there is still a need to accurately estimate log volumes in the field for research and industrial purposes (Patterson & Doruska, 2004). There are several ways for estimating log volume in the literature, forestry practices, and research, and these procedures often produce outcomes that are very similar to one another. These strategies, however, cannot be used interchangeably and necessitate extensive investigation (Li *et al*., 2015)

The Smilian, Huber, and Newton techniques are the most well-known cross-section methods for a volume estimate, and these three methods determine the volume based on their cross-sectional area (Cruz de León & Uranga-Valencia, 2013). Huber's equation produces precise answers in the cylinder, truncated paraboloid, and paraboloid shapes, but it gives incomplete results in nyloid and cone shapes. Smalian equation delivers higher volume in various solids of revolution bodies while offering correct results in a cylinder, truncated paraboloid, and paraboloid shapes. Since the Newton equation produces accurate values for cone, paraboloid, and nyloid, it is said to be a safer approach to determining the log volume compared to other methods. Apart from this, the Hossfeld equation calculates the correct volume for the paraboloid and cone, while it calculates a smaller volume for the nyloid (Özçelik, 2002). According to Philip (1994) although Newton equation gives more accurate results when calculating the volume of irregular logs, it is less preferred than Smalian and Huber equations, which are simple to use (Avery & Burkhart, 1994). The tree trunk can also be volumized by dividing it into sections of equal length. This method is generally used in scientific research to determine the volume of felled trees, determine the volume of the stand, or determine the volume of very tall and valuable tree trunks. Although some equations are more accurate in volume calculation performance, they may be more difficult to implement and vice versa. The ideal equation for calculating volume, on the other hand, should take the fewest measurements and should be straightforward and useful (Carus, 2002). It is indicated that while estimating the log volume, numerous elements such as the tree sample data set and clarity influence the choice of the equation, additionally, researchers pay attention to the precision and correctness of a chosen volume equation (Mushar *et al*., 2020).

2.14 Goods and services of plantation forests

The functions and services of plantation forests are diverse. FAO for instance, makes a distinction between 'productive' and 'protective' plantations (FAO, 2006). Productive plantations are focused primarily on the production of industrial wood, fuelwood and non-wood forest goods (e.g. animal fodder, apiculture, essential oils, tan bark, cork, latex, food), whereas protective plantations are established to provide conservation, recreation, carbon sequestration, water quality control, erosion control and rehabilitation of degraded lands, which also includes landscape and amenity enhancement (Lamb *et al*., 2005). According to Brown *et al.* (2005) the industrial plantation goods and service are of limited literature sources and analysis, and much uncertainty still exists about how to measure service performance and the influence of management on the provision of goods and services. For example, it is generally assumed that forests prevent erosion and reduce run-off (Brown et al, 2005) but exactly to what extent, and whether this varies between different forest types is not well understood (Bruijnzeel, 2004). One problem with determining sustainable use levels is that many goods and services depend on the same function (Brown *et al*., 2005) which means that use of one good or service will influence the availability of another. For example, a continuous supply of timber will depend directly on production functions (biomass production), which, in itself, will depend on habitat functions (i.e. suitable conditions for timber-producing species) and regulating functions (e.g. soil and climate regulation, pollination, etc.). Maintenance of these habitat and regulating functions will contribute, in turn, to the provision of other services (Campos *et al*., 2005). In plantations, one service is usually maximized (e.g. timber production) at the expense of most other services and much external input (labour, energy, nutrients) is needed to maintain the productivity. The extent to which this trade-off is acceptable (ecologically, socio-culturally and economically) is the subject of the next section on 'valuation'.

Once the capacity of an ecosystem to provide goods and services is known, their importance or 'value' can be determined. This importance or value primarily consists of three types of values: ecological, socio-cultural and economic (MEA, 2005) The 'Ecological Value', or importance of a given ecosystem, is determined mainly by the degree to which the ecosystem provides Regulation and Habitat Services, which, in turn, is measured by ecosystem criteria such as naturalness, diversity and rarity. According to Dixon and Pagiola (1998) whether plantation forests lead to a decrease in the overall ecological value of an area or landscape depends largely on the condition of the original ecosystem or production system they replaced. For example, ecological values are likely to increase if plantations are established on former agricultural land, and likely to decrease if established on land converted through the clearing of native ecosystems. Social values (such as cultural diversity, identity, heritage and spiritual values) and perceptions play an important role in determining the importance of ecosystems and their services to human society (De Groot *et al*., 2006). Native forests have many such values and are often an important source of non-material wellbeing to many individuals and societies. Usually, socio-cultural values are reduced or lost when a native forest is replaced by a plantation (Campos *et al*., 2005). However, there are large differences depending on the management system, and so-called 'community forests' (which are usually more or less heavily managed native forests), can have considerable socio-cultural importance.

Finally, ecosystem services have economic importance, although some authors regard cultural values and their social welfare indicators as a sub-set of economic values. Others state that, in practice, economic valuation is limited to efficiency and cost-effectiveness analyses, usually measured in monetary units, and disregards the importance of, for example, spiritual values and cultural identity. To analyze the economic value of ecosystems, the concept of Total Economic Value (TEV) has become a framework widely used for quantifying the utilitarian value of ecosystems (De Groot *et al*., 2006).

2.15 Forest management agreement model

According to the Forest Conservation and Management Act (2017) Sec. 43(1), it gives the Kenya Forest Service powers to enter into a management agreement with the applicant. The specific matters to be addressed in this concession agreement are expanded in the Sec 44(3a-f). The agreement is normally required due to the long-term nature of the license (Robinson, 2010). Accordingly, a thorough review is required to ensure that the agreement is consistent with the forest act policy and the constitution. Robinson (2010) notes of a specific issue which is in protecting community rights and interests as they might evolve over the term of the agreement when they are not a party to the concession agreement.

2.16 Challenges and future trends

Global demand for forest products has grown at a rapid pace over the past decade and this is expected to continue in the foreseeable future. According to Barr and Cossalter (2004) in the Asia Pacific region alone, annual consumption of hardwood pulp is expected to increase by 73 million cubic metres and annual consumption of softwood pulp by 32 million cubic meters. There is a shift in the consumption and production of forest products. Recent studies show that current demand for forest industry products will grow less than before in Organization for Economic Cooperation and Development (OECD) countries, while at the same time the demand will continue to increase considerably in many developing countries and in countries in transition. This means a shift in the consumption of forest products from

Western Europe, North America and Japan to the rest of Asia, Eastern Europe and Russia (Barr & Cossalter, 2004). The success of forest plantations as sources of industrial round wood supply has been obvious. In the past 25 years, according to FAO (2006b) their share of total industrial round wood production has increased from 5 per cent to over 30 per cent. In the next 25 years, it is expected to reach 50 per cent of total industrial round wood production. This success is often contrasted with social and environmental problems that large-scale plantation schemes have repeatedly caused. In many cases, most smallholders and forest inhabitants have had limited participation – or no engagement at all – in the profitable business developed by large or medium size companies, and they have not shared significant benefits (direct income or other) in the planting, tending and logging operations performed by these companies. In other cases, companies have planted in large uniform blocks of land and this has led to the displacement of local people from the rural villages or small holdings where they have traditionally lived. To improve the situation, certification schemes, concessions and other safeguards have been introduced. The voluntary guidelines for the responsible management of planted forests established by FAO (2006b) and ITTO (1993) and by various certification schemes are moves in the right direction. However, there is much still left undone to ensure their general application in practice

One of the negative impacts of large-scale plantations has been on biodiversity (FAO, 2006b). However, this has depended very much on the land use that was replaced by the plantations. If properly planned and managed, plantations can play a role in building connectivity in fragmented landscapes (Salo, 2007) or acting as catalysts for native species (Otsamo, 2000). But as biodiversity continues to be lost, fixed, single-objective plantation management is likely to be a less attractive option in the future (Lamb, 1998). The plantation management paradigm has to move towards the management of multi-functional landscapes by incorporating multiple ecosystem services as an integral part of the overall production function of forest plantation schemes.

Ecosystem services markets are growing fast and forest plantation will have an important role to play in global carbon markets and, more locally, in payments for ecosystem services schemes for managing water resources. Both of these areas are expected to gain increasing importance in the future, when the actions to combat climate change – both through adaptation and mitigation become part of the new paradigm of sustainable plantation management

2.17 The conceptual framework

The study was conceptualized on the basis of long run sustainable forest management. It was planned on the premise that the forest policy, the environmental parameters remain the same in the forests plantations. However, the various economic incentives among the different stakeholders may impact the end results. In order to address these challenges and achieve the intended goals, the management strategies including the licensing, concessions among others need to be thought of and implemented. Yield tables were formulated to depict the various age class distributions. The net present value was used as a common measure of the actual amount of fee to be paid for the concession consideration. Consequently, the visible region from the programming method adopted reflected both the minimum land sizes that will be applicable for various timber industries.

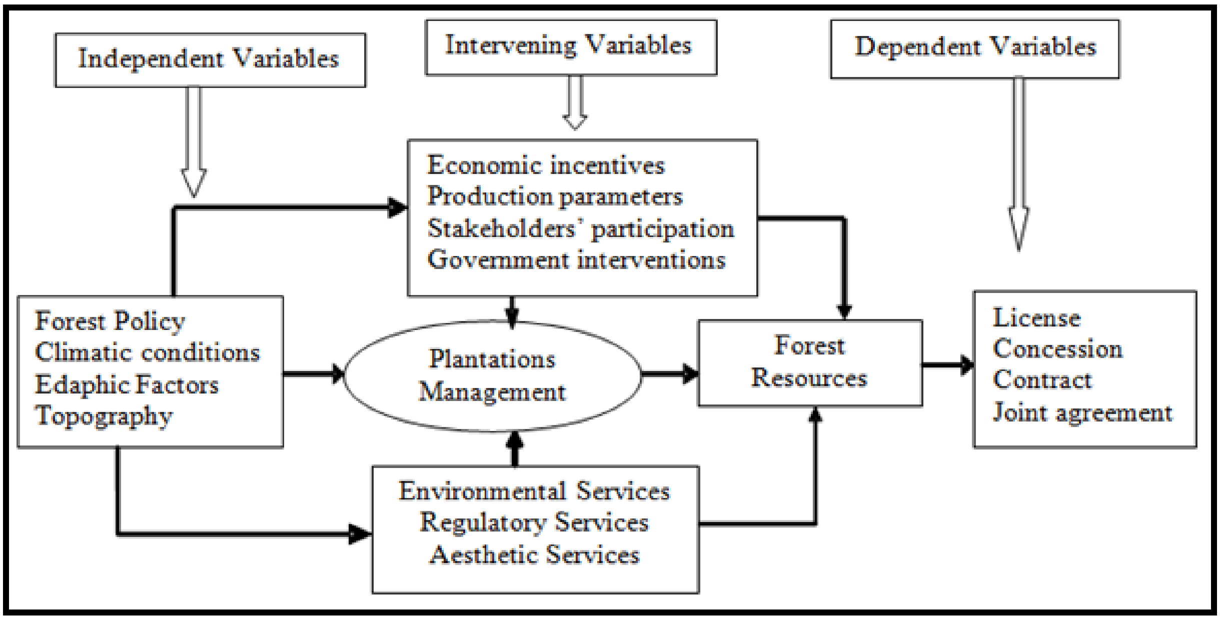

Figure 1: The conceptual framework

The various industrial capacities were reflected against the available resources for the purposes of concession consideration in the study area. Any of the objective functions to be considered reflected the various management scenarios that so far exist for the purposes of concession. When the concession agreement is followed to the latter, it is expected that the both the forest resources and the chosen qualified type of industry will exist in perpetuity.

The general form for maximization of the optimum volume in the plantation will take this form;

$$Z = c_1x_1 + c_2x_2 + \dots + c_nx_n \qquad \text{Equation} \dots\dots 1$$

Subject to

$$a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n \leq r_1$$

$$a_{21}x_1 + a_{22}x_2 + \dots + a_{1n}x_n \leq r_2$$

$$a_{m1}x_1 + a_{m2}x_2 + \ldots a_{mn}x_n \leq r_m$$

and

$$x_j \geq 0$$

$j = 1,2,\ldots,n$

$i = 1,2,\ldots,m$

Where;

Z = the optimum volume

Xj = choice of variable for which the problem is solved.

Cj = coefficients of the choice variables that are already known.

Ri = constraints or restrictions imposed on solving the problem and are already known.

Aij = coefficients which quantify the effect of the *i*th constraint on the *j*th choice variable and are already known.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Study area

The study area was conducted in Koibatek and Maji-Mazuri forest stations (Baringo County) due to vast plantation area and favorable climatic conditions. Koibatek Forests Zone is located between longitude 35‟35”, and 35‟15” and between Latitude 0‟11” south and 0‟ 15” North. The Zone borders Kericho and Uasin Gishu Zones to the West, Keiyo to the North, Baringo to the South, Laikipia to the South East and Nakuru to the South (Keith, 2020). The forests have both plantations and natural forests. According to Keith (2020) Koibatek Forests Zone is composed of eight (8) gazetted forests blocks namely: Chemorgok, Narasha, Chemususu, Sabatia, Esageri, Maji Mazuri, Kiptuget and Koibatek Forests. The main vegetation of the gazetted forest blocks constitutes natural forest, grassland vegetation, and industrial plantation. In addition to the gazetted forests, there exist forests on trust lands within the jurisdiction of Koibatek and Mogotio Sub-Counties of Baringo County. Koibatek forest station has a total area of 8,871 hectares. Out of the total area, 2,800 hectares is under plantation area, 5,700 hectares under natural forest and 371 hectares on grassland (KFS, 2009, p.46). Maji-Mazuri forest station on the other hand has a total of 6,096 hectares. This includes 3,500 hectares is on under plantation forests and 2,596 hectares under natural forest. The two forests are located in Baringo County, Rift Valley province, Kenya. The stations are bordering each other.

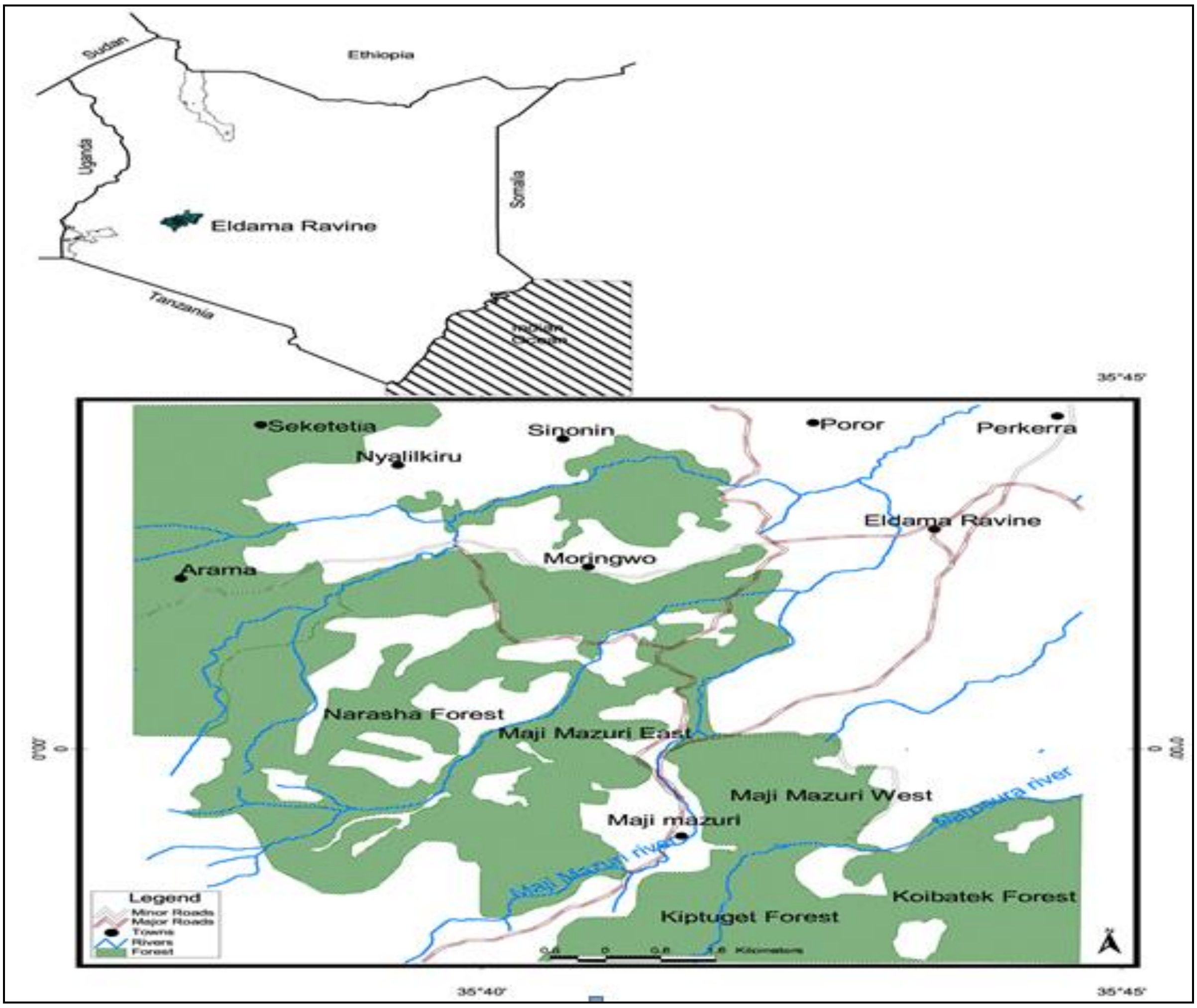

Figure 2: Map showing location of Maji-Mazuri and Koibatek forest stations

3.2 Land use practices, soils and climate

Agriculture is the main stay of people around the forests. Both forests fall under the forests opened up for Plantation Establishment and Livelihood Improvement Scheme "PELIS" to enable them get good harvest. The main crop being cereals such as maize and beans are the dominant crops of the areas. Horticultural crops such as French Peas, Kales, Cabbages and Tomatoes are also cultivated while the cash crops are coffee, cotton, macadamia and pyrethrum. Livestock kept are Cattle and Sheep. Soils are perfectly drained to moderately deep and dark brown colour. This is classified as sand to loam and loam with rock outcrops (Republic of Kenya, 2000, p.16). Both forests represent in Afro-Montane forests classification of Teel (1984) with cool wet areas. Rainfall patterns are between March to June, for long rains and October to December for short rains.

3.3 Research design

A reconnaissance was first done to the Koibatek and Maji-Mazuri forest stations plantations, in which forest characteristics, compartment sizes and familiarization with the various stakeholders was done to provide an insight on the challenges and available opportunities to address and for use respectively. An experimental research design was employed in this study. Systematic sampling method using the plot line method was used. Circular plots of 15 meters radius were established systematically in a grid pattern with a sampling intensity of 10%. The main aim was to derive the various tree attributes within and between stands for purposes of volume projection. Tools used included the following; Haglof caliper, Hagar suunto for shooting the heights, crayon for marking the trees within the plots, a clipboard, pencils and field sheets, maps of the sub compartment from the KFS and a G.P.S for area verification.

3.4 Data collection and analysis

Species composition, size of compartments/ sub compartments and planting blocks, stocking of the plantations, and dominant height of the plantations were taken was taken for purposes of volume computation. Due to limitation of time and resources for the inventory of the proposed study area, existing data from the KFS inventory team was also used for comparability. The data collected was entered and analyzed using excel version 8.0 and regression analysis using R. The results were presented in form of tables, figures and charts.

3.5 R squared (percentage of variation)

R^2 is the square of the correlation coefficient. It is the proportion of the variation in *Y* that is accounted by the variation in *X*. R^2 varies between zero (no linear relationship) and one (perfect linear relationship). R^2, officially known as the coefficient of determination, and defined as the sum of squares due to the regression divided by the adjusted total sum of squares of *Y*.

R^2 was the most popular measure of how well a regression model fits the data. R^2 may be described either as a ratio or a percentage. Since the ratio form was used, its values range from zero to one. A value of R^2 near zero indicates no linear relationship, while a value near one indicates a perfect linear fit.

3.5 Data analysis matrix

Table 1: Operationalization of variables and statistical testing tools

Objectives	Hypothesis	Independent Variables	Intervening Variables	Statistical Tool	Expected Output
To assess the best forest attributes for volume projections for effective management and sustainable utilization of the forests.	Tree height and diameter are not the best forest attributes for volume projections for effective management and sustainable utilization of the forests.	Forest Policy Climatic conditions Edaphic Factors Topography	Economic incentives (Mean diameters at breast height, Cutting units, Stocking)	-Linear regression -Huber's formulae -GPRS	Show the tree attributes that can be used to manage forest plantations
To determine if the long run sustainable yield can be projected using tree volume of the total area.	The long run sustainable yield cannot be projected using tree volume of the total area.	Forest Policy Climatic conditions Edaphic Factors Topography	Economic incentives (Mean diameter at breast height, mean heights, Age of the stands, Determined rotation age)	-Huber's formulae -Von mantel's formulae -Linear regression -GPRS	Show the correlation between tree volumes and long run sustainable yield.
To evaluate the various types of	There is no timber-based industry that can	Forest Policy Climatic	Production Parameters (Mil types, Volume of	-Capacities of various timber	Show the connections

timber-based industry that can be supported on long run sustained yield basis within the study area.	be supported on long run sustained yield basis within the study area.	conditions Edaphic Factors Topography	trees, Age of the stand)	industries -Volumes consumed	between the long run sustainable yield and the number of timber-based industries to be supported.

3.6 Attributes for volume projection

Field data collection for the inventory of the plantations included the determination of the density of all the young plantations with a DBH below 5cm while all plantations with mean DBH above 5cm were sampled for data collection. Systematic sampling with even distribution of plots within compartments, sub-compartments and established blocks was established. For the existing mature plantations, due to the likely variability in the tree sizes, systematic sampling with even distribution of plots within compartments, sub- compartments and planting blocks was established. All plots were circular, 0.1Ha size. The length of transects and location of plots along transects is dependent on compartments/ planting block sizes, hence this was based on the total area of the sub-compartment.

The measurements made within each plot comprised species, stand age, spacing at planting, density, DBH, mean top height (height of 100 fattest trees per Ha) and diameter at breast height (at 1.3 meters from the ground). To determine stand volume, individual tree volumes within each plot using Huber's formula, was computed then sum plot volumes to determine average volume per stand. This is then extrapolated to stand volume per hectare. Huber's formula for volume calculation;

$$V = \frac{3.142*D2}{4} * h \qquad \text{Equation} \ldots\ldots 2$$

Where;

V = volume

h = length of the tree (height), dominant height

D= diameter at breast height

Basal area was calculated using the formula;

$$G = \frac{3.142*D2}{4} \qquad \text{Equation} \ldots\ldots 3$$

Where;

G = Stand basal area

D= diameter at breast height

According to Hamilton and Brack (1999 p. 30) basal area is the horizontal cross-section area of all stems in a hectare at 1.3 meters above the ground. 1.3 meters is known as "breast height" and basal area for any tree calculated from measurement of diameter at breast height (dbh). The accurate determination of the mean tree was as important since the relative basal area instead of the number of trees was used as the inflation factor, considering that the plantations were homogenous in nature:

$V = v/g * G$ Equation……………………………………4

Where;

V denotes stand volume, v denotes sample tree volume; g denotes sample tree basal area and G denotes stand basal area.

Using basal area instead of stocking effectively turns the sample tree method into a stand tariff or volume line where the intercept is assumed to be 0 and the slope of the line determined as v/g.

Volume line (= v/g line)

The volume line is a linear regression of v and g on the form

$V = a + bg$ Equation ………………….………………5

The main advantage of the volume line over volume curve according to Brack (1996) is that the line is easier to fit by eye and fewer observations are needed to establish it. The regressions is the best calculated by method of least squares. In practice, according to Brack (1996), the volume line of a stand is established from sample trees. Although objective selective of the sample is desirable to avoid bias, subjective selection is widely adopted.

Demaerschalk and Kozak (1974, p.17) and Hooke (1963, p.19) suggest that when the relationship is known to be linear, the best estimates of the slopes of the regression line are obtained when half of the observations are taken at each end of the range of independent variable. When there is any doubt about linearity, the observations should be distributed over the whole range over uniformly or with a greater concentration of observations towards end of the range.

3.7 Determination of long run sustainable yield from volume projections

The long run sustained yield calculation resulting from this study was based on tabular data about the plantations of the forested land base. Some of the data are site specific, other data are more generalized. Specifically, a model was designed to provide a reasonable and defensible estimate of an annual sustainable harvest.

As a first step in developing a Forest Management Model to calculate the long run sustained yield on 6,442.9 hectares, a comprehensive forest inventory was conducted to collect forest resource information. This concentrated mainly on the plantation forest inventory data compilation. The calculation of a sustained yield was based on projections about how tree stands will grow and change over time, under different management regimes (i.e., private forest, government or community forests). These projections also provide information about stand conditions that are important for understanding impacts on other resources (e.g., number of large trees per hectare and species composition).

According to Mason (2013, p.22) fundamental input to most growth and yield models is a "volume table" for each tree species type. The volume table can be thought of as a summarized list of the tree volume in the stand. With information about the species, size, and number of trees in a stand, and any management applied to the stand, (Mason, 2013, p. 23) the growth model projects the stand into the future. This therefore describes the process to derive volume tables to be input into the growth and yield model.

3.7.1 Mean annual increment (MAI)

The MAI (Mean Annual Increment) is the volume of wood growing on one hectare of forest during one year (m^3/ha/year) on average since the forest has been established. For a tree plantation, the MAI is the present total growing stock volume of one hectare divided by the total age. In this study, MAI is calculated in order to develop the yield table, (Mason 2013, p.24).

3.7.2 Deriving average volume tables

The individual plot data for each tree species type was grouped by different sub-compartments and was compiled using Excel - a computer software system. Data checks, including the diameter at breast height and average dominant height were conducted to make sure that the plot data matched up to the intended stand and that the data characterized each stand's species type. Finally, plots within each sub compartment were averaged together, resulting in average volume tables.

3.7.3 Linear programming method

The linear programming harvest scheduling model was developed in a computer spread sheet by adopting the Ware and Clutter (1971) model with little adjustments to fit the study area. In this case, some of the considerations included the following;

3.7.3.1 Selection of time period lengths

Period of time over which optimization will occur and the harvest will be scheduled will be considered in this case i.e., 1.5 to 2 rotations long. The cutting period length will as well be selected. This is the smallest time period for which a harvest scheduling program will schedule the harvest i.e., time period during which one set of management plans would have been executed.

3.7.3.2 Identification of cutting units

The cutting unit is the area, on the ground that will be scheduled for harvesting. Within the study area, only areas in a particular cover type or age class will be identified. In case the study area has been divided into cutting units already by the Kenya forest service inventory team, it will be adopted for mathematical programming. Sub compartments to be used.

3.7.3.3 Identification of management regimes

A management regime is the sequence of harvests that may take place on a particular cutting unit within the planting horizon. Other forest management activities may be associated with the harvest sequence, such as thinning, pruning or regeneration. In the case of the study area, the management regime (government forest) will define one alternative for managing the cutting unit, the costs and revenues for that alternative through the determination of the stand age.

3.7.3.4 Identification of the constraints

Constraints are the other considerations that involve cost acquiring as a result of the management regimes. In the study area required for different types of mills were considered verses what the different mill can consume sustainably. Other constraints such as the cost of making the forest roads and plantation establishment per hectare will also be factored in as constraints. All these will be identified from the study area.

3.7.3.5 Calculation of the objective function values

The process involved the calculation of objective function values for each management regime for all the cutting units. The assumption here will be that the management objective has already been identified; in which case harvest volume maximization will be used. Since this may take most time, Clutter's (1978, p.25) modification will be adopted to capture the basic information about timber yields, costs and revenues in the program.

3.7.3.6 Optimization of the objective function

As adopted by Ware and Clutter (1971, p.21) this is when the actual harvest is actually scheduled. The management regime in the first cutting unit with the highest objective function value was chosen. The maximum for the second cutting was chosen, which, as the first one, schedules the harvest. The procedure is to continue over all cutting units, each having its rotation determined and harvest scheduled by the particular management regime that will have the optimal objective function value for the cutting unit. Using a computer program that chooses the maximum number in the list performed this search. Mathematical programming method, LINDO, was used. The objective function thus be:

Maximize

$$Z= \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij} X_{ij} \qquad \text{Equation} \ldots\ldots\ldots\ldots\ldots 6$$

Where;

Z= the present net worth

Cij = the present net worth for cutting unit i when managed by regime j.

Xij = the proportion of cutting unit I managed by regime j.

I= 1,……………………,m, the number of cutting units

J= 1………………….n, the number of management regimes?

Appropriate program that captured data from the linear program, and combine it with data that were input earlier, translating them into reports containing simplified information was developed. Field equipments used included suunto hypsometers for tree height measurements, graduated 3m poles for short tree and bole height measurements, 2cm diameter tapes, 12 channel GPS units, compasses.

3.8 Categorization of timber-based industry the resource in the study area can support

Robinson (2010) on development of concession framework in Kenya categorization was adopted (Refer to Table 2). In this case, the development of a plantation strategy led to a more precise articulation of a concession management strategy, in terms of the identifying the particular circumstances among the plantations that may favour the initial concession area. A hypothetical distribution given about 70% of the plantation base is in management agreement.

Table 2: Proposed mill categories and implied annual land base requirement

Mill _wood m3/day	**Round wood m3/yr**	**Indicated stocked area requirement per year (ha)**	
Small	<10	5,500 <	**<18**
Medium	10 to 20	5,500 to 9,500	**18 to 35**
Large	**<20**	**>9,500**	**>35**

Source Robinson (2010)

According to Robinson (2010, p.8) the size concessions should be related to per hectare yield, cutting cycle and logging costs. The size of tenures, particularly TL's may be adjusted in response to industry feedback (Refer to Table 3).

Table 3: Area based categories

Element_License (TL)	**Forest Management License**	
Location **Size/ Volume per license**	Geographic balance	**Geographic Balance**
Large	100 to 200 ha	**4,000 to 10,000 ha**
Medium	Up to 35 ha	**1,000 to 4,000 ha**
Small	**Up to 20 ha**	**?**

Source: Robinson (2010)

From the calculations of the total volume and the yield table of the study area, the categorization of the timber-based industry the resource would support was derived based on the Robinson's proposal. This meant calculating the appropriate harvesting levels. The correct harvest level was calculated using the one of the control methods. Specifically, Von Mantel's formula was chosen. This was compared with the linear programming method for the purposes of adapting long run sustainability through allowable cut.

Von Mantel's formula;

$$Y_a = \frac{2G_a}{R} \qquad \text{Equation} \ldots\ldots 7$$

Where;

Y_a = allowable cut

G_a = the volume of growing stock at rotation age

R= rotation age

The formula was chosen since it does not require formulation of a yield table and its simplicity in application (Parkash, 1985).

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 General Summary

The general observation appears that the forest is normal given that the mean diameter of *Cupressus lusitanica* is 34.61cms with a mean height of 23.9 meters in the 103 blocks. *Pinus Patula* also shows a very perfect mean diameter class of 40.56 cm with a height of 30.46 metres in the 45 blocks. However, as observed by Leuschener (1984) "other than the normal means one needs to further subject the data into other mathematic programming techniques to ascertain its authenticity" (p.33). Indeed table 1 shows the summary. It should be noted that the forest is contrary to this observation since every block of the forest had a backlog area combined with young sapling trees of less than 5cm diameters which could not be tabulated.

Table 4: *Cupressus lusitanica* plantations and *Pinus patula* plantation

	Cupressus lusitanica			***Pinus patula***		
	DBH(CM)	**MHT**	**B/AREA**	**DBH(CM)**	**MHT**	**B/AREA**
Number	103	103	103	45	45	45
Mean	34.61	23.90	17.38	40.56	30.46	16.59
Variance	88.53	18.25	154.74	58.39	42.71	144.96
SD	9.41	4.27	12.44	7.64	6.54	12.04
SE	0.93	0.42	1.23	1.14	0.97	1.79

4.1.1 Age distribution table and mean annual increment

Age distribution, being the proportionate representation of different age classes in the forest depicts an abnormality and irregularity. The age distribution table for both *Cupressus lusitanica* and *Pinus Patula* clearly shows that most of the trees are over mature leading to this kind of scenario. This can be attributed to ten years logging ban that had been imposed in the forest in the early 1990's.

As observed by Parkash (1985, p.54) "abnormality in a forest may be as a result of normal growing stock volume but abnormal distribution of age classes". This, Parkash (1985, p.55) recognises as "the worst form of abnormality". The observation in this forest block is a similar scenario. The conversion of this forest to normality becomes a difficult problem and may involve either an interruption in sustained yields or sacrifice of material to decay.

The mean annual increment being the total increment of the plantation divided by the age depicts that it is not linear as it is supposed to be. Both *Cupressus lusitanica* and *Pinus Patula* in figure 2 and 3 below shows that the age of the trees is over matured and as such has no additional value in the forest. MAI is significant in testing the maturity of individual trees (FAO, 2005, p.19). The MAI of single trees varies greatly with age and increases continually to maturity until it diminishes. It is evident that MAI has diminished for both the species as indicated in figure 2 and 3.

The data therefore confirms that the majority of both *Cupressus lusitanica* and *Pinus Patula* should be selected for felling given that there is no additional value. This is an indicator of poor forest management practices by the body mandated to manage the forest.
Consequently, the data was subjected further and analysed using excel version 8.0 and regression analysis using R.

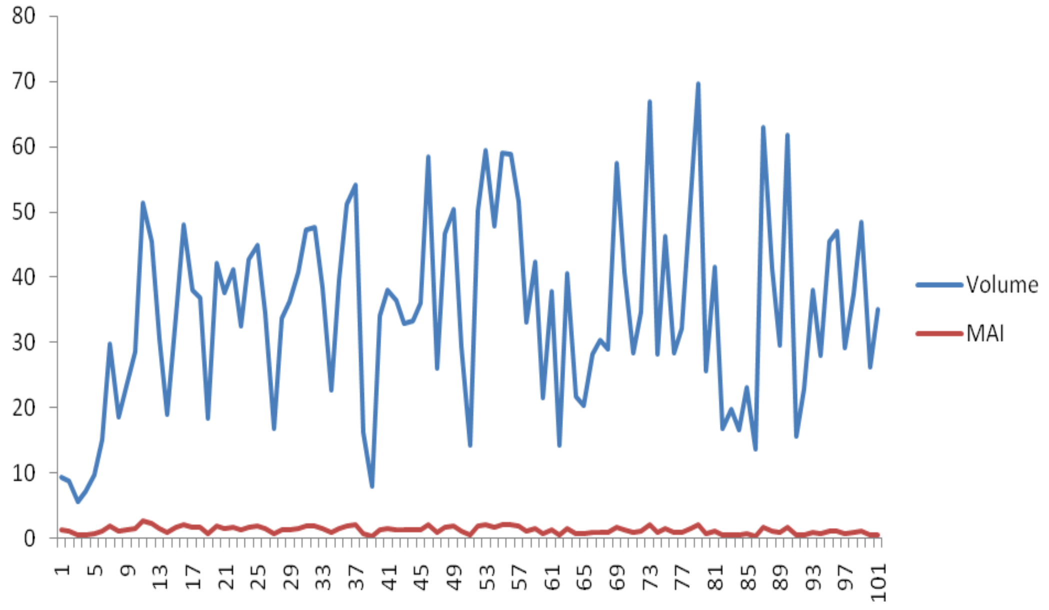

Figure 3: *Cupressus lusitanica*

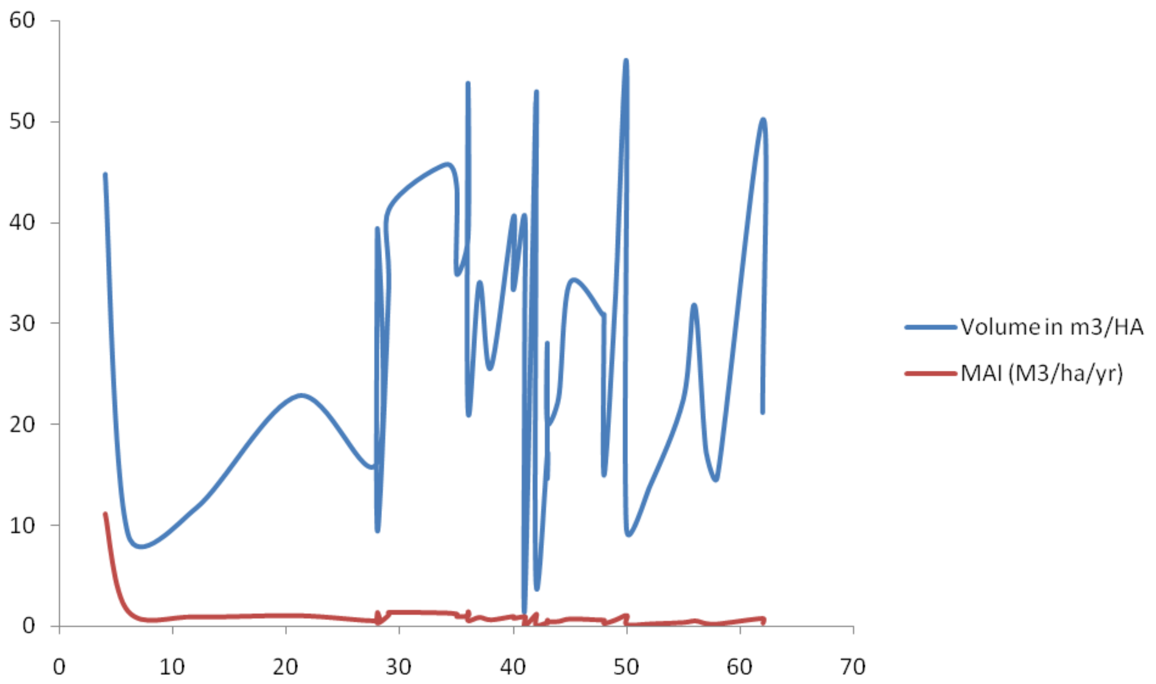

Figure 4: *Pinus Patula*

4.2 Relationship between trees attributes for volume projection

4.2.1 Mean height vs. Diameter at Breast Height

Data from the standing trees (Figure 4 and 5, derived from appendix A) indicate a slight increase in the mean height with increase in the diameter at breast height. The increase is however, weak as suggested by low coefficient of determination (r^2=0.17). Therefore, relying on increase in mean height to predict increase in mean diameter at breast height is not strong enough as a scientific proof of tree growth.

Previous studies had shown that the inclusion of stand characteristics as independent variables in height-dbh models improved the prediction accuracy of tree height estimation. The variation in the height-dbh relationship for stands of different ages confirms studies by Abetz and Kladtke (2002, p.16) that, owing to the allometric relationship between tree height and dbh, the rate of increase of tree height will mostly be significantly different from that of dbh. Though the stand age was not the most important variable in the tree height-dbh relationship, some differences in parameter estimates were found in the data.

This confirms Johnsen *et al.* (2004) studies that "given that tree height and dbh usually increased with tree age and are influenced by density, any models predicting the development of the height-dbh curve for a stand will never have significant difference" (p.11). This has thus been confirmed in both cypress and pines with r^2 = 0.1 and r^2 = 0.17

respectively. Data from the standing tees indicates a negligible increase in mean height as the diameter at breast height increases. This is derived from the coefficient of determination which is low (r^2=0.1). Therefore, this makes the diameter at breast height not accurate method to predict mean height.

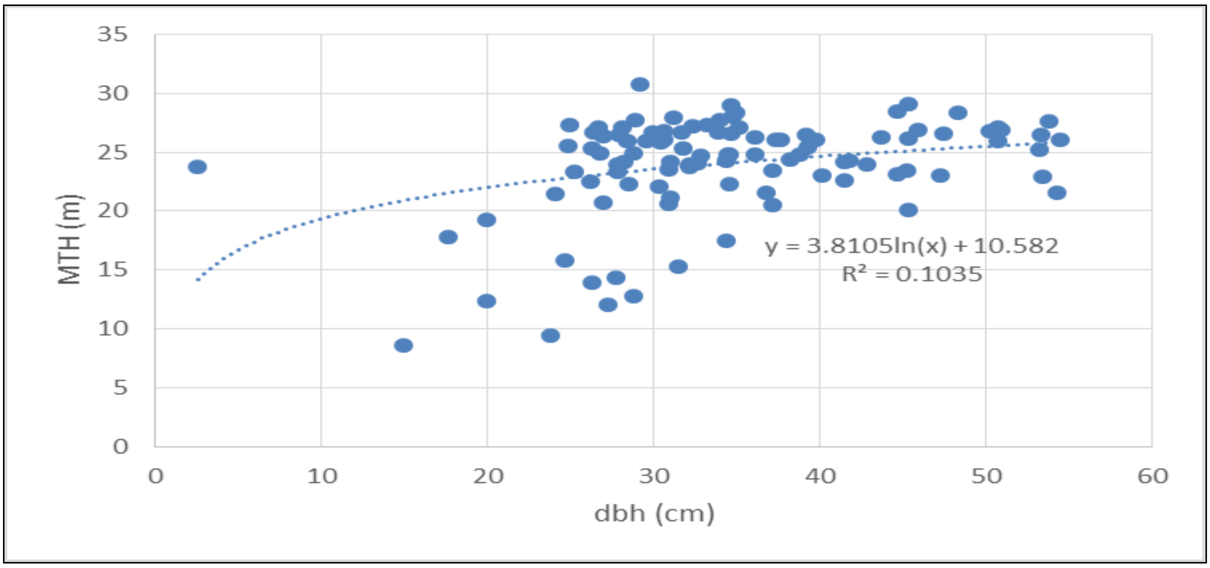

Figure 5: *Cupressus lusitanica* Height – DBH trends

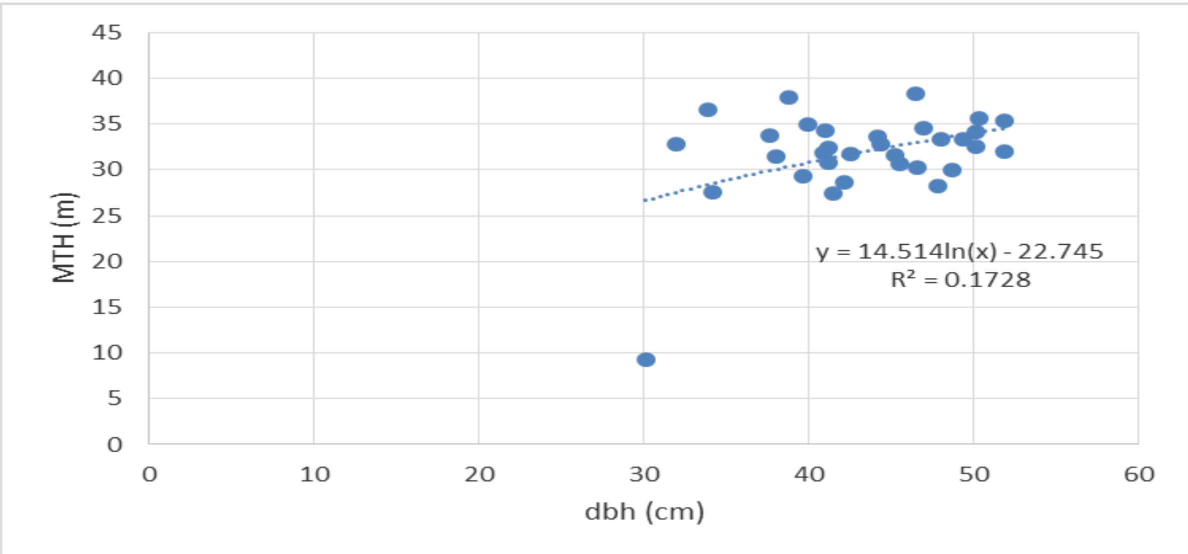

Figure 6: *Pinus patula* Height – DBH trends

4.2.2 Volume vs. basal area

There was a strong relationship in volume and basal area (Figure 6 and 7, derived from appendix A and B). An increase in basal area resulted in a corresponding increase in stand volume (r^2=0.97). Increase in basal area therefore a strong determinant in stand volume and shows good management of the plantation of *Cupressus lusitanica* species.

The relationship between stand density and average tree size is very important for optimizing thinning regimes and ultimately fixing rotation age. A large basal area is desirable for pulpwood and wood fuel stands while stands where saw timber production is the prime objective large diameters are more important. According to Gadow and Bredenkamp (1992, p. 37) strong variations of this relationship have frequently been used in the past to produce silvicultural guide curves. A number of other density and stocking measures such as the stand density index (SDI) and the relative spacing have been derived from this relationship.

The regulation of stand density is therefore an important function of woodland management (Gadow & Bredenkamp, 1992, p. 28) to developed methods to estimate the maximum possible basal area for a given site when this information is not available from long-term research plots. In all the *Cupressus lusitanica*, r^2 = 0.97 showing strongly that the thinning regimes have not been adhered. Similarly, for *Pinus patula*, with r^2 = 0.77, there is still strong evidence that most have not been thinned.

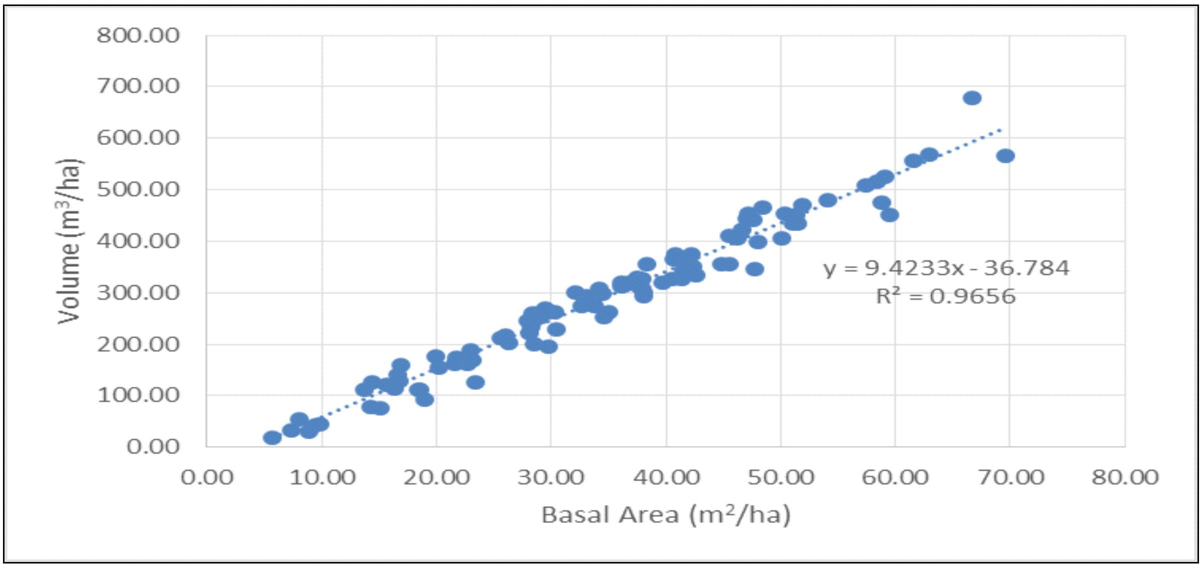

Figure 7: Volume - Basal Area Trends for *Cupressus lusitanica*

There were clear indications that increase in basal area results to increase in tree volume, therefore a good indicator to predicted forest growth volume. This is evident with the high correlation coefficient of determination of *Pinus patula* also at (r^2=0.77). For regulation of the study area, it is important that the thinning regimes be observed. As well, the over mature plantations in all the species be harvested due to the variations.

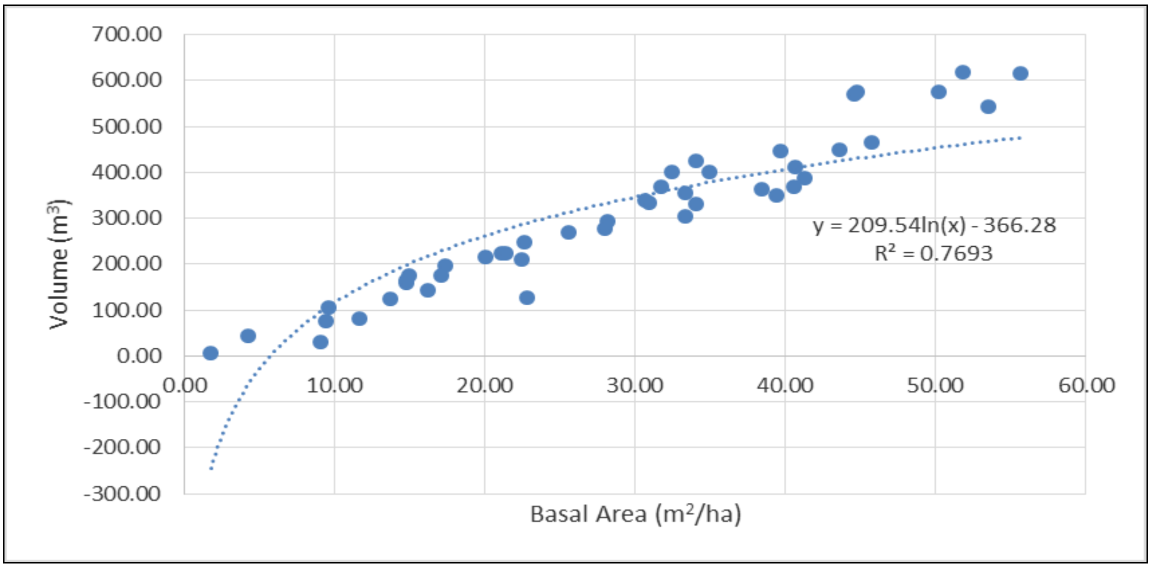

Figure 8: Volume - Basal Area trends for *Pinus patula*

4.2.3 Basal Area vs. Stocking

High stocking in *Pinus patula* suggest larger basal area from the coefficient of determination (r^2=0.630) (Figure 8, derived from appendix B). As high stocking suggests increased basal area, there is projected increase in forest volumes. This therefore, gives enough reasons to execute silvicultural operations, such as thinning on a plantation forest considering that volume is the main target. Meanwhile slightly low stocking of *Cupressus lusitanica* translated to increased basal area. This is given the coefficient of determination that was high at (r^2=0.53). At the same time, this could be attributed to the fact that the more the stems, the higher the basal area translating to increased stand volume.

There is an important relationship between stand density and average tree size on any given site and species. According to Kimmins (1997, p.29) populations of even-aged trees growing at high densities are subject to density-dependent mortality or self-thinning. For any given mean diameter there is a limit to the number of live trees per hectare that may coexist in even-aged stands. Ecologically this limiting relationship can be interpreted as the carrying capacity of any given site (Kimmins, 1997, p.42). The mean diameter in an unthinned plantation of a given initial density will increase until the limiting relationship is reached. Thereafter, further growth will be accompanied by mortality (Gadow & Bredenkamp, 1992, p.37).

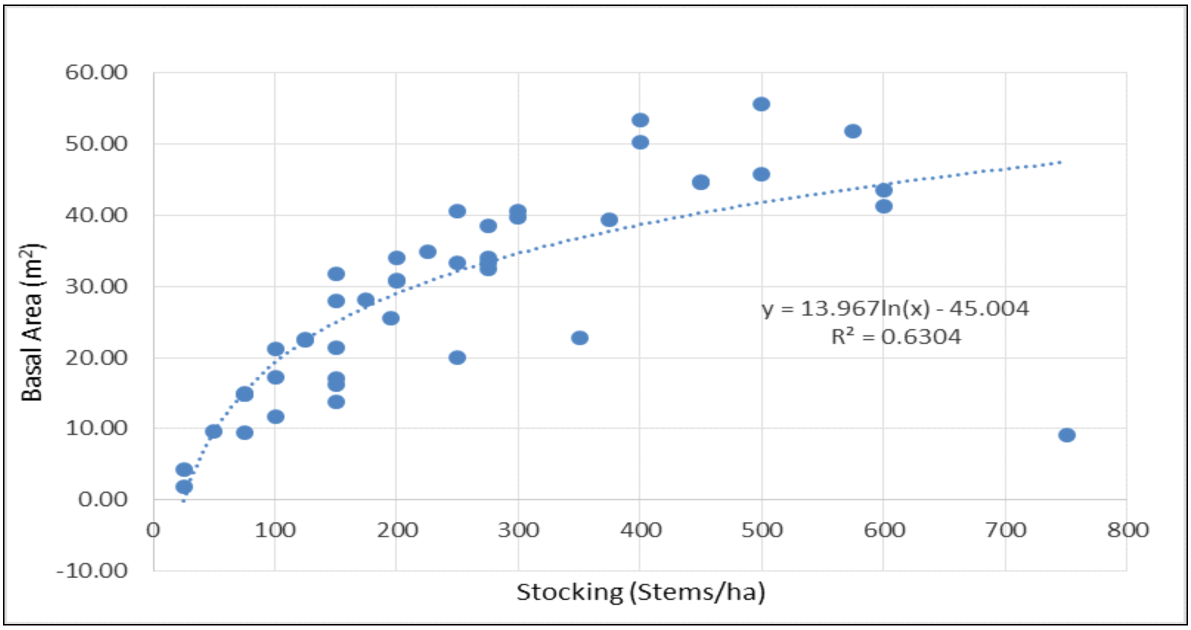

Figure 9: Basal area trends against stocking density for *Pinus patula*

The r^2 = 0.63 is an indicator of poaching for the mature plantations due to poor management. It was expected to be at better though for *Cupressus lusitanica* being the worse by r^2 = 0.53. Johnsen *et al.* (2004) found that "the inclusion of stand age and density contributed to model performance for even-aged *Pinus radiata* stands" (p.11). Vanclay (1988) also reported that, "stand density played an important role in even-aged pure plantations" (p. 40).

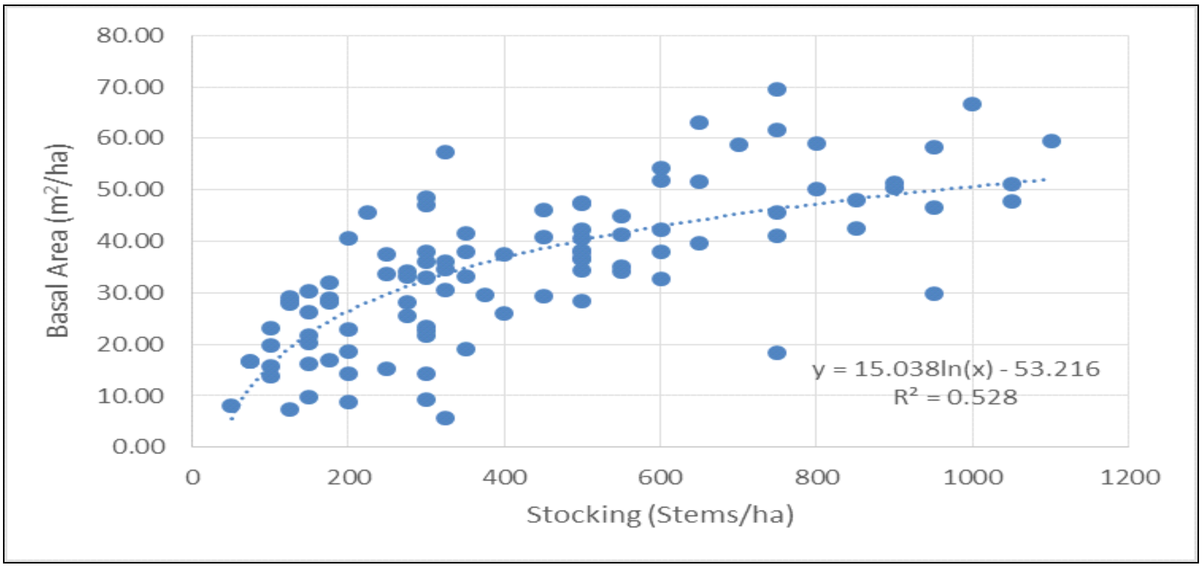

Figure 10: Basal area trends against stocking density for *Cupressus lusitanica*

4.2.4 Volume against Age

Considering forestry from the economic point of view, investment in forestry is expected to yield continuous returns in terms of definite class of produce and in greatest possible quantity within a reasonable time and to the best financial advantage. According to FAO (2005, p.17) the best method of achieving this objective of sustainable annual yield is to maintain a complete succession of equal area of crops of all ages and all age classes.

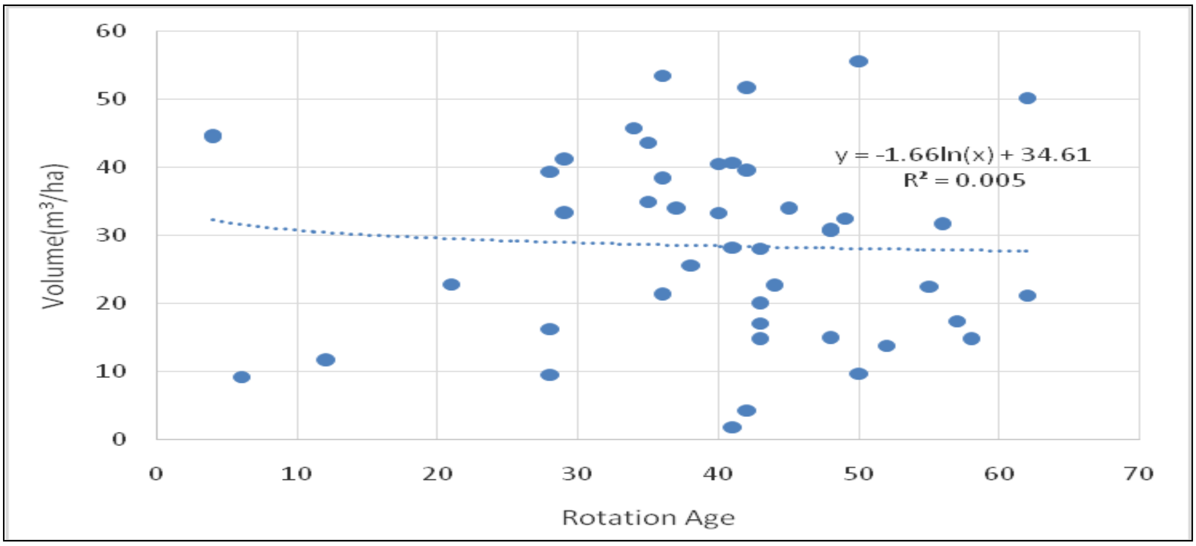

Figure 11: Volume trends against rotation age for *Pinus patula*

According to Schlich (1985, p.55) the volume of a normal growing stock stands in a forest with normal age classes and with normal increment is expected to be a straight line. However, the data is irregular showing $r^2 = 0.005$ for *Pinus patula* and $r^2 = 0.099$ for *Cupressus lusitanica* (Figure 11, derived from appendix C and D). This irregularity in the plantations requires that the forest is transformed into a normal forest.

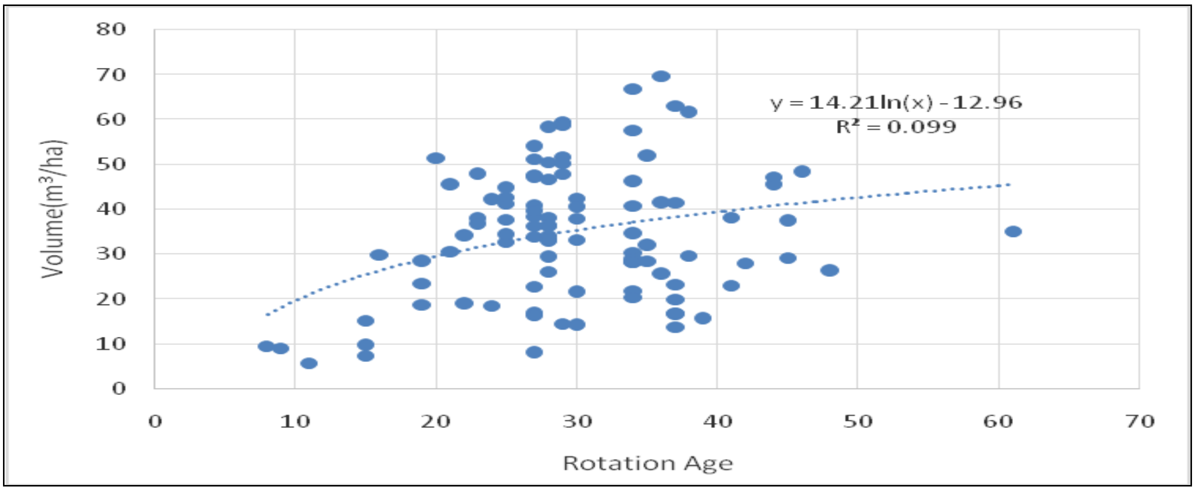

Figure 12: Volume trends against rotation age for *Cupressus lusitanica*

4.3 Long run sustainable yield based on the volume projections of the total area

4.3.1 Analyses of LRSY outputs

Stands with the same rotation ages allows for harvesting of equal areas despite variation in volumes. This is attributed to the variation in the stand attributes (basal areas and tree heights). LRSY is dependent on MAI and stocking considering that the basal areas were computed using the stocking per plot.

An even data with increasing target rotation ages did not typically indicate an increase in LRSY, MAI, and annual harvested volumes. This definitely indicates that the data obtained for this study from the two forest stations was maintained to the expected output. LRSY for lower rotation ages should typically be less than those of higher target rotation ages as volume increases from young to higher ages up to an optimum. This was not the case and mainly was attributed to a logging ban that had lasted for a period of sixteen years, from 2000 to 2006 and poor forest management practices.

Parkash (1985, p.45) recognizes the abnormality of forests due to being overstocked. He notes that a forest past the age of or having excessive distribution of older age classes will have more volume per unit area than the normal. Therefore, from this study, LRSY has guaranteed the conversion of the existing forests into a normal forest, where harvesting equal volumes from the target forest annually, is possible. This is from the $r^2 = 0.513$ (Figure 12, derived from appendix C). Consequently, concession would be the best management tool to have a uniform data, and a normal forest.

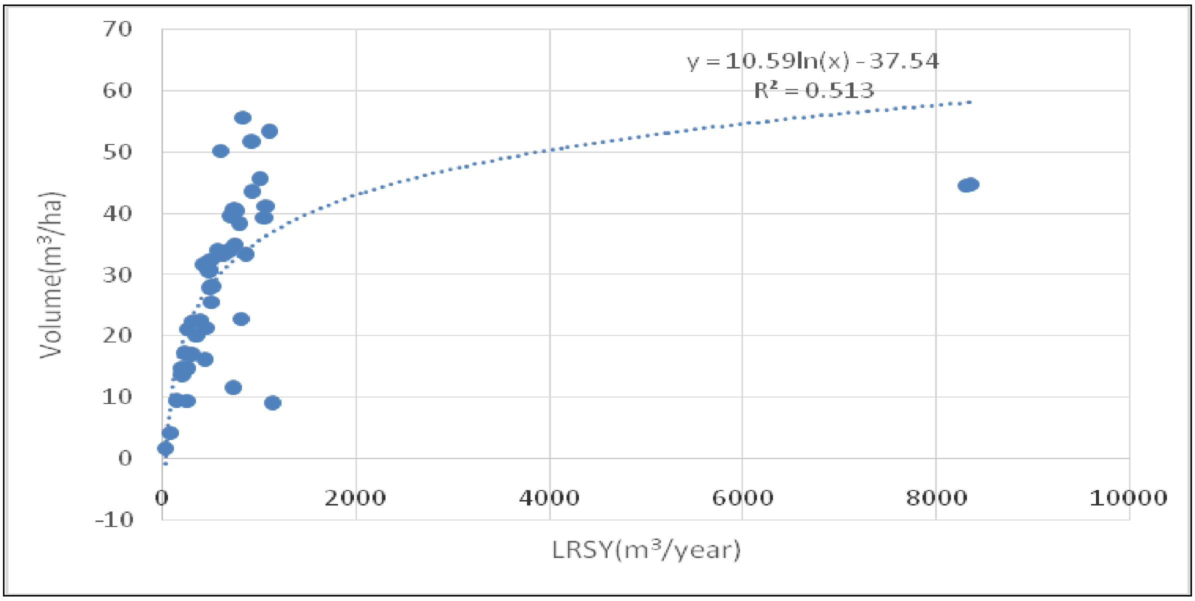

Figure 13: Volume trends against LSRY for *Pinus patula*

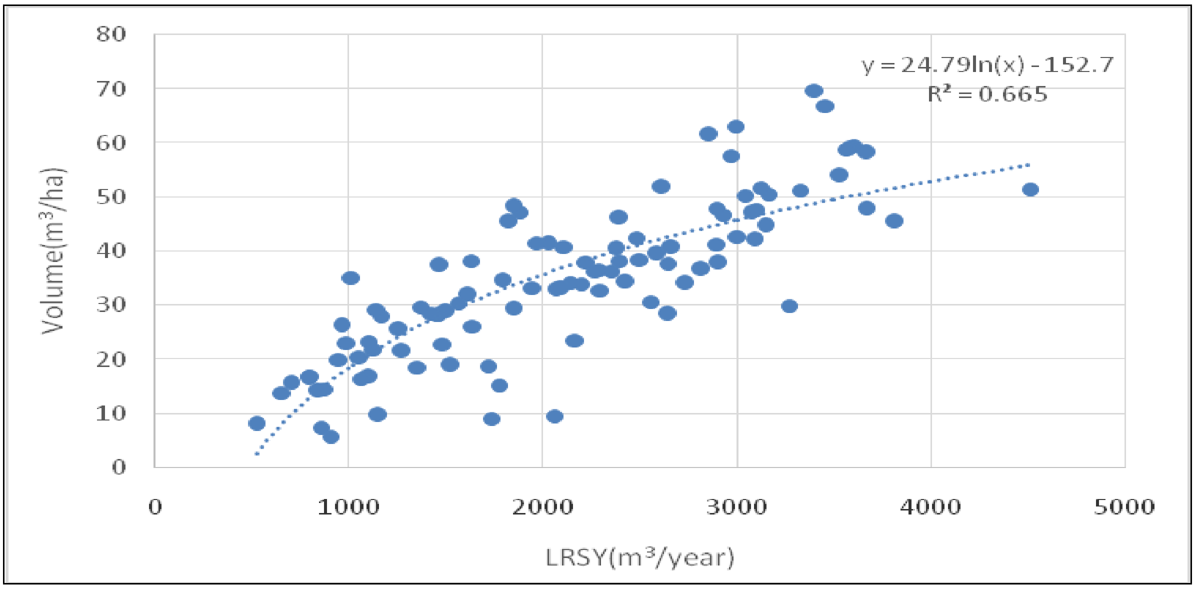

Figure 14: Volume trends against LSRY for *Cupressus lusitanica*

4.4 Categorization of timber-based industry supported study area resource

4.4.1 Area based categorization

Total area covered by tree plantation for only cypress and pines (6,442.9 ha. refer to Table 3) indicates that all categories of wood-based industry can be supported. Nevertheless, the calculation did not consider the backlogs and cedar plantations which when incorporated give an additional area of 3,795.3 hectares.

Table 5: Area based categorization

Element_License (TL)	No. **of firms that can be supported**	**Total area (ha) with establishment**	
Location **Size/ Volume per license**	Geographic balance	Geographic Balance	
Large	Up to 200 ha	3	**6,442.9**
Medium	Up to 35 ha	18	**6,442.9**
Small	**Up to 20 ha**	**32**	**6,442.9**

Data shows a high number of firms in all categories that can be supported from the total area. Area based method is not the best categorization tool due to the high number of firms it shows it can support. This is compared with volume-based method that indicates a smaller and scientific reasonable number of firms. When the rotation age taken at 20 years, all the categories of timber-based industries can be supported, given the resource.

4.4.2 Volume based categorization

Data shows that categorization based on the volume method is the most realistic way to know the number of industries the resource can support. Area based method has shown a double of the number the resource can support which appears unrealistic. With concession, an enhanced forest practice is likely to improve the current management scenario given that the volume per hectare is lower than the optimal point. This could be attributed to excess poaching; which with a concession will definitely be minimized (Refer to Table 6).

Total volume = 17,795,887.7 m3

Allowable cut = 1,779,588.77 m3

Table 6: Volume based categorization

Mill _wood **M^3/day**	**Round wood M^3/yr**	**No. of firms to be supported**	
Small	1,000	364,000	**5**
Medium	2,000	728,000	**2**
Large	**3,000**	**1,092,000**	**2**

CHAPTER FIVE
CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

i. There is a weak relationship between mean height and diameter at breast height in both species verses a very strong relationship between volume and basal area. To this end therefore, the tree attributes of mean tree height and the tree diameter at breast height can be used successfully to give precise volume projections in plantations management.

ii. The long run sustained yield shows variations in volume attributed to difference in the stand attributes, basal area and height.

iii. The long run sustained yield for lower rotation ages was more than of higher rotation ages. It can be concluded that the long run sustained yield cannot be projected from the tree volume of any total forest area. This is due to poor forest management practices, including poaching activities leading to lower volumes in higher rotations.

iv. The area-based method of categorization of the number of firms to be supported in the study area is quite higher than when volume-based method is used and therefore the volume-based method is more effective and efficient.

5.2 Recommendations

i. The relationship between various tree attributes is a scientific proof of tree growth and good stocking. Forest concession could be an option help manage the scenario given that the stocking is very high.

ii. In expanse forest plantations, the various tree attributes can be very vital in the projections and hence estimate the production per area. Despite the incorporation of other management options such as Community Forest Association, LRSY is for higher rotations was lower than for lower rotations.

iii. For the achievement of the sustainable yield, other than relying on the projections from the volume related tree attributes, there need to look for other forest management options such as concessions. Therefore, the volume-based categorization method has qualified need to adapt concession with one large firm and a few of both small and medium firms.

iv. There is a need to pilot concession as a forest management tool to rectify the problems encountered in the current scenario to be able to determine the maximum number of timber-based industries that can be supported by a given forest area.

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APPENDICES

Appendix A: Data for *Cupressus lusitanica* Plantations

Sub Comp.	Species	Planting year	Age	Stocking	Mdbh (mm)	dbh(cm)	Mht	P/Area
1F	*C.lusitanica*	1976	34	150	428.9	42.89	24	9.8
1H	*C.lusitanica*	1976	34	150	414.8	41.48	22.6	12.4
1H3	*C.lusitanica*	1976	34	175	452.5	45.25	23.4	3.4
1I	*C.lusitanica*	1976	34	150	507	50.7	25.9	13.7
1J	*C.lusitanica*	1976	34	175	458.9	45.89	26.9	22.9
1L	*C.lusitanica*	1976	34	325	474.4	47.44	26.6	9.6
1M	*C.lusitanica*	1976	34	200	509	50.9	26.9	7.2
1R	*C.lusitanica*	1999	11	325	149	14.9	8.6	7.5
1S	*C.lusitanica*	1976	34	125	537.8	53.78	27.6	5.9
1Z	*C.lusitanica*	1976	34	325	368.3	36.83	21.6	3.8
2A	*C.lusitanica*	1973	37	75	534	53.4	22.9	11.4
2B	*C.lusitanica*	1975	35	175	453.9	45.39	26.2	13.8
2C	*C.lusitanica*	1975	35	175	482.9	48.29	28.4	12.7
2D	*C.lusitanica*	1982	28	275	397.4	39.74	26	22
2E	*C.lusitanica*	1982	28	350	372.2	37.22	23.4	14.2
2F	*C.lusitanica*	1982	28	500	304.7	30.47	25.8	12.4
2G	*C.lusitanica*	1982	28	300	374	37.4	26	17.5
2H	*C.lusitanica*	1982	28	275	392.5	39.25	25.4	19.2
2I	*C.lusitanica*	1982	28	325	376.2	37.62	26	20.5
2K	*C.lusitanica*	1983	27	175	350	35	28.4	38.5
2W	*C.lusitanica*	1983	27	250	414.7	41.47	24.2	16.5
4A	*C.lusitanica*	1983	27	300	391.7	39.17	26.5	46.1
5A	*C.lusitanica*	1973	37	100	503	50.3	26.8	16.3
5C	*C.lusitanica*	1973	37	75	532.1	53.21	25.2	18.2
5F	*C.lusitanica*	1983	27	450	339.7	33.97	27.7	54.3
5G	*C.lusitanica*	1983	27	500	346.7	34.67	29	14.3
5H	*C.lusitanica*	1983	27	500	348	34.8	28	25
1A	*C.lusitanica*	1995	15	125	272.8	27.28	12	21.3
1P	*C.lusitanica*	1990	20	900	269.4	26.94	26.4	8
1Y	*C.lusitanica*	1995	15	150	288	28.8	12.8	2
1Z	*C.lusitanica*	1995	15	250	277.7	27.77	14.3	8
2A	*C.lusitanica*	2001	9	200	237.7	23.77	9.4	18
2D	*C.lusitanica*	1971	39	100	446.4	44.64	23.1	27
3B	*C.lusitanica*	1976	34	1000	291.5	29.15	30.8	2.5
3L	*C.lusitanica*	1949	61	550	284.7	28.47	22.3	11.1
3M	*C.lusitanica*	1985	25	400	346	34.6	24.8	3.9
4K	*C.lusitanica*	1976	34	275	361.5	36.15	24.8	10.1
4L	*C.lusitanica*	1981	29	200	302.3	30.23	26.2	16.2
4M	*C.lusitanica*	1983	27	500	312.3	31.23	27.9	7.9
4N	*C.lusitanica*	1985	25	750	264.2	26.42	26.7	11.2
4O	*C.lusitanica*	1985	25	600	263	26.3	25.3	4.3

5E	*C.lusitanica*	1980	30	350	347.1	34.71	26.6	9.9
5N	*C.lusitanica*	1988	22	350	263.1	26.31	13.9	0.9
5T	*C.lusitanica*	1989	21	750	278	27.8	23.3	2.1
6H	*C.lusitanica*	1980	30	500	328.5	32.85	24.7	15
6I	*C.lusitanica*	1983	27	300	310.5	31.05	21.1	44.8
6J	*C.lusitanica*	1982	28	950	279.6	27.96	26.5	23.4
6L	*C.lusitanica*	1980	30	300	303	30.3	22.1	21.1
6N	*C.lusitanica*	1983	27	650	278.7	27.87	24	67.5
6Q	*C.lusitanica*	1985	25	850	252.7	25.27	23.3	35.3
6S	*C.lusitanica*	1973	37	100	543	54.3	21.6	2.9
6W	*C.lusitanica*	1973	37	100	417.9	41.79	24.3	14.4
6X	*C.lusitanica*	1980	30	500	310.5	31.05	24.2	23.2
6Z	*C.lusitanica*	1981	29	800	282.5	28.25	24.2	16.7
6Zi	*C.lusitanica*	1994	16	950	199.7	19.97	19.2	7.5
7I	*C.lusitanica*	1981	29	1100	262.3	26.23	22.5	24
7K	*C.lusitanica*	1983	27	1050	248.8	24.88	25.5	14.3
7N	*C.lusitanica*	1985	25		308.8	30.88	20.6	12.8
7W	*C.lusitanica*	1965	45	125	544.7	54.47	26.1	20.8
7Y	*C.lusitanica*	1981	29	1050	240.7	24.07	21.4	12.9
7Z	*C.lusitanica*	1986	24	750	176.8	17.68	17.8	1.5
8C	*C.lusitanica*	1980	30	300	246.2	24.62	15.8	5.4
8E	*C.lusitanica*	1966	44	225	507.5	50.75	27.1	22.1
8F	*C.lusitanica*	1964	46	300	453.2	45.32	29.1	49.5
8H	*C.lusitanica*	1966	44	300	447.1	44.71	28.5	36.5
8I	*C.lusitanica*	1965	45	250	436.8	43.68	26.3	56.5
8J	*C.lusitanica*	1968	42	125	533.2	53.32	26.5	18.5
8L	*C.lusitanica*	1969	41	200	382.4	38.24	24.4	22.8
8M	*C.lusitanica*	1989	21	325	345.6	34.56	22.3	6.5
9F	*C.lusitanica*	1987	23	850	268	26.8	24.9	10.8
10A	*C.lusitanica*	1962	48	150	472.7	47.27	23	6.3
10C	*C.lusitanica*	1969	41	300	401.7	40.17	23	30.6
10D	*C.lusitanica*	1973	37	650	351.2	35.12	27.1	15.2
10E	*C.lusitanica*	1974	36	750	343.6	34.36	24.3	11.5
11C	*C.lusitanica*	1983	27	600	338.9	33.89	26.7	19
11D	*C.lusitanica*	1972	38	375	316.8	31.68	26.7	25.9
11E	*C.lusitanica*	1972	38	750	323.4	32.34	27.2	25
11F	*C.lusitanica*	1975	35	600	332	33.2	27.3	26.9
11I	*C.lusitanica*	1976	34	450	361.6	36.16	26.3	12.1
12B	*C.lusitanica*	1973	37	550	309.5	30.95	23.5	13.7
12D	*C.lusitanica*	1974	36	275	344.4	34.44	24.8	10.1
12E	*C.lusitanica*	1974	36	350	388.5	38.85	24.8	19.7
12F	*C.lusitanica*	1981	29	800	306.5	30.65	26.8	17.3
12G	*C.lusitanica*	1981	29	700	326.9	32.69	24.1	16.9
12H	*C.lusitanica*	1981	29	650	317.7	31.77	25.3	13.9
12I	*C.lusitanica*	1982	28	400	287.6	28.76	24.9	20.9

12J	*C.lusitanica*	1982	28	950	250	25	27.3	17
12K	*C.lusitanica*	1985	25	550	322	32.2	23.7	20.7
1F	*C.lusitanica*	1982	28	900	267	26.7	27.1	15.9
1I	*C.lusitanica*	1982	28	450	288.6	28.86	27.7	17.5
2B	*C.lusitanica*	1980	30	500	321.3	32.13	24	13.1
2H	*C.lusitanica*	1987	23	600	283.7	28.37	25.9	25.5
2J	*C.lusitanica*	2002	8	300	199.4	19.94	12.3	4
2R	*C.lusitanica*	1983	27	150	371.8	37.18	20.5	6.8
2S	*C.lusitanica*	1991	19	200	344	34.4	17.5	14.5
2W	*C.lusitanica*	1988	22	550	281.1	28.11	27.1	24.1
2X	*C.lusitanica*	1986	24	600	299.2	29.92	26.7	44
2Y	*C.lusitanica*	1987	23	500	306	30.6	26	11.8
2Z1	*C.lusitanica*	1991	19	300	314.8	31.48	15.3	2
3B	*C.lusitanica*	1991	19	500	269.5	26.95	20.7	32.9
3C	*C.lusitanica*	1987	23		25.4	2.54	23.8	19.1
3E	*C.lusitanica*	1985	25	500	296	29.6	25.9	6.7
4G	*C.lusitanica*	1983	27	50	454	45.4	20.1	9.3

Appendix B: Pinus Species Plantation Data

Sub Comp.	Species	Planting Year	Age	Stocking	M.D.B.H (mm)	dbh(cm)	MHT	P/Area
7U	*P.patula*	1948	62	400	399.7	39.97	35	10.5
2T	*P.patula*	1948	62	100	519	51.9	32	3.9

7L	*P.radiata*	1952	58	75	501.5	50.15	34.1	14.1
7Q	*P.radiata*	1953	57	100	469.7	46.97	34.6	28.1
7R	*P.patula*	1954	56	150	519.2	51.92	35.4	4.4
7S	*P.radiata*	1955	55	125	478.4	47.84	28.2	27.7
7V	*P.radiata*	1958	52	150	341.5	34.15	27.5	19.6
8A	*P.patula*	1960	50	500	376.3	37.63	33.8	20.1
1D	*P.radiata*	1960	50	50	494.3	49.43	33.3	4.5
9B	*P.radiata*	1961	49	275	387.8	38.78	37.9	26.4
6U	*P.radiata*	1962	48	200	442.1	44.21	33.6	10.5
9C	*P.radiata*	1962	48	200	443.6	44.36	32.8	46.2
2Z	*P.radiata*	1962	48	75	503.9	50.39	35.6	10.9
8G	*P.patula*	1965	45	275	397.1	39.71	29.3	38.1
4D	*P.patula*	1966	44	125	480.5	48.05	33.3	17.3
1H	*P.patula*	1967	43	150	380.5	38.05	31.4	35.5
2L	*P.patula*	1967	43	75	501.3	50.13	32.5	12.1
2N	*P.patula*	1967	43	150	487.4	48.74	30	44.3
2U	*P.patula*	1967	43	250	319.7	31.97	32.8	42.6
8K	*P.patula*	1968	42	575	338.6	33.86	36.6	3.7
2P	*P.patula*	1968	42	300	410.2	41.02	34.3	27.5
2Z2	*P.patula*	1968	42	25	465.6	46.56	30.3	12.5
6C	*P.patula*	1969	41	250	455.1	45.51	30.7	4.3
6V	*P.patula*	1969	41	175	452.8	45.28	31.6	22.1
4E	*P.patula*	1969	41	25	301	30.1	9.3	2.6
7X	*P.patula*	1970	40	300	414.8	41.48	27.4	13.5
3D	*P.patula*	1970	40	250	412	41.2	32.4	3.5
5D	*P.patula*	1972	38	195	408.8	40.88	31.9	29.5
2H	*P.patula*	1973	37	200	465.5	46.55	38.3	16.5
10H	*P.patula*	1974	36	275	421.9	42.19	28.6	3.5
12L	*P.Patula*	1974	36	400	412.5	41.25	30.8	1.2
9A	*P.radiata*	1974	36	150	425.7	42.57	31.7	9
11G	*P.patula*	1975	35	600	304.2	30.42	31.3	15.6
2G	*P.patula*	1975	35	225	444.5	44.45	35.2	5.8
11H	*P.patula*	1976	34	500	341.3	34.13	30.9	10.2
6T	*P.patula*	1981	29	275	393.1	39.31	27.4	2.6
6Y	*P.patula*	1981	29	600	295.9	29.59	28.3	22.1
10F	*P.patula*	1982	28	150	371	37.1	26.5	10.7
13A$B	*P.patula*	1982	28	375	365.6	36.56	26.7	26.1

2L	*P.radiata*	1982	28	75	400.6	40.06	23.7	14.1
6R	*P.patula*	1989	21	350	288.1	28.81	16	5.7
11B2	*P.radiata*	1998	12	100	385.8	38.58	20.5	10.1
1B	*P.patula*	2004	6	750	124.4	12.44	8.4	11.5
2C	*P.patula*	2006	4	450	356	35.6	39.4	22.9
2C1	*P.patula*	2006	4	450	355.1	35.51	39.4	22.9

Appendix C: Long Run Sustainable Yield for *Pinus Patula*

Total Forest Area (Ha)	Target Rotation	Volume (M^3/ha)	MAI (M^3/ha/yr)	Annual harvest Area(ha/yr)	LRSY (M^3/year
746.5	4	44.79	11.2	186.63	8359
746.5	4	44.57	11.14	186.63	8317
746.5	6	9.12	1.52	124.42	1134
746.5	12	11.69	0.97	62.21	727
746.5	21	22.82	1.09	35.55	811
746.5	28	16.22	0.58	26.66	432
746.5	28	39.37	1.41	26.66	1050
746.5	28	9.45	0.34	26.66	252
746.5	29	33.38	1.15	25.74	859
746.5	29	41.26	1.42	25.74	1062
746.5	34	45.74	1.35	21.96	1004
746.5	35	43.61	1.25	21.33	930
746.5	35	34.92	1.00	21.33	745
746.5	36	38.45	1.07	20.74	797
746.5	36	53.46	1.48	20.74	1108
746.5	36	21.35	0.59	20.74	443
746.5	37	34.04	0.92	20.18	687
746.5	38	25.59	0.67	19.64	503
746.5	40	40.54	1.01	18.66	757
746.5	40	33.33	0.83	18.66	622
746.5	41	40.67	0.99	18.21	740
746.5	41	28.18	0.69	18.21	513
746.5	41	1.78	0.04	18.21	32
746.5	42	51.78	1.23	17.77	920
746.5	42	39.65	0.94	17.77	705
746.5	42	4.26	0.1	17.77	76
746.5	43	17.06	0.4	17.36	296
746.5	43	14.8	0.34	17.36	257
746.5	43	27.99	0.65	17.36	486
746.5	43	20.07	0.47	17.36	348
746.5	44	22.67	0.52	16.97	385
746.5	45	34.06	0.76	16.59	565
746.5	48	30.7	0.64	15.55	477
746.5	48	30.91	0.64	15.55	481
746.5	48	14.96	0.31	15.55	233
746.5	49	32.48	0.66	15.23	495
746.5	50	55.61	1.11	14.93	830
746.5	50	9.59	0.19	14.93	143
746.5	52	13.74	0.26	14.36	197
746.5	55	22.47	0.41	13.57	305
746.5	56	31.76	0.57	13.33	423
746.5	57	17.33	0.3	13.1	227
746.5	58	14.81	0.26	12.87	191
746.5	62	50.19	0.81	12.04	604
746.5	62	21.16	0.34	12.04	255

Appendix D: Long Run Sustainable Yield for *Cupressus Lusitanica*

Total Forest Area (ha)	Age (Target rotation Age)	Volume (M^3/ha)	MAI (M^3/ha/yr)	Annual harvest Area (ha/yr)	LRSY (M^3/year)
1758.2	8	9.37	1.17	219.78	2059
1758.2	9	8.88	0.99	195.36	1734
1758.2	11	5.67	0.52	159.84	906
1758.2	15	7.31	0.49	117.21	856
1758.2	15	9.77	0.65	117.21	1145
1758.2	15	15.14	1.01	117.21	1775
1758.2	16	29.76	1.86	109.89	3270
1758.2	19	18.59	0.98	92.54	1720
1758.2	19	23.35	1.23	92.54	2161
1758.2	19	28.52	1.50	92.54	2639
1758.2	20	51.30	2.57	87.91	4510
1758.2	21	45.52	2.17	83.72	3811
1758.2	21	30.49	1.45	83.72	2553
1758.2	22	19.03	0.86	79.92	1521
1758.2	22	34.13	1.55	79.92	2728
1758.2	23	47.95	2.08	76.44	3665
1758.2	23	37.93	1.65	76.44	2899
1758.2	23	36.77	1.60	76.44	2811
1758.2	24	18.41	0.77	73.26	1349
1758.2	24	42.19	1.76	73.26	3090
1758.2	25	37.61	1.50	70.33	2645
1758.2	25	41.12	1.64	70.33	2892
1758.2	25	32.60	1.30	70.33	2292
1758.2	25	42.63	1.71	70.33	2998
1758.2	25	44.79	1.79	70.33	3150
1758.2	25	34.41	1.38	70.33	2420
1758.2	27	16.84	0.62	65.12	1096
1758.2	27	33.77	1.25	65.12	2199
1758.2	27	36.15	1.34	65.12	2354
1758.2	27	40.78	1.51	65.12	2656
1758.2	27	47.20	1.75	65.12	3074
1758.2	27	47.56	1.76	65.12	3097
1758.2	27	38.30	1.42	65.12	2494
1758.2	27	22.72	0.84	65.12	1479
1758.2	27	39.65	1.47	65.12	2582

1758.2	27	51.05	1.89	65.12	3324
1758.2	27	54.12	2.00	65.12	3524
1758.2	27	16.29	0.60	65.12	1060
1758.2	27	8.09	0.30	65.12	527
1758.2	28	34.11	1.22	62.79	2142
1758.2	28	38.08	1.36	62.79	2391
1758.2	28	36.46	1.30	62.79	2289
1758.2	28	32.96	1.18	62.79	2069
1758.2	28	33.27	1.19	62.79	2089
1758.2	28	36.13	1.29	62.79	2268
1758.2	28	58.33	2.08	62.79	3663
1758.2	28	25.99	0.93	62.79	1632
1758.2	28	46.63	1.67	62.79	2928
1758.2	28	50.39	1.80	62.79	3164
1758.2	28	29.44	1.05	62.79	1848
1758.2	29	14.35	0.49	60.63	870
1758.2	29	50.14	1.73	60.63	3040
1758.2	29	59.44	2.05	60.63	3604
1758.2	29	47.78	1.65	60.63	2897
1758.2	29	59.03	2.04	60.63	3579
1758.2	29	58.75	2.03	60.63	3562
1758.2	29	51.53	1.78	60.63	3124
1758.2	30	33.12	1.10	58.61	1941
1758.2	30	42.38	1.41	58.61	2484
1758.2	30	21.63	0.72	58.61	1268
1758.2	30	37.86	1.26	58.61	2219
1758.2	30	14.28	0.48	58.61	837
1758.2	30	40.54	1.35	58.61	2376
1758.2	34	21.67	0.64	51.71	1121
1758.2	34	20.27	0.60	51.71	1048
1758.2	34	28.14	0.83	51.71	1455
1758.2	34	30.28	0.89	51.71	1566
1758.2	34	28.94	0.85	51.71	1497
1758.2	34	57.45	1.69	51.71	2971
1758.2	34	40.70	1.20	51.71	2104
1758.2	34	28.39	0.84	51.71	1468
1758.2	34	34.62	1.02	51.71	1790
1758.2	34	66.74	1.96	51.71	3451
1758.2	34	28.23	0.83	51.71	1460

1758.2	34	46.21	1.36	51.71	2390
1758.2	35	28.32	0.81	50.23	1422
1758.2	35	32.05	0.92	50.23	1610
1758.2	35	51.94	1.48	50.23	2609
1758.2	36	69.54	1.93	48.84	3396
1758.2	36	25.62	0.71	48.84	1251
1758.2	36	41.49	1.15	48.84	2026
1758.2	37	16.80	0.45	47.52	798
1758.2	37	19.87	0.54	47.52	944
1758.2	37	16.68	0.45	47.52	793
1758.2	37	23.16	0.63	47.52	1100
1758.2	37	13.72	0.37	47.52	652
1758.2	37	62.97	1.70	47.52	2992
1758.2	37	41.38	1.12	47.52	1966
1758.2	38	29.56	0.78	46.27	1368
1758.2	38	61.61	1.62	46.27	2850
1758.2	39	15.65	0.40	45.08	706
1758.2	41	22.97	0.56	42.88	985
1758.2	41	38.02	0.93	42.88	1630
1758.2	42	27.91	0.66	41.86	1168
1758.2	44	45.51	1.03	39.96	1819
1758.2	44	47.10	1.07	39.96	1882
1758.2	45	29.13	0.65	39.07	1138
1758.2	45	37.46	0.83	39.07	1464
1758.2	46	48.39	1.05	38.22	1850
1758.2	48	26.32	0.55	36.63	964
1758.2	61	35.01	0.57	28.82	1009

Appendix E: Inventory Data for Koibatek and Maji-Mazuri Forests

1. KOIBATEK FOREST STATION

JOGOO BLOCK

SUB COMP.	SPECIES	PLANTING YEAR	DENSITY	M.D.B.H	M. HT	AREA
1 D	*P. patula*	2004	1150			9.6
1 E	*E. saligna*	2004	500			2.4
3A	*Cup.lusitanica*	2005	1200			28.6
3B	*P. patula*	2002	1300			29.5
3C	*Cup.lusitanica*	2004	1500			16
3D	*P. patula*	2003	1000			7.9
3M	*Cup.lusitanica*	2003	1050			7.3
3N	*Cup.lusitanica*	1999	250	188.6	13.1	9
3O	*E. saligna*	Coppices	100	249.9	19.8	9.8
4A	*P. patula*	2004	550			15.1
4B1						19.9
4B2	*E. saligna*	1981	250			2.2
4C	*P. patula*	2006	500			25.1
4C$R	*P. patula*	2007	550			6.9
4D	*Cup.lusitanica*	2005	900			27.1
4E	*Cup.lusitanica*	2004	800			22.6
4F						27.3
4G	*Cup.lusitanica*	1995	175	225.4	12.3	10.4
4H1a						8.2
4H1b						1.6
4H2	*Cup.lusitanica*	1985	600	287.8	26.6	20.2
4I	*Cup.lusitanica*	1981	50	360	B/T	5.6
4J						1.4
4J	*E. saligna*	1975	100			11.7
4K						3.4
4L	*Cup.lusitanica*	1985	100	368.8	22.3	28.4
4M1	*P. patula*	2007	1450			20.6

4M2						2.4
4N	*P. patula*	2007	1250			13.2
4O	*Cup.lusitanica*	2005	750			25.3
4P	*Cup.lusitanica*	2004	900	170	6	3.8
4P1	*Cup.lusitanica*	2004	950	90	8	5
4Q	*E. saligna*	2006	1250			2.1
4R	*P. patula*	2006	750			28.5
4S	*Cup.lusitanica*	1995	75	246.7	10.3	3.8
4T	*Cup.lusitanica*	2004	1050			24.1
4U	*Cup.lusitanica*	2004	650			4.8
4V	*E. saligna*		250			2.9
4W	*Mex.grevelia*	UNK				4
4X	*Cup.lusitanica*	1997	200	255	12.8	0.6
4Y	*E. saligna*	2004	250			4.2
4Z	*E. saligna*	2006	500			1.1
5A	*Cup.lusitanica*	1998	125			4.4
5B	*E. saligna*	1985	650			10.6
5C	*Cup.lusitanica*	1982	125	345	19.4	19.1
5D	*Cup.lusitanica*	1984	175	382.9	25.1	9.4
5D1	*Cup.lusitanica*	1984	225	308.9	21.9	0.3
5E	*Cup.lusitanica*	1985	325	313.5	22.9	9.6
5EI	*E. saligna*	2007	550			7.4
5F	*Cup.lusitanica*	2005	200			14.2
5G	*P. patula*	2004	700			22.1
5H	*Euc. Spp*	1985	850	69.4	11.8	3.6
5I						6.9
5K	*Euc. Spp*	1961	4250			9.4
5M	*E. saligna*	1922	2500			12
5M1	*A.mela*	1922	100	263.9	15.3	5.4
5N	*cup.lusitanica*	1998	450	214.1	15.2	6.2
5O	*Cup.lusitanica*	1968	750	200.9	15.6	3.5
5P	*Cup.lusitanica*	2006	450			16.7

5Q	*Cup.lusitanica*	2002	600			34.4
5R	*P. patula*	2004	1150			17.7
5S	*A.mac$P.p*	2005	800			7.4
5T	*E. saligna*	1981	2550			23.8
5U						4.1
5V						14.1
5W						9.5
5X	*E. saligna*	1982	2400			14.1
6A$G	*Cup.lusitanica*	1987	400	365.3	25.8	52.9
6C						19.1
6D	*Cup.lusitanica*	2002	550			14.7
6E	*Cup.lusitanica*	2005	1100			13.3
6F	*Cup.lusitanica*	2005	900			13.2
7A	*P. patula*	2008	550			6.8
7B	*Cup.lusitanica*	1988	200	304.5	18.8	15.1
7C	*Cup.lusitanica*	2008	600			55
7D	*P. patula*	2005	850			44.9
7E	*P. patula*	2005	650			4.7
7F	*E. saligna*	2003	100	156.9	14.9	15
7G	*P. patula*	2008	500			17.2
7H	*P. patula*	2008	200			14.3
7I						25.6
7J						13.2
7K						28.8
7L	*E. saligna*	2008	800			16.3
7O	*P. patula*	2008	400			7.5
7P	*Cup.lusitanica*	2005	1150			4.5
7Q						19.3
7R	*P. patula*	2007	1200			30.9
7S	*P. patula*	2008	250			2
7S	*Cup.lusitanica*	2008	1000			2
7T	*E. saligna*	2005	250			5.6

8A	*Cup.lusitanica*	1979	25	200	5.5	6.6
8B						14.9
8C	*P.radiata*	1964	200	403.5	27.9	8
8D						40.4
8E						16.1
8F						19.4
8G	*Cup.lusitanica*	1972	25	629.3	26	15.5
8H	*Cup.lusitanica*	1972	50	651.7	28.5	8
8I						7.6
8K						13.6
8L	*Cup.lusitanica*	1981	125	391.9	21	14.8
8M	*P.patula*	1981	300	272.6	26	10.1
8N	*P.patula*	1979	250	455.4	32.8	3
8O	*cup.lusitanica*	1981	75	431.3	19	1.4
8P	*E. saligna*	1981	900	163.9	18.3	5
8Q						5.4
8S						10.4
9A						14.7
9B						36.3
9C	*Cup.lusitanica*	1981	350	333.5	22.9	17.4
9D	*Cup.lusitanica*	1981	200	329.5	22.5	12.8
9E	*Cup.lusitanica*	1981	75	430.2	21.2	23
9F	*Cup.lusitanica*	1981	25	444.1	22	17.5
9G						5.6
10B	*P.radiata*	2002	900			11.1
10D	*P.radiata*	2007	900			18.4
10F	*P.radiata*	2004	700			1.3
11B1	*Cup.lusitanica*	2007	500			12.6
11C	*Cup.lusitanica*	2006	500			39
11D	*Cup.lusitanica*	2006	600			12.9
11E						40.1
11F	*P.patula*	2005	600			18.5

11F1	*C.egusetifolia*	2005	200			3
11G						3.2
11H	*P.patula*	1986	50	277	15	28.2
11I	*P.patula*	2006	400			18.6
11J	*Cup.lusitanica*	1986	450			42
11k	*Cup.lusitanica*	2005	650			9.1
11k1	*C.egusetifolia*	2005	700			5.6
11M						8.4
11N						23.5
SACHANGWAN BLOCK						
1A	*Cup.lusitanica*	2004	1300			30.7
1B	*P.patula$E.saligna*	2004	750	124.4	8.4	11.5
1C	*Cup.lusitanica*	2004	1550			10.6
1D	*P.patula*	2004	850			21.9
1E	*P.patula*	2010	1000		8	25.6
1F	*Cup.lusitanica*	1976	150	428.9	24	9.8
1G	*Cup.lusitanica*					16.2
1H	*Cup.lusitanica*	1976	150	414.8	22.6	12.4
1H3	*Cup.lusitanica*	1976	175	452.5	23.4	3.4
1I	*Cup.lusitanica*	1976	150	507	25.9	13.7
1J	*Cup.lusitanica*	1976	175	458.9	26.9	22.9
1K						18
1L	*Cup.lusitanica*	1976	325	474.4	26.6	9.6
1M	*Cup.lusitanica*	1976	200	509	26.9	7.2
1O	*Cup.lusitanica*	2005	650			20.1
1P						19.1
1Q						7.7
1R	*Cup.lusitanica*	1999	325	149	8.6	7.5
1S	*Cup.lusitanica*	1976	125	537.8	27.6	5.9
1T						6.9
1U						1.2
1V						7.3

1W	*P.patula*	2007	700			11.3
1X						10.5
1Y	*P.radiata*	2005	1000			1.6
1Z	*Cup.lusitanica*	1976	325	368.3	21.6	3.8
2A	*Cup.lusitanica*	1973	75	534	22.9	11.4
2B	*Cup.lusitanica*	1975	175	453.9	26.2	13.8
2C	*Cup.lusitanica*	1975	175	482.9	28.4	12.7
2D	*Cup.lusitanica*	1982	275	397.4	26	22
2E	*Cup.lusitanica*	1982	350	372.2	23.4	14.2
2F	*Cup.lusitanica*	1982	500	304.7	25.8	12.4
2G	*Cup.lusitanica*	1982	300	374	26	17.5
2H	*Cup.lusitanica*	1982	275	392.5	25.4	19.2
2I	*Cup.lusitanica*	1982	325	376.2	26	20.5
2K	*Cup.lusitanica*	1983	175	350	28.4	38.5
2L	*P.radiata*	1982	75	400.6	23.7	14.1
2W	*Cup.lusitanica*	1983	250	414.7	24.2	16.5
4A	*Cup.lusitanica*	1983	300	391.7	26.5	46.1
5A	*Cup.lusitanica*	1973	100	503	26.8	16.3
5B						30.3
5C	*Cup.lusitanica*	1973	75	532.1	25.2	18.2
5D						20.4
5E						18.1
5F	*Cup.lusitanica*	1983	450	339.7	27.7	54.3
5G	*Cup.lusitanica*	1983	500	346.7	29	14.3
5H	*Cup.lusitanica*	1983	500	348	28	25
6A						13.9
6B						23.3
6C						38.4
11B2	*P.radiata*	1998	100	385.8	20.5	10.1
						2712.3

2. MAJI MAZURI FOREST

MAJI MAZURI EAST BLOCK						
LAIKWEN1i	*E.saligna*	1985	300	188.9	14.4	19.1
1A	*Cup.lusitanica*	1995	125	272.8	12	21.3
1N						2.2
1P	*Cup.lusitanica*	1990	900	269.4	26.4	8
1T						32.6
1Y	*Cup.lusitanica*	1995	150	288	12.8	2
1Z	*Cup.lusitanica*	1995	250	277.7	14.3	8
2A	*Cup.lusitanica*	2001	200	237.7	9.4	18
2B						15.5
2C	*P.patula*	2006	450	356	39.4	22.9
2D	*Cup.lusitanica*	1971	100	446.4	23.1	27
2E						23.3
2F						29
2G						29.9
2H	*P.patula*	1973	200	465.5	38.3	16.5
3A	*E.saligna*	1922	100	250.2	20.4	5.9
3B	*Cup.lusitanica*	1976	1000	291.5	30.8	2.5
3C	*Cup.lusitanica*	2008	850			10.9
3D	*Cedar*	1934	450	366.5	29.3	4.2
3G						5
3G1	*Mix Spp*	2003	450			27
3H						9.7
3I	*Mix Spp*	1928	700	265.9	26.9	36.1
3J	*G.robusta*	1935	100	208.1	27.2	29.9
3J	*Cedar*	1935	200	348.9	28.7	29.9
3K	*Cedar*	1920	300	357.6	25.4	9.1
3L	*Cup.lusitanica*	1949	550	284.7	22.3	11.1
3M	*Cup.lusitanica*	1985	400	346	24.8	3.9
3N						3

3O	*P.falcatus*	1922	75	178.4	13.8	4.7
3O	*Cedar*	1922	275	340.1	30.2	4.7
4A	*Cedar*	1932	450	319.2	26.4	8.6
4B						11.2
4C	*Cedar*	1931	400	322	28.5	78.9
4D	*Cedar*	1932	200	316.1	25.6	4.7
4E						7.1
4G						4.5
4J						2.3
4K	*Cup.lusitanica*	1976	275	361.5	24.8	10.1
4K	*E.pan…*	1980	75	337.3	18.4	0.6
4L	*Cup.lusitanica*	1981	200	302.3	26.2	16.2
4M	*Cup.lusitanica*	1983	500	312.3	27.9	7.9
4N	*Cup.lusitanica*	1985	750	264.2	26.7	11.2
4O	*Cup.lusitanica*	1985	600	263	25.3	4.3
4P						14.7
5A$B	*P.falcatus*	1924	50	289.5	17	26.5
5A$B	*E.macronata*	1924	300	356.5	26.1	26.5
5C	*Cedar*	1932	475	317.9	26.6	22.6
5D	*P.patula*	1972	195	408.8	31.9	29.5
5E	*Cup.lusitanica*	1980	350	347.1	26.6	9.9
5F	*Cedar*	1923/24	400	360.2	27.3	9.4
5G	*E.macronata*	1983	200	425.3	33.5	2.3
5H	*Cedar*	2008	1300			3.5
5J	*Cedar*	1925	325	413.3	29.1	3.2
5K	*Cedar*	1925	325	390.1	29	17.9
5L	*E.macronata*	1925	550	309	24.1	45.5
5M	*Cup.lusitanica*	2005	1200			10
5N	*Cup.lusitanica*	1988	350	263.1	13.9	0.9
5P	*Cedar*	1944	450	245.4	22.5	4.8
5Q	*Cedar*	1944	550	363.8	30.1	4.6
5S	*Cedar*	1925	525	340	30.6	0.9

5T	*Cup.lusitanica*	1989	750	278	23.3	2.1
5W	*E.saligna*	1980	775	177.5	25.2	1.5
6A	*Cedar*	1923	350	343.4	26.2	1.6
6B						34.2
6C	*P.patula*	1969	250	455.1	30.7	4.3
6D						9.7
6E	*Cedar*	1923	375	426.1	32.8	1.3
6F	*E.saligna*	1983	50	124.7	17.1	8.6
6G	*G.robusta*	1944	100	203.9	19.7	16.9
6G	*Cedar*	1944	300	321.1	22.4	16.9
6H	*Cup.lusitanica*	1980	500	328.5	24.7	15
6I	*Cup.lusitanica*	1983	300	310.5	21.1	44.8
6J	*Cup.lusitanica*	1982	950	279.6	26.5	23.4
6K						6.1
6L	*Cup.lusitanica*	1980	300	303	22.1	21.1
6M						35.7
6N	*Cup.lusitanica*	1983	650	278.7	24	67.5
6O	*Cedar*	1944	425	391.2	30.2	0.4
6P	*P.car………*	1958	200	484.9	24.7	4.9
6Q	*Cup.lusitanica*	1985	850	252.7	23.3	35.3
6R	*P.patula*	1989	350	288.1	16	5.7
6S	*Cup.lusitanica*	1973	100	543	21.6	2.9
6T	*P.patula*	1981	275	393.1	27.4	2.6
6U	*P.radiata*	1962	200	442.1	33.6	10.5
6V	*P.patula*	1969	175	452.8	31.6	22.,1
6W	*Cup.lusitanica*	1973	100	417.9	24.3	14.4
6X	*Cup.lusitanica*	1980	500	310.5	24.2	23.2
6Y	*P.patula*	1981	600	295.9	28.3	22.1
6Z	*Cup.lusitanica*	1981	800	282.5	24.2	16.7
6Zi	*Cup.lusitanica*	1994	950	199.7	19.2	7.5
7A	*E.pan…*	1933	150	266.6	23.4	45.4
7A	*P.kik……..*	1933	50	669.6	19.7	45.4

7A	*Cedar*	1933	300	348.2	23.5	45.4
7D						19.7
7D2						16.8
7E	*Cedar*	1933	450	363.8	26.7	29.7
7F	*E.macronata*	1933	550	199.3	19.6	4
7G	*E.saligna*	N/A	350	135.9	20.3	27.4
7G	*Cedar*	1933	850	260.9	25.2	3.7
7H	*E.saligna*	N/A	175	282.5	25.3	4.5
7I	*Cup.lusitanica*	1981	1100	262.3	22.5	24
7K	*Cup.lusitanica*	1983	1050	248.8	25.5	14.3
7L	*P.radiata*	1952	75	501.5	34.1	14.1
7N	*Cup.lusitanica*	1985	2350	308.8	20.6	12.8
7Q	*P.radiata*	1953	100	469.7	34.6	28.I
7R	*P.patula*	1954	150	519.2	35.4	4.4
7S	*P.radiata*	1955	125	478.4	28.2	27.7
7T						5.4
7U	*P.patula*	1948	400	399.7	35	10.5
7V	*P.radiata*	1958	150	341.5	27.5	19.6
7W	*Cup.lusitanica*	1965	125	544.7	26.1	20.8
7X	*P.patula*	1970	300	414.8	27.4	13.5
7Y	*Cup.lusitanica*	1981	1050	240.7	21.4	12.9
7Z	*Cup.lusitanica*	1986	750	176.8	17.8	1.5
8A	*P.patula*	1960	500	376.3	33.8	20.1
8B						34.9
8C	*Cup.lusitanica*	1980	300	246.2	15.8	5.4
8E	*Cup.lusitanica*	1966	225	507.5	27.1	22.1
8F	*Cup.lusitanica*	1964	300	453.2	29.1	49.5
8G	*P.patula*	1965	275	397.1	29.3	38.1
8H	*Cup.lusitanica*	1966	300	447.1	28.5	36.5
8I	*Cup.lusitanica*	1965	250	436.8	26.3	56.5
8J	*Cup.lusitanica*	1968	125	533.2	26.5	18.5
8K	*P.patula*	1968	575	338.6	36.6	3.7

8L	*Cup.lusitanica*	1969	200	382.4	24.4	22.8
8M	*Cup.lusitanica*	1989	325	345.6	22.3	6.5
9A	*P.radiata*	1974	150	425.7	31.7	9
9B	*P.radiata*	1961	275	387.8	37.9	26.4
9C	*P.radiata*	1962	200	443.6	32.8	46.2
9D	*Cup.lusitanica*	N/A	1000	227.6	18.4	18.6
9D						9.2
9E						35.4
9F	*Cup.lusitanica*	1987	850	268	24.9	10.8
10A	*Cup.lusitanica*	1962	150	472.7	23	6.3
10B						56.7
10C	*Cup.lusitanica*	1969	300	401.7	23	30.6
10D	*Cup.lusitanica*	1973	650	351.2	27.1	15.2
10E	*Cup.lusitanica*	1974	750	343.6	24.3	11.5
10F	*P.patula*	1982	150	371	26.5	10.7
10H	*P.patula*	1974	275	421.9	28.6	3.5
11A						25.9
11B						37.7
11C	*Cup.lusitanica*	1983	600	338.9	26.7	19
11D	*Cup.lusitanica*	1972	375	316.8	26.7	25.9
11E	*Cup.lusitanica*	1972	750	323.4	27.2	25
11F	*Cup.lusitanica*	1975	600	332	27.3	26.9
11G	*P.patula*	1975	600	304.2	31.3	15.6
11H	*P.patula*	1976	500	341.3	30.9	10.2
11I	*Cup.lusitanica*	1976	450	361.6	26.3	12.1
12A						14.4
12B	*Cup.lusitanica*	1973	550	309.5	23.5	13.7
12C						14.7
12D	*Cup.lusitanica*	1974	275	344.4	24.8	10.1
12E	*Cup.lusitanica*	1974	350	388.5	24.8	19.7
12F	*Cup.lusitanica*	1981	800	306.5	26.8	17.3
12G	*Cup.lusitanica*	1981	700	326.9	24.1	16.9

12H	*Cup.lusitanica*	1981/82	650	317.7	25.3	13.9
12I	*Cup.lusitanica*	1982	400	287.6	24.9	20.9
12J	*Cup.lusitanica*	1982	950	250	27.3	17
12K	*Cup.lusitanica*	1985	550	322	23.7	20.7
12L	*P.Patula*	1974	400	412.5	30.8	1.2
13A$B	*P.patula*	1982	375	365.6	26.7	26.1
MAJI MAZURI WEST BLOCK						
1A	*Cedar*	1926	225	368.4	30.1	16.4
1C	*Cedar*	1926	175	380.8	31.5	26.4
1D	*P.radiata*	1960	50	494.3	33.3	4.5
1E	*Cedar*	1926	125	418.7	29.8	38
1F	*Cup.lusitanica*	1982	900	267	27.1	15.9
1G	*P.patula*	2006/7	350			35
1H	*P.patula*	1967	150	380.5	31.4	35.5
1I	*Cup.lusitanica*	1982	450	288.6	27.7	17.5
2A	*Cedar*	1934	175	436.4	23.9	8.4
2B	*Cup.lusitanica*	1980	500	321.3	24	13.1
2C						13.7
2C1	*P.patula*	2006	450	355.1	39.4	22.9
2C2						13.7
2D						14.7
2E	*P.pan…..*	1942	225	400.3	34	4.4
2F						16.2
2G	*P.patula*	1975	225	444.5	35.2	5.8
2H	*Cup.lusitanica*	1987	600	283.7	25.9	25.5
2I						3.2
2J	*Cup.lusitanica*	2002	300	199.4	12.3	4
2K	*Cup.lusitanica*	2005	900			4
2L	*P.patula*	1967	75	501.3	32.5	12.1
2M	*E.saligna*	1990	200	351	32.5	2
2N	*P.patula*	1967	150	487.4	30	44.3

2P	*P.patula*	1968	300	410.2	34.3	27.5
2Q						6.2
2R	*Cup.lusitanica*	1983	150	371.8	20.5	6.8
2S	*Cup.lusitanica*	1991	200	344	17.5	14.5
2T	*P.patula*	1948	100	519	32	3.9
2U	*P.patula*	1967	250	319.7	32.8	42.6
2V						4
2W	*Cup.lusitanica*	1988	550	281.1	27.1	24.1
2X	*Cup.lusitanica*	1986	600	299.2	26.7	44
2Y	*Cup.lusitanica*	1987	500	306	26	11.8
2Z	*P.radiata*	1962	75	503.9	35.6	10.9
2Z1	*Cup.lusitanica*	1991	300	314.8	15.3	2
2Z2	*P.patula*	1968	25	465.6	30.3	12.5
3A	*P.patula*	2008	1050			2.9
3B	*Cup.lusitanica*	1991	500	269.5	20.7	32.9
3C	*Cup.lusitanica*	1987	750	25.4	23.8	19.1
3D	*P.patula*	1970	250	412	32.4	3.5
3E	*Cup.lusitanica*	1985	500	296	25.9	6.7
3F	*E.saligna*	1986	200	224.4	20.9	15.3
3G	*Cup.lusitanica*	2007	1000			6.1
3H						0.7
3I						9.6
3K	*P.patula*	2008	850			7
4A						66.4
4C						31.7
4D	*P.patula*	1966	125	480.5	33.3	17.3
4E	*P.patula*	1969	25	301	9.3	2.6
4F						33.9
4G	*Cup.lusitanica*	1983	50	454	20.1	9.3
4H						3.6
7A	*E. pan*	1933	150	266.6	23.4	45.4
7A	*P. KIK*	1933	50	669.6	19.7	45.4
						3730.6

Appendix F: Model Timber Concession Agreement

This agreement is made this................ Day of............... 20…......between the Kenya Forest Service (hereinafter referred to as "the Service") of Postal Address.............. Nairobi in the Republic of Kenya and.. ("the Concession Holder") of Postal

Address... Kenya.

WHEREAS

a) The Service is desirous of ensuring the optimum use and development of its industrial forest plantations so that the maximum benefits accrue for the people of Kenya.

b) Through an open bidding process, the Service has selected the concession Holder as an appropriate body to perform this objective on its behalf with a view to establishing a beneficial long term operational relationship in the interests of the people of Kenya and the mutual interest of both Parties.

c) Thus in accordance with Section 37 of the Forestry Act 2005 and the powers contained therein the Board has decided to grant to the Concession Holder a concession at... (Name or reference to forest plantation) .....covering an area as hereinafter demarcated.

d) Accordingly, the Board and the Concession Holder have agreed to conclude this Agreement on the following terms and conditions.

1. Definitions and Interpretations

In this Agreement unless inconsistent with the context or otherwise specified. The following expressions have the following meanings:

"The Act" is the Forest Act, 2005;

"Agreement" means this Agreement (with the schedule and annexure attached thereto) as varied from time to time pursuant to its terms;

"Annual **Concession Fee"** has the meaning ascribed to it in Section 11;

"Annual Operations Plan" has the meaning ascribed to it in Clause 37 of the Forest Rules (2009).

"The Board" means the Board of Kenya Forestry Service as designated in section 6 of the Forestry Act 2005;

"Community Forest Association" has the meaning ascribed to it under Part IV of the Act.

"Community Forest Management Agreement" means an agreement between the Service and the Community Forest Association under Part IV of the Act, with its operative force being limited to those matters directly related to the Land, specifically those matters drawn from the Community Forest Management Agreement and contained in Annex 4;

"Commencement Date" means the date upon which the Parties have agreed that the Concession Holder may commence the activities as stated in Clause 5 herein following satisfaction of the condition's precedents listed in clause 4 herein;

"Concession Holder" is the party to this agreement and shall include their successors and assignees;

"Customary Rights" has the meaning under Clause 22 of the Act.

"The Director" means the Director of Kenya Forestry Service as designated in Section 10 of the Forestry Act 2005;

"ElA" means an Environmental Impact Assessment, an evaluation carried out under the Environmental Management and Coordination Act 1999 (of a project to determine its impact on the environment and the conservation of natural resources;

"Facilities" mean as listed in Annex 4 roads, tracks, access-ways, airstrips, firebreaks, bridges, culverts, irrigation works, erosion works, drainage works, water storage works, together with all works related to the prevention, detection, or fighting of fire;

"Concession Management plan" means systematic programme prepared showing all activities to be undertaken by the Concession Holder on the Land over a period of at least 5 years and includes conservation, utilization, silviculture operations and infrastructure developments, Annual Operations Plan and the Fire Prevention, Protection and Control Plan;

"Harvest" means to fell, cut, collect or otherwise dispose of Timber from the Land;

"Land" means the area to which this Agreement relates as more particularly described in clause 3 herein and demarcated in the schedule attached hereto;

"Local Authority" means a District Assembly, Town Assembly, Municipal Assembly or City Assembly as defined under.....;

"Period" means the period to which this Agreement relates (including any agreed renewals thereof) as specified in clause 8 herein;

"Parties" mean the parties to this Agreement and "Party" means any one of them;

"Provisional Management Plan" means the concession management plan prepared by the Service and contained in Annex III;

"The Service" means the Kenya Forestry Service as designated in section 4 of the *Forestry Act 2005* and shall include their successors and assignees;

"Structures" means all buildings and other structures affixed to the Land;

"Timber" has the meaning ascribed to it in the Act.

a) References to clauses, schedules and annexures are to the clauses of, the schedules to and annexures to this Agreement;
b) Words importing gender include each gender;
c) References to persons include bodies corporate, firms and unincorporated associations;
d) The singular includes the plural and vice versa;
e) Clause headings are included for the convenience of the Parties only and do not affect its interpretation, and
f) Any references to legislation including subordinate legislation shall include that legislation as from time to time modified, re-enacted, consolidated or replaced. The Service warrants that the Land is a state forest.

2. Conditions Precedent

This Agreement is subject to and conditional upon (and for die purpose of satisfying the requirements of these conditions precedent the Concession Holder is granted access by the Director to the Land between the date of signature of this Agreement and the Commencement Date or the date of lapse of this Agreement for failure to satisfy the conditions precedent whichever is the earlier):

a. the completion of an EIA (if required) and the approval thereof under section 26 of the Environmental Management Act 1999 ;
b. the completion of an Operations Plan and the Fire Prevention consistent with the Provisional Management Plan and the approval thereof by the Director;
c. Meet with the Community Forest Association and agree to the respective duties of Concession Holder and Community Forest Association under this Agreement,
d. Issuance by the Director of the requisite licenses under of the Forestry Act undertakes as an fundamental requirement for the legal operation of this Agreement not to revoke the aforesaid requisite licenses while this Agreement continues in force;
e. Payment of any amounts due by the Concession Holder as required in order to allow commencement of the activities stated in clause 8 herein,
f. Arrange by the Concession Holder a performance security for the benefit the Director in the amount for the initial value of Kenya Shillings...............

And in the event that such conditions precedent are not satisfied within 6 (six) calendar months from the signature date of this Agreement or as extended by mutual agreement, this Agreement shall lapse and be considered null and void by the Parties. If the conditions precedent not satisfied is under article (c) then amounts paid will be refunded to the Concession Holder in full, otherwise the amounts payable will be forfeited by the Concession Holder.

3. The Land subject to this agreement and the purpose of the agreement

a) The purpose of this agreement is to provide for the sustainable long-term management of the forest area for the production of forest products, including timber by concession in ....Compartment(s) in....................... Forest Block at ....Forest station in........................Forest Division ("the Land"),

b) The Land comprises.......................... (in words) hectares and its

c) Boundaries are described in a map and table in the Annex 1 and Annex II respectively to this Schedule.

d) These Annexes form an integral part of this agreement.

4. Duration

The concession granted in clause 6 is for a term of ...... twenty (20)............years from the .... day of .... 20.................and ending on the ....day of ....20………….........

5. Basic Warranties of the Service

a) The Service warrants that the Land is a state forest

b) The Service warrants that at the time of making this agreement, the property rights attached to the Land consist of:

i. the claims of record, including easements, rights-of-way,

ii. servitudes and mineral rights;

iii. Any customary rights established under Section 22 of the Forests Act; and the Government's own right of ownership.

c) The Service agrees to indemnify and defend the Concession Holder against third-party claims of unrecorded, non-customary rights. In the case of claims of customary rights, the Service may either elect to defend the claim or allow the Concession Holder to defend the claim and reimburse the costs of defense if the defense substantially succeeds.

6. Basic Warranties of the Concession Holder

a. The Concession Holder warrants that all information in its bid for the concession is complete and correct.

b. The Concession Holder warrants that it is properly incorporated or registered or validly existing and in good standing in the Republic of Kenya.

c. The Concession Holder must retain its competence in carrying out its rights and obligations under this agreement

d. Unless the Service has a specific intent to cause harm or acts with gross negligence, the Concession Holder shall hold the Service harmless for any acts of omission or commission that may result in physical injury, harm, death or damage or loss of property to the Concession Holder or its servants, agents, employees, visitors or guests, including injury caused by rivers, streams, trees, animals, objects or other risks of harm in the forest.

7. Grant of Concession

a. Subject to the conditions and undertakings contained herein, the Service grants the Concession Holder a concession for the use of the Land.

i. This agreement gives the Concession Holder the right to use, harvest, and sell forest products from the Land, subject to the planning and management requirements in clause 8.

ii. This agreement does not give the Concession Holder the right to extract minerals, to quarry or to undertake other activities which are not authorized by this agreement.

iii. This agreement does not give a right to divert or use surface or ground water or to develop hydropower.

iv. This agreement does not convey any title to the concession holder.

v. This concession does not give the Concession Holder power to pledge die Land as security or encumber the Land with liens.

vi. This concession does not give the Concession Holder power to grant easements or servitudes.

vii. This agreement does not give the Concession Holder exclusive possession of the Land or any part thereof and does not create nor is it intended to create a lease or tenancy in any way whatsoever.

b. The Concession Holder shall allow persons holding pre-existing or Customary Rights a reasonable opportunity to enter the Land and exercise those rights,

c. The Government of the Republic of Kenya retains the right to grant future easements on the Land.

d. The Service retains the right for itself and its agents to enter the land for law enforcement and to inspect whether the Concession Holder is complying with this agreement.

8. Plans and Operations

a. The Provisional Management Plan, prepared the Service, is part of this agreement and is attached as the Annex III.

i. within one year of the Commencement Date submit a forest management plan that will replace the Provisional Management Plan and upon acceptance by the Director is the Concession Management Plan;
ii. The Concession Holder shall revise the concession management plan at least once every five years,
iii. The Service shall review the revised plans for consistency with the existing strategic forest management plan and applicable laws.

b. The Concession Holder shall prepare an annual Operations Plan covering planned activities for each year and submit the plan to the Service for approval. The. Service shall review the annual operations plan for consistency with the existing concession and strategic forest management plans and applicable laws.

c. The Concession Holder shall only undertake forest management and construction activities that are described in the annual Operations Plan, and shall only construct improvements described in the Concession Management Plan.

d. The Concession Holder shall prepare any environmental assessments required by law for the granting of the concession and for operations taken under the concession. Where the law assigns primary responsibility for preparing these assessments to the Service, the Concession Holder shall obtain the approval of the Service before submitting the assessments.

e. Approval of plans and assessments under this clause is within the discretion of the Service. However, the Service shall not unreasonably delay review and approval of plans and in the course of review shall not require changes to plans and assessments beyond what is reasonable to meet the requirements described in the *law* or in this agreement.

9. Risk and Compensation

a. The Concession Holder assumes the risk of fire, insects, disease, wind, water or other natural agents reducing the value of the concession.

b. The Concession Holder assumes the risk of theft of forest products, vandalism, and encroachment on land and other harmful acts of third parties.

c. If the Concession Holder seeks to have the area of the concession reduced for whatever reason other than in response to actions of the Service according to this agreement this shall not result in payment of reduced fees in the remaining duration of this agreement.

d. If the Service takes actions that physically intrude on the Land, that exclude the Concession Holder from part of the Land or that allow persons to lawfully remove forest cover from part of the Land, the Service is liable to the Concession Holder for the resulting loss.

e. If the Service amends the applicable strategic forest management plan making some forest resources unavailable to the concession holder, the Service is liable to the Concession Holder for the resulting loss. If the amendment to the strategic management plan was non-discretionary, due to a change or revised interpretation of law, "then this shall not apply.

f. If the Service takes an action that lowers the value of the concession but that is not covered under clauses 9(d) or 9(e), the Service is not liable for the resulting loss.

g. The Concession Holder assumes the risk of any fault it may have made in assessing the commercial value of the concession prior to entering this agreement.

h. Except for injuries to property caused in part by a breach of the Service's warranties in clause 4,, the Concession Holder shall indemnify the Service against all losses, claims, demand actions, proceedings, damages, costs or expenses or other liability in any way stemming from actions or omissions of the concession holder, its agents, employees, guests or contractors or any breach of any of the obligations on the part of the concession holder, its agents, employees, guests or contractors contained in this agreement or the exercise or purported exercise of the rights given herein.

i. If the Service breaches its warranty of land title in clause 5(b) the Service shall be liable to the Concession Holder for the resulting loss in the value of the concession. This compensation shall be by reduction by the Concession Holder, of the fees due under clause 11 (a) by the percentage of the area of the original concession made unavailable to the Concession Holder due to the breach. This reduction shall not apply to payments made before the Service or the Concession Holder discovers the breach.

10. General Duties of the Concession Holder

a. The Concession Holder shall manage the Land in a sustainable manner consistent with all applicable plans, the Forest Act and all other applicable laws.

    i. The Concession Holder shall not abandon the Land or fail to implement beneficial measures described in applicable plans,

    ii. The Concession Holder shall follow all applicable laws governing finance, taxation, land use, crime, environmental protection, labour, safety, and disposal of waste, pollution and health.

b. The Concession Holder will meet with the Community Forest Association at least annually, or more frequently by agreement, to review pertinent activities under the Concession Management Plan, Annual Operations Plan, and the Community Forest

Management Agreement.

c. The concession Holder [insert clause indicating the holder recognizes the issues related to gender, marginalized groups and HIV / Aids and will endeavor to conducts its activities pursuant to this agreement in a manner that will be beneficial to these groups.]
d. At the termination of this agreement, the Concession Holder shall turn the Land back to the Service with all improvements in an ell-maintained state, considering age and amount of use.
e. The Concession Holder shall protect the forest from encroachment; from unauthorized use; and from damage from fire, insects, disease and other natural agents.
   i. The Concession Holder shall maintain the physical boundaries of the land, including existing survey marks, signs and fences,
   ii. Unless a third party has a property right or the consent of the Service in the form of a license, the Concession Holder shall not allow third parties to construct improvements on the Land.
   iii. In case of an emergency that threatens the forest such as a fire or insect outbreak, the Concession Holder shall provide the Service all practical support in abating the emergency, even if this requires action on adjacent lands
f. The Concession Holder shall pay the fees and charges listed in clause
   11.
g. The Concession Holder shall post a performance bond as required by the Service under the law. The performance bond shall be for the duration of the Agreement.
h. The Concession Holder shall allow reasonable access to persons authorized by the Government to conduct activities on the Land, including surveys, prospecting and maintenance or construction along rights of way.
i. The Concession Holder shall notify the Service before conducting inventories of forest resources and shall share with the Service the data from those inventories.
j. The Concession Holder shall keep written records documenting all forest management actions taken to implement this agreement and applicable plans, all actions that cause the Concession Holder to become liable to the Government for fees or taxes, and all payment of those fees and taxes.
   i. The records must be of sufficient detail to allow an inspector to determine whether the forest management aspects of this agreement and applicable plans have been fully implemented, what fees or taxes were incurred, and whether those fees and taxes were paid in a timely fashion.

ii. The Concession Holder shall retain the records until at least six years after the termination of this agreement and any renewal of this agreement.

iii. The provisions of the Public Procurement and Disposal Act (Act No. 3 of 2005) on confidentiality of data shall apply to this concession agreement. However, the Concession Holder may, on a periodical basis, release such information as it may deem fit to the public.

k. The Concession Holder shall supervise its employees, agents, guests and contractors and is liable for any actions that they take that inflict injury to life or property or that violate this agreement.

11. Fees and charges

a. The Concession Holder shall pay the Service the fees that the Concession Holder bid in the concession auction, as indicated herein and as better described in the Annex IV of this Schedule. Bid price: Kenya Shillings.. (In words).

b. The Concession Holder shall pay the Government all other fees and taxes due by law, including stumpage payment related to timber harvested, taxes related to employment, sale of goods or services and generation of income.

12. Force majeure

a. If overwhelming acts of third parties or nature make it temporarily impossible for a party to comply with this agreement, the affected party may invoke the legal principle of force majeure to postpone obligations under this agreement.

   i. Examples of such overwhelming acts include organized labor actions, armed conflicts and natural disasters,

   ii. The parties may not invoke force majeure to excuse non-compliance lasting more than six months.

b. The party invoking force majeure shall give notice to the other party as soon as possible. The notice must describe the nature of the outside action making compliance impossible, the anticipated extent of non-compliance and the time when the party expects to return to full compliance with the agreement.

13. Dispute resolution

a. This clause applies to disputes between the Service and the Concession Holder in their capacity as parties to this agreement,

b. The parties pledge to work together in good faith to maintain communications, discuss disagreements and resolve problems. Where appropriate and mutually agreeable, the parties may seek the assistance of a neutral third party to help them arrive at voluntary resolution of disputes.

c. If the parties have failed to resolve a dispute voluntarily, either party may apply for the dispute be resolved through arbitration provided that: Any disputes arising from the environmental impact assessment and licenses issued pursuant thereto shall be adjudicated by the national Environmental Tribunal established under the Environmental Management and Coordination Act 1999 and under the procedures established the render.
d. Where the parties submit a dispute for arbitration, both parties shall jointly appoint an arbitrator. In the event that an independent arbitrator is not agreed to by both parties, the Chairman of the Kenyan Chapter of the Chartered Institute of Arbitrators shall be requested by either party in writing to appoint an arbitrator.
e. The costs of arbitration shall be borne equally by both parties,
f. The arbitration shall take place in Nairobi and the arbitration shall be conducted in English,
g. The provisions of the Arbitration Act (Act No 4 of 1995) shall apply to any arbitral proceedings conducted under this agreement.
h. Nothing in this clause prevents the Government of the Republic of Kenya from enforcing criminal, tax, environmental, labour, forest or other laws. i.
i. If one party is in material breach of this agreement, the other party may take steps to terminate or suspend the agreement under Article 15 without resorting to arbitration.

The arbitrator shall have no power to delay a party from taking action to terminate or suspend the agreement, however the arbitrator may reinstate the agreement or award damages or both if a party acts to terminate or suspend the agreement without proper cause.

14. Public Rights

The Concession Holder shall take the steps to benefit people and communities dependent on the Land as provided in Annex V of this Schedule. The Annex forms an integral part of this agreement.

15. Transfer or Assignment of Rights

- The Concession Holder shall not transfer or assign rights under this agreement without the consent of the Service,
- In exercising its discretion to consent, the Service shall follow the requirements of the Forest Act and other applicable law.
- The Concession Holder shall give the Service notice of any change of officers or ownership that alters who is in effective control of the concession holder. Change of

beneficial interest or control of the Concession Holder shall where applicable, be subject to the Restrictive Trade Practices, Monopolies and Price Control Act (Cap. 504) Laws of Kenya.

16. Breach and Termination

a. In addition to any breach of the requirements stated in the other clauses of this agreement, or any material falsehood or misrepresentation in any of the warranted facts, the following are breaches of this agreement:

i. The Concession Holder becomes insolvent, or takes steps to end or alter its existence as a business entity,

ii. The Concession Holder is more than 30 days late in the payment of fees listed in clause 10.

iii. The Concession Holder or one of its agents or subcontractors working on the land is convicted of a violation of the Forest Act or its subsidiary regulations.

iv. The issuer of the performance bond revokes or declines to honor the bond and the bond is not replaced to the Service's satisfaction.

SEALED with the common seal of the KENYA FOREST SERVICE in the presence of	))
	)
	)
Director	)
	)
	)
Secretary	)
	)
	)
	)
Sealed with the common seal of ……………in the presence of	))
	)
	)
	)
	)
Director	)
	)
	)
	)
Secretary	)
	)
	)
	)

Annex 2: Table on details of the concessional land

No	Forest division	Forest station	Block	Compartment	Sub-Compt	Area (Ha)	Species	Density (SPF)	Age (years)	Volume (M)	Remark
1											
2											
3											
4											
5											

ANNEX 3: PROVISIOBNAL MANAGEMENT PLAN

ANNEX 4: TABLE WITH DETAILS ON PAYMENTS

YEAR	Concession area	Bid price per hectare (kshs)	Annual fees per hectare (kshs)	Total

Appendix G: Data collection Permit

Telegrams: "FORESTRY" Eldama Ravine
Telephone :Eldama Ravine 0709748860
Emailzmkoibatek@kenyaforestservice.org

When replying please quote

REF. KFS/BAR/8/1/2 VOL.1/29

KENYA
Forest Service

ECOSYSTEM CONSERVATOR
BARINGO COUNTY
P.O BOX 28-20103
ELDAMA RAVINE

Date: 3rd June 2015

TO; SAMWEL M. OSEE
EGERTON UNIVERSITY STUDENT
P. O. BOX 536
EGERTON

Dear Sir,

RE: DATA COLLECTION OF PLANTATIONS OF KOIBATEK AND MAJIMAZURI FORESTS.

Following your application to resume data collection for your study on 'The potentiality of forest concession in Koibatek and Maji Mazuri forests, Kenya', your application has been granted. This follows the end of the court order by the Lembus Council of elders that just ended in March 2015. You are expected to report to our inventory office – Koibatek for further guidance on the kind of data you want to collect from the forests at any given any time you are getting in the forest blocks. Your cooperation with our inventory team will be mandatory.

Thanks, as I wish you the best.

Yours faithfully,

ANTONY K MUSYOKA
ECOSYSTEM CONSERVATOR
BARINGO COUNTY

Appendix H: Publication

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Researchjournali's Journal of Forestry

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ABSTRACT

Public forests all over the world are managed in different ways. Forest concession policy concerns with all matters pertaining to the award and management of forest concession and, therefore, influences the achievement of the goal of sustainable forest management. Even though the Forest Conservation Management Act (2017); which is currently used in the management of public forests in Kenya recognizes management of plantations through a license, concession, contract and joint agreement, no efforts have been attempted on any of these management scenarios. The objective of the study is to evaluate and assess the potential of adopting forest concession as a management tool in plantations of Koibatek and Maji-mazuri forests, Kenya. In particular, the study determined the long run sustainable yield based on volume projections. Volumes were determined following the method used by the Kenya Forest Service inventory section for comparability. Systematic sampling method using the plot line method was used. This has given the categorization of timber based industries that the study area can support. The study will be of special interest to the Kenya Forest Services, the custodians of public forests in Kenya, communities living adjacent to the forest, water companies, timber industries and power lighting institution and individuals could gain new insights into how the contracting mechanism can be used to broaden the benefits of forest management.