Analysis of some Financial and Institutional Aspects of Production
and Marketing of Firewood from *Acacia seyal* Plantations in Wad El Basheir
Forest Reserve, Al Gadarif State, Sudan

By

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DEDICATION

I dedicate my effort to my parents, for their love and support throughout my life.

To my dear father, mother, brothers, family, friends and colleagues

With my love

Suliman

2012
ACKNOWLEDGMENT

I am grateful to Allah for the success to accomplish this research, and let me offer my gratitude to my supervisor, Dr. Dafa-Alla Mohamed Dafa-Alla, Department of Forest Management, Faculty of Forestry, U. of K. This thesis would not have been possible without his help and support. Besides the scientific supervision, he was like a father-figure during the study period. Most sincere thanks to him.

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Analysis of Some Financial and Institutional Aspects of Production and Marketing of Firewood from *Acacia seyal* Plantations in Wad El Basheir Forest Reserve, Al Gadarif State- Sudan

Abstract

Suliman Yusif Mohamed Ali

This study was conducted to highlight institutional factors that influence the production and marketing, and to examine financial profitability of firewood produced from *Acacia seyal* plantations at Wad El Bashier Forest Reserve in Al Gadarif State, Sudan. Growth and yield data were collected in 2010 through temporary sample plots while market and institutional data were collected through questionnaires targeted key informants from Forests National Corporation, Trade Union of firewood producers and traders, and commercial banks, in addition to secondary sources of data. Profitability was assessed under current forest management regime and existing production relationships using Net Present Value (NPV) as decision criterion first for a single 20-year rotation and second for a perpetual series of like rotations. To test the sensitivity of the profitability of firewood production reduction of discount rate, increase price per cubic meter of wood at harvest and adoption of commercial thinning were made. The study showed that several institutional factors limit the production and marketing of firewood. Taxes, Zakat, market and administration fees are contributing to relatively high production and marketing cost. The results also showed that the financial NPV (SD.G./feddan, at 12% annual profit margin) of firewood production from *Acacia seyal* plantation managed for a single rotation of 20 years at current practice is negative. Except for compartment 8 the NPV remained negative even with adoption of two thinnings at ages 6 and 10. The results indicated that increasing of price from SDG 52 to 60 per cubic meter at harvest does not show positive outcome. The reduction of annual profit margin to 7% converted NPV of most compartments to positive value. NPV (SDG/feddan) at 12% and 7% profit margin for a perpetual series of like rotations of *Acacia seyal* managed for firewood production were -35.7 and 125.4, respectively. The study concluded that the relative low wood volume and high production cost per unit area of existing crop are important factors that explain the low returns from the production of firewood.
تحليل بعض الجوانب المالية والمؤسساتية لإنتاج وتسويق حطب الحريق من غابات الطحل المزروعة بغرب ودبيش المحجوز، ولاية القضارف، السودان

المستخلص

سلمان يوسف علي

أجرت هذه الدراسة لتسليط الضوء على العوامل المؤسسية التي تؤثر على إنتاج وتسويق وفحص الربحية المالية لحطب الحريق المنتج من غابات الطحل المزروعة بغرب ودبيش المحجوز، ولاية القضارف، السودان. تم جمع بيانات النمو والانفجارية في 2010 بواسطة عينات مؤقتة، بينما تم جمع بيانات السوق والمؤسسات بواسطة استبانات استهدفت مفاتيح المعرفة من الهيئة القومية للغابات واتحاد منتجي وتجار حطب الحريق والبنوك التجارية إضافة إلى المصادر الثانوية للبيانات. تم تقييم الربحية تحت نظام إدارة الغابات الحالي وعلاقات الإنتاج القائمة باستخدام صافي القيمة المالية (جنيه/فدان) كمعيار للاختيار الأول لدوره واحدة طولها 20 سنة. وakhirًا لسلاسلة لإنتاجية من الدورات المتتالية. لاختبار حساسية ربحية إنتاج حطب الحريق تم تخفيف معدل الخصم، زيادة سعر المتر المكعب من الخشب عند الحصاد وتبني عمليات الشبل الانتاجي. أظهرت الدراسة عددًا من العوامل المؤسسية التي تحد من إنتاج وتسويق حطب الحريق. الضرائب والزكاة ورسوم المحلية وإدارة السوق تساهم في رفع تكاليف الإنتاج والتسويق والتي تعكس في ارتفاع سعر الوحدة من الحطب المعرض للبائعين والمستهلكين.

أظهرت النتائج أيضًا أن صافي القيمة المالية المفيدة (جنيه/فدان عند 12% هامش ربح سنوي) لإنتاج حطب الحريق من غابات الطحل المزروعة عندما تدار لدوره إنتاج واحد لمدة 20 سنة سالبة. باستثناء مربع 8, ظل صافي القيمة المالية سالبة على الرغم من إضافة عمليات شلل عند عمر 6 و10 سنوات. أبنت النتائج أن زيادة السعر من 52 الي 60 جنيه لكل متر مكعب عند الحصاد لم تعط نتائج إيجابية. أدى خفض هامش الربح السنوي من 12% إلى 7% إلى تحويل صافي القيمة المالية لمعظم المراحي إلى الموجب. صافي القيمة المالية (جنيه/فدان) لسلسلة لإنتاجية من الدورات المتتالية لإنتاج حطب الحريق من غابات الطحل المزروعة عند هامش ربح 12% و7% هي 35.7 و4.42 على التوالي. خلصت الدراسة إلى أن انخفاض حجم الخشب وتكاليف الإنتاج العالية لوحدة المساحة من المحاصيل الحالية عاملين مهمين يفسران العادات الضئيلة من إنتاج حطب الحريق.
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CHAPTER ONE

INTRODUCTION

1.1 Background

Forests constitute one of the world's important industrial sectors satisfying major needs e.g. timber and wood based panels for housing, construction transport furniture, packaging printing and writing paper. In addition firewood and charcoal are essential commodities in the developing countries. For typical African country, (FAO, 2001) mentioned that firewood and charcoal account for 80-90% of all wood that consumed; representing 65-80% of the total energy consumption. Sudan derives 71% of its energy from wood fuel. The remaining 29% is from petroleum and electricity. Out of all the wood harvested, 88% is used for wood fuel and the remaining 12% for poles, posts and timber (FAO, 2001). In Sudan, firewood and charcoal constitute 10% of the plantation program of the Forest National Corporation (FNC) to supply forest products and ensure environmental protection (Mahgoub and Abdelmagid, 1996). Fuel wood is the cheapest fuel available per unit of heat in most developing countries. The annual use of fuel wood has been estimated at 1,200 million cubic meters world wide (Arnold and Jongma, 1978). It can be produced from most tree species and from a wide range of silvicultural systems and is easily stored and dried. If fuel wood production is a primary management aim for tree planting, a variety of factors needs to be considered in order to optimize both the quantity and value of fuel wood produced. For example, a species with high volume production is, of little fuel wood value, if the wood is, very light or the burning wood produces toxic smoke (Arnold and Jongma, 1978). Acacia seyal var. seyal (local named Talh), is one of the important indigenous tree in Sudan. It is widely distributed and covers most of the Sudan, extending from the desert in the north, to the savannah woodland in the south (Badi et al., 1989). Economically, A. seyal is very important tree. It is one of the gum producing trees in Sudan. Commercially, its gum comes next to that of A. senegal (Hashab). The tree is considered to produce the best charcoal in the Sudan and it produces most of the charcoal brought to big towns (Badi et al., 1989). On the other hand, from a conservation point of view, A. seyal is of great importance as vegetation cover on clay plains and helps to stabilize the soil. In addition, the tree is capable of fixing atmospheric nitrogen, thus improving the soil fertility (Badi et al., 1989). Acacia seyal
provides good firewood, but cannot be stored for long time as it is subject to attack by the bosttrychid battle *Sinoxylon senegalenses*. However, the abundance of the tree means that it is one of the most important sources of fire wood. The species yields excellent charcoal and it is the most important charcoal source in Sudan (Badi *et al.*, 1989). Unfortunately, the areas where *A. seyal* trees are intensely distributed are subjected to heavy clearance for growing agricultural crops especially the mechanized rain-fed schemes. Further to the damage of agricultural mechanized schemes, the charcoal production threatens its existence. In both cases, vast areas have been cut without regeneration (El sheikh, 1987).

*Acacia seyal* is widely distributed in Northern Africa in the Sahelian zone from Senegal to Chad and Sudan and Eastern Africa from Egypt south to Somalia, Kenya, Mozambique and Namibia. It has also been recorded in Syria, Jordan and Sinai (NFTA, 1994). Fad Alla (1963) mentioned that this wide sporadic distribution of *A. seyal* in Africa from the desert edges in the north through the dry and wet savannah to equatorial regions suggest a wide range of both aridity and high moisture levels. This range of environment can be found in Sudan, but the main belt which suits the conditions mentioned above lies between latitudes 10 and 14 N°. This belt covers most of the clay plains of central Sudan which receive 500-800 mm annually. It includes most of Kassala locality, Blue Nile province, and Southern Kordofan province. In addition to that belt, there are extensive plains with dark cracking clays between the large masses of grouped hills of the Nuba Mountains and Ingessana hills, carrying *Acacia seyal*. One point should be mentioned here about the distribution of *A. seyal* in the Central plain of the Sudan. This belt of *A. seyal* is the same area which annually witnesses the seasonal movements of the nomads with their herds of animals, from the north to the south in the dry season and *vice versa* in the wet season. On their movement, these herders of animals in addition to grasses and hens rely mainly on the pods and leaves of Acacia’s especially *A. seyal Var. seyal*. This can serve two purposes. First, the undigested seeds when deposited with animal feces came out well treated. Secondly, as these herds move from one area to another, the seeds are widely distributed. These two facts facilitate easy germination and wide distribution of the species all over the belt (Elsheikh, 1987).
1.2 Research problem

Because of the ecological and economical importance of *A. seyal* it deserves a special study. The process of firewood production and marketing in Sudan in general and Wad El Bashier forest Reserve in particular, is challenged with some socio-economic constraints. The elements of the research problem are:

- The financial profitability of Talh forests under current management is unknown. This is a result of many factors including variable stocking, method of sale harvest and rotation length.
- The contribution of various cost elements to the total cost of production and marketing per unit is specifically unknown for different production sites and transportation distances.
- The impact of forest policy, institutions and local government economic instruments are discouraging firewood production and marketing. This is reflected in rising consumer prices of firewood at main consumption areas.
- Lack of rotation age specifically determined for firewood production from *Talh* resulting in retaining tree crops to an age of 22 years, which far beyond the rotations prescribed for fire wood production in comparable environments.

1.3 Research objectives

The broad objective of this research was to examine the financial and institutional aspects of *A. seyal* forests managed for firewood production from the FNC perspective. It aims to:

Estimate Net Present Value per unit area at existing production relationships, under current and alternative management regimes

1. Identify cost elements and analyze their relative contribution to production and marketing cost
2. Analyze the influence of public and forest policy on production and marketing costs of firewood.
1.4 Research questions

To tackle the research problems below the following research questions were set.

1. What is the financial returns to land from production of firewood from A. seyal?
2. What are the cost centers and what are their relative contributions the costs of firewood production and marketing?
3. What are the kind and influence of policy instruments on the production and marketing of firewood?
CHAPTER TWO

LITERATURE REVIEW

2.1 Classification

*Acacia seyal* belongs to the genus *Acacia*, which is one of largest genera within the family *Mimosaceae*. The genus *Acacia* includes about 1200 species and widely distributed in the dry land over the world. Australia has the largest number of *Acacia* species (900) centered in South Western areas. In Sudan, 31 species have been reported, mainly in central Sudan, extending north and South (El Amin, 1973). *A. seyal* is a resilient, drought-tolerant tree of the African dry land which resists forest and grass fire. Its wood is dense and highly prized for firewood in parts of the world where few other plants survive. Its foliage provides good animal feed. Trees are 3-17m high (El Amin, 1973). The tree is tall, stipular spines in pairs, straight about 4 cm long, white with brown tips. The flowers are yellow with globular heads. Fruits are long, slightly curved, constricted between the seeds (Badi *et al.*, 1989). The tree leaves appear early in the rainy season, often before any considerable amount of rain has fallen. They are shed soon after the rains cease, at least on clay soils, flowers appear after the rainy season, from November to March, seeds available in December onwards. There are about 25,000 seeds per kilogram. Most of the roots are confined to the top meter of soil, but it occasionally develops a deeper root system. In upper Nile province roots were recorded attaining a depth of 7.9 meters, and a lateral spread of 9.0 meters (Badi *et al.*, 1989).

*Acacia seyal* Delile (family *Fabaceae*, subfamily *Mimosoideae*) is one of over 60 African acacias referred to the Uniseriae group of subgenus *Acacia*. The species usually reaches 9-10 m in height at maturity stage and in well-formed individuals a flat-topped crown develops. There are two varieties, differing primarily in whether or not pseudogalls ("ant galls") develop and in bark color. In *var. seyal* there are no pseudogalls and a reddish bark color prevails, although periodic bark exfoliation exposes a pale powdery surface which darkens slowly. In *var. fistula* pseudo-galls are present and the powdery bark typically remains whitish or greenish-yellow. Both varieties have paired, straight, strong, pale-colored, stipular spines up to 8 cm long which in *var. fistula* are often fused at the base into the inflated pseudo-gall the leaves
are bipinnate - usually with 48 pairs of pinnate, each of which bears 10-20 pairs of close-set, obscurely veined leaflets. Individual leaflets are 1-15 mm wide and about 5-8 mm long. Small bundles of up to 5 pedunculate capitate inflorescences arise in auxiliary positions on the young parts of shoots. Each inflorescence is vivid yellow in color, about 15 mm in diameter, and is borne on a peduncle 34 mm long. The dehiscent pods are flat and somewhat curved, brown and up to about 20 cm long and 5-10 mm wide when ripe, with slight constrictions between the seeds. In a well-developed pod 6-10 seeds are present, each 69 mm long, 4-5 mm wide and about 2 mm thick - in 1 kg there are 20,000-25,000 seeds. The chromosome number of 2n = 52 suggests tetraploidy (NFTA, 1991). The species is widespread on dark cracking clays on higher slopes of rivers and valleys on the hard clay plains of central Sudan and on clay of seasonally wet depression. Two varieties occur in the Sudan: *seyal* without inflated spines and green white or red bark, widespread in grass and woodland savanna on dry cracking clay and *fistula* with inflated spines and whitish bark, common in central and South East Sudan (East. of Nile) in deciduous forests on clay of seasonally wet depression (El Amin, 1973). Duke (1983) reported several botanical variants of *A. seyal Del.* beside var. *fistula*. These are var. *multijuga* and var. *stenocarpa*, the later is characterized by greenish – brown bark on the main stem, peeling on papery roll, and red – brown bark branch indicating some of similarities with *A. seyal var seyal*.

Acacia species are widely distributed through the drier tropical and subtropical regions, they have been called the most successful survivors in arid and semi arid region, and possess most of the features required to withstand severe climatic conditions (El-Amin, 1976). In Saudi Arabia the acacia communities represent the climax stage of xerophytic vegetation and generally have high cover and low species diversity (Shaltout and Mady, 1996). Most of acacia species are important sources of browse fuel and pole timber; some are important commercial sources of gums and tannins. Some can be effectively utilized for shade, shelter, live fences, soil stabilization as well as street trees and ornamentals. Many are utilized by the rural populations for local medicines, for fiber, domestic utensils and handicrafts (Wickens, 1995).

Recently, efforts have been directed to producing biomass through short-rotation forestry. The sustainability of short-rotation forest for biomass production is dependent upon such factors as biomass yield, biomass potential, tolerance of poor habitant,
climatic condition, and biomass fuel value (Neenan, 1980). Maximizing the efficient production by means of optimizing the biomass growth of selected woody species is the goal of plantations for energy (White and Gambles, 1988).

2.2 Ecology

*Acacia seyal* trees distribution large area Through the greater part of the range with mean annual rainfall is 500-1200 mm annually and there is a well-defined 6-8 month dry season with mean annual rainfall less than 50 mm. (NFTA, 1994), the area is more arid climate which to associated with the presence of water and direct rainfall.

Given suitable climate and edaphic condition, stands of *Acacia seyal* develop and admit sufficient light to grass to under stories grow it. (NFTA, 1994). *A. seyal* is found in elevated areas up to 2100 m in tropical regions but it generally occurs gregariously at lower elevations on level sites of dark cracking clay soils. It is usually found in the form of pure stands or mixed with other species. In most cases it is more or less found to be mixed with *Balanites aegyptiaca* in the drier thorny woodland savannah will 350-1000 mm rainfall per annum and high temperature (39-42°C). Occasionally, it grows on sandy soil under rainfall of 200 mm per annum (NFTA, 1994). Old trees can withstand inundation for a period up to three month which is better than other Acacias and therefore sometimes fringing the flood plains of rivers and basins. The trees are also fire resistant and withstand the annual grass fire of the woodland savannah and the young regeneration is stimulated by such fires. However, the natural regeneration has been observed at those localities which are free of risk of fire (El sheikh, 1987). The phenological cycle relates closely to the rainfall regime. Where there is a well defined unimodal rainfall pattern, leaf fall takes place by the middle of the dry period and trees remain leafless for 4-7 months, depending on the beginning of wet season. Leafless periods are briefer in bimodal equatorial rainfall regimes. Flowering is concentrated in the middle of the dry season and ripe fruits are occurred to 4 months later (Booth and Wickens, 1988).

Temperature regimes vary through the range particularly for variety *seyal* which is subject to main annual temperature of (18-25°C) in cooler climate in Ethiopia at the upper elevation limit (1700-2000m). Relationship with extreme temperature follows
similar pattern in parts of West Africa where variety *seyal* is found. Absolute minimum temperature through the range of the species are generally 5-10°C (NFTA, 1994).

The relationship with the soil is well defined. There is an unusual degree of adaptations for deep heavy soils (Ph 6-8) accumulated at low point of landscape or formed directly from fine grained rocks. In communities including both varieties, variety *fistula* displays great tolerance in depressions and along drainage lines. Saline soils are not suitable (NFTA, 1994).

Over forty species of insects are reported associated with *A. seyal*. These include ten species of branched beetles which may damage high proportion of stored seeds. Beetles of various other families attack the wood, the bostrychid, *Sinoxylon senegalense* being the most notorious and swiftly locating and infesting freshly cut wood, especially if lying on the ground. Attacks are much reduced if the bark is removed and the cut stems stacked upright. Subsequent creosote treatment ensures extended durability (Badi et al., 1989).

### 2.3 Silviculture and management of *Acacia seyal*

#### 2.3.1 Regeneration

Both varieties of *A. seyal* are noteworthy for their occurrence in undisturbed stage and even-aged stands. Reconstitution of an exploited var. *seyal* the stand doesn’t depend on coppice shoots but on the presence of abundant seed and its exposure to a mild fire which enhances the germination of var. *seyal* but checks the regeneration of competing species. Stands with 15 years old when are harvested produce a seed reserve sufficient to regenerate the stand. However, individual trees or uncut patches of the original cover should be left as seed sources to insure abundant regeneration.

Seed collection has only been tried on a very limited scale. The method which has been used is a traditional are for *A. Senegal*. In the method when the pods are ripe, the ground under the trees is cleaned, sheets are spread out, branches are shaken and beaten by means of sticks, and the seeds are collected from the sheets. The problems which are connected to this method of seed collection of *A. seyal* are: when ripe, the pods explode or open and scatter the seeds at least to some extent. Sine *A. seyal* grows
on cracking clays many seeds will fall in the cracks and cannot be collected. Other will be eaten by goats (FAO, 1986).

2.3.1.1 Natural regeneration

*Acacia seyal* trees naturally regenerate from seeds that spread from mother trees or vegetatively by coppice from stumps of felled trees. In the natural conditions *A. seyal* regenerates in thick pure stands. It is a fast growing species and can attain a height of 5 meters in 2 years under favorable conditions (Elsheikh, 1987).

Like *Acacia mellifera*, *A. seyal* occurs in a cycle with grassland, and when mature trees die, or are felled, there is a period of a number of years when grassland persists. However if the trees are felled before they are mature there is usually natural regeneration from coppice and seedlings. A large area in Sudan felled during the war for production charcoal was restocked with *Acacia seyal* six years later, and similar good results have been obtained with natural regeneration in upper Nile province. Disturbance of soil helps natural regeneration of *A. seyal* (Badi *et al.*, 1989).

Progressive invasion of grass, then fire, cutting down trees, periodical poor and brief rainy season are all lead to the absence of conditions which favor natural regeneration and subsequent forest establishment (Fad Alla, 1963).

2.3.1.2 Artificial regeneration

Natural regeneration in most places is sufficient, by direct seed sowing. (Badi *et al.*, 1989). Stands of *var. seyal* have been established in Sudan often by direct sowing of pretreated seeds in prepared planting spots. Sowing of seed in batches ensures a high proportion of spots become occupied. Competition from weed growth is overcome by using taungya system, with mechanized site preparation and sowing. Sesame (*Sesamum orientale*) or Sorghum (*Sorghum purpureosericeum, Sorghum arundinaceum*) is intercropped among widely spaced (4 m) row of trees (NFTA, 1994).

Like most acacias seeds, those of *A. seyal* require some treatment for germination. This can be done by dipping them in boiling water or soaked in concentrated Sulphuric acid. Wunder (1966) mentioned that within three days, *A. seyal* seeds reached a germination percentage of 100% when they have been exposed to concentrated H$_2$SO$_4$ for (45) minutes (El sheikh, 1987).
2.3.2 Rotation

For poles and fuel wood a 20 year rotation is projected in Sudan. Initial stocking is 1000 stems ha\(^{-1}\). Thinning after 10 and 14 years reduce stocking to 675 and 450 stems ha\(^{-1}\), respectively (NFTA, 1994). \textit{A. seyal, var. seyal} especially, is an important source of rural energy (fuel wood and charcoal). Stands management to 10-15 years rotation yield 10-35 m\(^3\) ha\(^{-1}\) fuel wood (NFTA, 1994). IPCC (2006) gives estimates of MAI of \textit{Acacia seyal} in productive plantations, productive semi-natural forests, protective plantations and protective semi-natural plantations. Minimum MAI (m\(^3\) ha\(^{-1}\) yr\(^{-1}\)) over rotation was estimated at 2.0, 1.8, 1.9 and 1.8 respectively. Maximum MAI (m\(^3\) ha\(^{-1}\) yr\(^{-1}\)) over rotation was estimated at 6.0, 3.2, 4.3 and 3.3, respectively.

Currently, the world uses about 1.8 billion m\(^3\) of fuel wood and charcoal (FAO, 2005) and the common view is that the developing regions and industrialized countries resulting in people switching from fuel wood and charcoal to fossil fuels (FAO, 2001a). But FAO (2005) also assess that the used wood fuel in 1997 was 53\% of the total round wood production and points out that the most important source of energy for more than two billion people and wood energy is likely to gain in useing developed countries during the next 20 years (FAO, 2001a).

2.3.3 Management of \textit{Acacia seyal} stands

Stands of \textit{Acacia seyal var. seyal} have been established in Sudan, often by direct sowing of pretreated seeds to prepare planting spots. Sowing seeds in batches ensures a high proportion of spots become occupied. Competition from weed growth is overcome by using taungya, mechanized site preparation and sowing. Fencing and intercropping are necessary for more protection and to reduce the cost of establishment and weeding. Weeding is done annually to reduce grass competition and fire hazard during the dry season. Thinning is recommended for production firewood (Fad Alla, 1963).

Where management for fodder production is concerned, evaluation of responses to lopping and cutting of \textit{var. seyal} indicate limited recovery capacity in mature trees. Beating branches to detach leaves and fruits without damage to auxiliary buds is therefore preferred to exploit these resources in the dry season (NFTA, 1994).
Many pastoral groups in the arid and semi-arid tropics habitually lop branches from various forage species (*Acacia seyal*, in particular) to make the forage accessible to livestock during the dry season. This shows clearly that browse is perceived as a necessity by traditional herders (Le Houérou, 1978).

The forest resources of the Sudan, whether natural or plantations, managed or unmanaged, exhibit a wide variation in standing wood volume per unit area in different climatic zones and over time. Whereas in the early 1960s, the average volume per hectare of natural unmanaged forests in the semi-arid zone was estimated at 15 m$^3$/hectare, in the savannah 30 – 50 m$^3$/ha and 70 - 150 m$^3$ in the montane and riverine forests. The average standing volume declined during the last five decades to a range of 5.0 – 7.0 m$^3$/ha in the arid regions and 12.0 – 15.0 m$^3$/ha in the savannah. Managed plantation exhibits higher volume production per hectare when compared with natural forests in any zone. Plantation establishment is usually planned and developed at regular spacing while the natural forests are spontaneous in regeneration. *Acacia nilotica* plantations on the flood basins produce between 120 - 300 m$^3$/ha within 20 – 30 years of rotation depending on the site and proper management, while Eucalyptus species under irrigation produces 50 – 60 m$^3$/ha over a 6 – 7 year rotation (FAO, 2001). The splitting of Sudan have had significant implications for the forestry sector and its current policies and programmes. Table shows approximately how a land and forest resource is divided between Sudan and South Sudan.

**Table 1: Land area and forest resources in Sudan and South Sudan**

<table>
<thead>
<tr>
<th>Country</th>
<th>Land area in million ha and (%)</th>
<th>Forest resources in million feddan* and (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudan</td>
<td>187.8</td>
<td>51.96</td>
</tr>
<tr>
<td>South Sudan</td>
<td>68.2</td>
<td>109.62</td>
</tr>
</tbody>
</table>

Source: FNC (2011)

*One feddan equals 0.42 ha

According to this preliminary assessment report by FNC (2011), the forests in the north are mainly dry subtropical forests with low tree density, between 150-300 trees per feddan, and are mostly classified as protected forest. Sudan has lost around two
thirds of its forest resources after separation of the South Sudan. Accordingly, the forest cover decreased from 67 to 21.8 million hectares, representing about 11% of the total area of the Sudan. This lead Sudan’s classification as a lower forest cover country. Moreover, separation from the South resulted in increasing in the deforestation rate from 0.74% to 2.2% annually. This estimation was mainly based on the fact that, the largest percent of deforestation occurs in the Sudan (about 90%). Furthermore, the average tree density per hectare is reduced and consequently the annual allowable removal is expected to be decreased from 11 to 8 million cubic meters. This is significant given the forest biomass consumption in the Sudan was approximately 22 million cubic meters in 2010. This figure was twice more than the existing annual allowable removal. Such situation will lead to the rapid deterioration of the forest resource unless, some efforts are made to increase the rate of forestation and increase the protection of the remaining forest area in the Sudan (IFAD, 2011).

2.3.4 Fuel wood production process in Sudan

The production of wood-based fuels can contribute to energy independence and improve livelihoods of local communities, through employment and income generation. However, an increased utilization of wood for energy may also cause additional pressures on forests leading to additional deforestation and forest degradation if actions for the sustainable production of wood fuels are not taken (FAO, 2001). Wood fuel production is closely linked to deforestation. Over 90 percent of the wood produced in African countries is used as fuel, mainly by the rural and urban poor. While most wood fuels are derived from forests and trees outside forests which have great contribution (FAO, 2001). Unsustainable farming and forestry activities are the major causes of deforestation in Africa, and fuel wood. Charcoal are the main by-products of land-clearing operations. Near east countries have a dominant role in global energy supply but fuel wood and charcoal are also a major source of energy in rural households. In fact, about 66 percent of the wood in the near east is used for fuel compared with a global average of 40 percent. With international prices of fossil fuel rising, it can be expected that fuel wood use will also increase not only in these regions but also in all other parts of the world (FAO, 2001).
2.3.5 Uses and economic importance of *Acacia seyal*

*Acacia seyal* yields a gum of good quality, inferior to that of *A. senegal*. Systematic tapping has produced a product of better color and taste. Bark contains tannin and yields a red liquid extract. The gum is said to be edible. The leaves are important for forage and the wood for fuel where the trees are abundant. In parts of Africa the tree is important for livestock, natives driving their animals to where it is common and lopping off branches for them, both leaves and young pods are eaten. The pods are sold, especially for fattening sheep. The tree is believed to provide the best firewood in Chad, and the best fodder in Sahelian savannas (NAS, 1980; Duke, 1983).*Acacia seyal* forests have many economic and environmental values. The economic values include the protection of fuel wood, gum tannins, and forage. It’s also used for building purposes and as a medicinal plant. The leaves, young branches, flowers and pods are valuable forage grazed by both domestic and wild animals especially during the dry season (El Ghazali, 1998). Local people use poles of medium size with forks for house construction. Branches are used for fencing. Poles of *A. seyal* are used for building temporary huts (*rakubas*). The trees with bright yellow flowers and/or green and red bark are used for decoration. The tree is good in soil stabilization and soil fertility as its roots fix atmospheric nitrogen. In addition, wood fumes and smoke is said to be an effective insect repellent. *Acacia seyal* tree is widely used as a medicinal plant in Sudan. Bark, leaves and gum are used in local medicine for the treatment of many diseases such as hemorrhage, cold, and diarrhea (El Ghazali, 1998).

2.3.5.1 Fuel wood

The major use of the wood from *A. seyal* is fuel. The firewood produced is not of good quality; the thermal value is low and can not be stored for it is readily attacked by insects and fungi. However the tree is considered to produce an excellent charcoal in the Sudan (El sheikh, 1987).

2.3.5.2 Tanning

The analytical result of *A. seyal* bark sample took from the Fung area carried out by UNDP (1966), It was found that the tannin content is high (21.24%) but the infusion was very dark in colour indicated by the proportion of reds (El sheikh, 1987). The same report continued that, small scale tanning trials produced intense redness. This
high colour is considered most undesirable but the use of the bark blended with light colour hydrolysable tannins (garad pods) in a ratio of 1:1 resulting in a leather of much improve colour with characteristics more in line with that required for sole leather (El sheikh, 1987).

2.3.5.3 Medicinal purposes

In Sudan the wood of A. seyal is used to make aromatic smoke and fumes over which woman smoke themselves. It softens their skin and gives it a nice smell and good color. This also protects them against cold and fever especially after childbirth. It is said that this fumes bath cures diarrhea in infants especially during the teething period. In addition to that it also cures rheumatic pains (El sheikh, 1987).

2.3.5.4 Fodder

Both varieties of Acacia seyal are viewed favorable as forage dry matter, net energy content is high 6-8 MJ/Kg of fruits (NFTA, 1994). A. seyal is important fodder trees for the nomads (Eltohami, 1995). The leaves, young branches, flowers and pods are grazed by domestic and wild animals especially in the dry season. Over much African countries, leaves, pods and flowers of A. seyal are the major source of early dry season fodder. Pods contain more than 20% protein and they are very nourishing (Elsheikh, 1987). The associated digestible protein levels are also high (100-150 gm/kg) in the foliage, and higher in the fruits. For both foliage and fruits, analysis indicates a well balance supply of minerals and favorable quantities in term of proximate fraction (ex. crude fiber 10-20%, ether fraction less than 7%). The foliage of var. seyal has been shown to contain secondary metabolites but experience suggested that level is not a matter of serious concern (NFTA, 1994).

2.3.5.5 Gum Talha

The tree produces gum which is darker and inferior to that of A. senegal. It is edible when fresh. This gum has some economic value and therefore it is collected from the trees and exported (El sheikh, 1987). Gum Talha has not been toxicologically evaluated and is not listed as an approved food additive. It contrasts with gum Arabic in several significant respects, being strongly dextrorotatory, of high molecular weight and low in nitrogen (0.06-0.24%) and rhamnose (<4% sugar composition). Ash
contents of cobalt, copper, iron, nickel and, especially, aluminum (>6000 ppm) are high and tannin is present (2%), restricting acceptable use to such applications as a binder for foundry molding and a sizing agent in the textile industry (NFTA.1994).

2.3.5.6 Protection

Acacia. seyal trees give some protection to the clay plain as a soil cover against washout during floods. They are also able to fix atmospheric nitrogen; thus improving the soil fertility (El sheikh, 1987).

2.3.5.7 Decoration

The tree can be planted for decorative purposes because of its beautiful yellow flowers and red or white green bark (El sheikh, 1987).

2.4 Needs for Conservation of A. seyal Forests

The belt of A. seyal in the Sudan is now subjected to a very severe disturbance due to human activity. The belt lies within the extensive clay plain of Central Sudan, with adequate amount of rainfall (500-800 mm per annum) and flat surface. These suitable environmental conditions encourage the growing agricultural crops such as Dura (Sorghum doura), cotton (Gossypium) and oil seeds. Large areas of A. seyal trees and the allied species in the community were clear-felled in many agricultural schemes. It is obvious that all major mechanized crop production schemes in Al Gadarif, Blue Nile, White Nile and S. Kordofan provinces lie within this zone (El sheikh, 1987).

2.5 Basic concepts pertaining to economic cost/benefit analysis

2.5.1 Factors of production

2.5.1.1 Land

The land on which the trees will be grown has to be purchased or rented. This of course, will raise direct cost, however, it is often the case in forestry sector that the land is already owned by those who propose to plant it with trees here fore the question of a purchasing price or rental does not arise. Land cost in terms of cash flow is zero. If when this land has an obvious alternative use, such as grazing or growing other crops, then there is a cost in using the land for forestry, the foregone net income for due to use
the land in the most profitable alternative use, this cost is termed an opportunity cost. This cost will be nil or zero if there is no alternative use for the land (Busby, 1985).

By the same reason, the land using for an agricultural project will not be generally difficult to determine where the land necessary for the project to be located and how much to be used. Yet problems may arise in valuing land because of the very special kind of market conditions that exist when land is transferred from one owner to another (Gittenger, 1982).

2.5.1.2 Labor

Neither will the labor component of agricultural projects be difficult to identify. From the highly skilled project manager to the farmer maintaining his orchard while it is coming into production. The labor inputs raise less a question of what than of how much and when. Labor may, however, raise special valuation problems that call for the use of a shadow price. Confusion may also arise on occasion in valuing family labor (Gittenger, 1982).

2.5.1.3 Capital

These are physical products of human labor that are used in production, or are in the course of exchange. Capital tends to make labor more productive

2.5.1.4 Technology

Including useful human skills and knowledge, even technology itself is ultimately the fruit of labor, (Gittenger, 1982).

2.5.2 Sources and classification of Costs

2.5.2.1 Variability and fixability of costs

Cost may usefully be classified according to its variability i.e. fixed and variable costs. Fixed costs for the enterprise tend to concentrate at headquarters. They are fixed in that they do not necessarily increase with scale of enterprise. These costs decline per unit size of the enterprise as well as per unit of output. Variable costs are that varied flexibly as conditions change. Productivity and costs are inversely related, so the variable costs change as the productivity of labor changes (Gittenger, 1982).
Another system distinguishes total cost (the cost of carrying out the complete operation on a hectare or stand), marginal cost (the cost of producing one more unit of a particular product) and incremental cost (the cost of applying one more unit of a factor of production, or intensifying an operation, or switching from one operation to another) (Gittenger, 1982).

2.5.2.2 The concept of opportunity cost

Opportunity cost is the revenue (or benefit) forgone when a factor of production withheld from an alternative course of action (Gittenger, 1982). The most obvious example is the opportunity cost of land for plantation, the forgone revenue in this case usually being its value to agriculture. Opportunity cost may affect enterprises which are external to forestry sector, particularly when forestry is expanding. However, more immediately relevant to forest managers is the opportunity cost of factors already employed by the enterprise, for legal, social or practical reasons, in the medium term. For example, workers have zero opportunity cost when weather makes normal forest production impossible. In case of alternative indoor work can be found, such as maintenance of machinery or manufacture of simple products, the revenue forgone by doing these jobs is zero (Gittenger, 1982). At the other extreme, during seasonal peaks of labor demand (near the end of the planting) the opportunity cost of labor probably exceeds its financial cost. The short time-scale may preclude hiring of additional workers, so additional jobs can only be withdrawing workers from urgent work within the enterprise (Gittenger, 1982).

2.5.3 Source of Benefits

Tangible benefits of agricultural projects can arise either from an increased value of production or from reduced costs. The specific forms, in which tangible benefits appear, are not always obvious, and their valuing may be quite difficult (Gittenger, 1982).

2.5.3.1 Increased production

Increased physical production is the most common benefit of agricultural projects. An irrigation project permits better water control so that farmers can obtain higher yields. Young trees are planted on cleared jungle land to increase the area devoted to growing
oil palm, (Gittenger, 1982). A credit project makes resources available for farmers to increase both their operating expenditures for current production—fertilizers, seeds, or pesticides—and their investment—for a tube well or a power thresher. The benefit is the increased production from the farm. In a large proportion of agricultural projects the increased production will be marketed through commercial channels. In that case identifying the benefit and finding a market price will probably not prove too difficult, although there may be a problem in determining the correct value to use in the economic analysis (Gittenger, 1982).

2.5.3.2 Quality improvement

In some instances, the benefit from an agricultural project may take the form of an improvement in the quality of the product (Gittenger, 1982).

2.5.3.3 Change in time of sale

In some agricultural projects, benefits will arise from improved marketing facilities that allow the product to be sold at a time when prices are more favorable (Gittenger, 1982). A grain storage project may make it possible to hold grain from the harvest period, when the price is at its seasonal low until later in the year when the price has risen. The benefit of the storage investment arises due to change in "temporal value." (Gittenger, 1982).

2.5.3.4 Change in location of sale

Other projects may include investment in trucks and other transport equipments to carry products from the local area where prices are low to distant markets where prices are higher. The benefits of such projects arise from the change in "locational value" (Gittenger, 1982).

In most cases the increased value arising from marketing projects will be split between farmers and marketing firms as the forces of supply and demand increase the price at which the farmer can sell in the harvest season and reduce the monopolistic power of the marketing firm or agency,(Gittenger, 1982). Many projects are structured to ensure that farmers receive a larger part of the benefit by making it possible for them to build storage facilities on their farms or to band together into cooperatives, but an agricultural project could also involve a private marketing firm or a government
agency, in which much of the benefit could accrue to someone other than farmers (Gittenger, 1982).

**2.5.3.5 Changes in product form (grading and processing)**

Projects involving agricultural processing industries expect benefits to arise from a change in the form of the agricultural product. Farmers sell paddy rice to millers who, in turn, sell polished rice. The benefit to the millers arises from the change in form. Canners preserve fruit, changing its form and making it possible at a lower cost to change its time or location of sale (Gittenger, 1982).

**2.5.3.6 Cost reduction through mechanization**

The classic example of benefit arising due to cost reduction in agricultural projects is that gained by investment in agricultural machinery to reduce labor costs. Examples are tube wells substituting for hand-drawn or animal-drawn water, pedal threshers replacing hand threshing, or (that favorite example) tractors replacing draft animals. Total production may not increase, but a benefit arises because the costs have been trimmed. (Gittenger, 1982).

**2.5.3.7 Reduced transport costs**

Cost reduction is a common source of benefit, where transport is a factor. Better feeder roads or highways may reduce the cost of moving produce from the farm to the consumer. The benefit realized may be distributed among farmers, truckers, and consumers (Gittenger, 1982).

**2.5.3.8 Losses avoided**

In some projects the benefit may arise not from increased production but from a loss avoided. (Gittenger, 1982).

**2.5.3.9 Taxes**

Recall that the payment of taxes, including duties and tariffs is customarily treated as a cost in financial analysis but as a transfer payment in economic analysis, (Gittenger, 1982). The amount that would be deducted for taxes in the financial accounts remains
in the economic accounts as part of the incremental net benefit and, thus, part of the new income generated by the project (Gittenger, 1982).

2.5.4 Differences between financial and economic analyses

The economic analysis of projects is similar in form to financial analysis. Both appraise the profit of an investment. The concept of financial profit is not the same as economic profit. The financial analysis of a project estimates the profit accruing to the project-operating entity or to the project participants, whereas economic analysis measures the effect of the project on the national economy, (Gittenger, 1982). For a project to be economically viable, it must be financially sustainable, as well as economically efficient. If a project is not financially sustainable on economic benefits will not be realized. Financial analysis and economic analysis are therefore two sides of the same coin and complementary. Both types of analysis are conducted in monetary terms, the major difference lying in the definition of costs and benefits. In financial analysis all expenditures incurred under the project and revenues resulting from it are taken into account. There are three very important distinctions between the two that must be kept in mind. (Gittenger, 1982).

2.5.6 Discounted measures of project worth

Every project has financial dimensions and all projects whose output is distributed or marketed have commercial features,(Gittenger, 1982). The test of the feasibility and soundness of a project idea requires an evaluation of the cost of the investment for undertaking it's scheduling, financing, and budgeting; and for the necessary input procurement, shipment and other output marketing aspects. In other words, the "financial" and commercial" characteristics or requirements of the project's inputs and outputs need to be analyzed and appraised to determine whether the project, as planned, is financially sound in these respects(Gittenger, 1982).

2.5.6.1 Discounting and the discount rate

Discounting is defined as "the appropriate value of rate to use in computing present discount value for social investments, determining this rate is not always easy and can be the subject of discrepancies in the true net benefit to certain projects, plans and policies, (Gruber and Jonathan 2007). the rate used to discount future cash flows to
their present values is which a key variable of project analysis. A firm's weighted average cost of capital (after tax) is often used, but many people believe that it is appropriate to use higher discount rates to adjust risk for projects or other factors. A variable discount rate with higher rates applied to cash flows occurring further along the time span might be used to reflect the yield curve premium for long-term debt (Taylor and Francis, 2000).

The discounting equation looks like equation 1 (Taylor and Francis, 2000).

\[
P V = \frac{F_{v1}}{(1+i)^1} + \frac{F_{v2}}{(1+i)^2} + \ldots + \frac{F_{vn}}{(1+i)^n} \ldots \ldots (1)
\]

Where:

- \( PV \) = present value
- \( F_v \) = projected cash flow for each period
- \( i \) = discount or hurdle rate
- \( n \) = number of time periods

The main discounted criteria used in financial and economic analysis of projects are Net Present Value (NPV), Benefit Cost ratio (B/C) and Internal Rate of Returns (IRR) (Taylor and Francis, 2000).

### 2.5.6.2 Net Present Value (NPV)

By definition, NPV equals the sum of the present values of all of a project's cash flows, both negative (cash outflows) and positive (cash inflows) (Price, 1989). For the sake of simplicity, the project cash flows are estimated on an annual basis. NPV is a standard method for using the time value of money to appraise long-term projects, capital budgeting, and widely throughout economics, it measures the excess or shortfall of cash flows, in present value terms, when financing charges are met (Price, 1989).

The PV of an income stream is the sum of the present values of the individual amounts in the income stream. Each future income amount in the stream is discounted, meaning that it is divided by a number representing the opportunity cost of holding capital from now (year 0) until the year when income is received or the outgo is spent. The
opportunity cost can either be how much you would have earned investing the money some place else or how much interest you would have had to pay if you borrowed money (Price, 1989).

The NPV of an investment in forms you how the investment compares either with your alternative investment or with borrowing, whichever applies to you. A positive net present value means this investment is better. A negative net present value means your alternative investment, or not borrowing, is better (Price, 1989).

NPV is the sum of all revenues, suitably discounted, minus the sum of all costs, suitably discounted. It is also known as net discounted revenue, net present worth, and net discounted cash flow (Price, 1989). According to Klemperor (1996) NPV is the present value of revenue minus the present value of costs. Symbolically, NPV is:

\[
NPV = R_0 + \frac{R_1}{(1+r)} + \frac{R_2}{(1+r)^2} + ... + \frac{R_n}{(1+r)^n} - C_0 - \frac{C_1}{(1+r)} - \frac{C_2}{(1+r)^2} - ... - \frac{C_n}{(1+r)^n} \quad (2)
\]

Formally it may be expressed as in equation 3 below according to Price (1989)

\[
NPV = \sum_{t=0}^{T-1} \frac{R_t}{(1+r)^t} - \sum_{t=0}^{T-1} \frac{C_t}{(1+r)^t} \quad (3)
\]

Where:

R_t and C_t are revenue and cost respectively at time t

T is the length of the production or rotation.

Financial rotation corresponds to the ages, where NPV is maximum. The most common forms for the simple plant and clear-cut situation are shown in equations 3 and 4 (Clutter et al., 1983).

\[
NPV = \sum_{t=0}^{T-1} \frac{R_t}{(1+r)^t} - \sum_{t=0}^{T-1} \frac{C_t}{(1+r)^t} \quad (3)
\]

and
\[ BLV_i = \frac{SY_i R (1+i)^t}{(1+i)^t - 1} - \frac{T}{i} \] (4)

Where:

- \(BLV_i\) = bare land value at discount rate \(i\).
- \(R\) = per acre regeneration cost.
- \(S\) = per unit stumpage price.
- \(T\) = annual per acre ad valorem tax and administration cost.
- \(Y\) = per acre yield in unit at the end of the rotation.
- \(I\) = inflation free interest rate.

For management regimes that involve expenses at various times and incomes from intermediate cuts, the BLV can be calculated using equation 5 (Clutter et al, 1983).

\[ BLV_i = \sum_{j=0}^{t} (I_j - C_j) * (1 + i)^{t-j} \] (5)

Where:

- \(BLV_i\) = bare land value at discount rate \(i\)
- \(I_j\) = Income in year \(j\)
- \(C_j\) = Cost in year \(j\)
- \(t\) = rotation age
- \(i\) = annual discount rate
2.5.6.3 The Benefit Cost Ratio

The Benefit/Cost Ratio (B/C) is a simple derivative of the net present value criterion. The ratio compares the discounted benefits to discounted costs as shown in equation 6 according to Gregersen and Contreras (1992).

\[
\frac{B}{C} \text{Ratio} = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}} \hspace{1cm} (6)
\]

Where:

\(B_t\) = Benefits in year \(t\)

\(C_t\) = Costs in year \(t\)

\(r\) = Annual interest rate

\(n\) = Time life or years of rotation

2.5.6.4 The Internal Rate of Return (IRR)

IRR is defined as the rate of return on an investment which equates the present values of benefits and costs. It is found by an iterative process and is equivalent to discount rate \(r\) that satisfies the following relationship (Price, 1989).

\[
IRR = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} = 0 \hspace{1cm} (7)
\]

Or

\[
IRR = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t} = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} \hspace{1cm} (7)
\]

Where:

\(B_t\) = Benefits in year \(t\)

\(C_t\) = Costs in year \(t\)
r = internal rate of return

n = Time life or years of rotation

The rule for interpolating the value of the internal rate of return lying between discount rates too high on the one side and too low on the other is shown in equation 8 (Gunter, 1984).

\[ IRR = R_L + \left( R_U - R_L \right) \times \frac{NPV}{NPV_{R_U} + NPV_{R_L}} \]  

(8)

Where:

IRR = internal rate of return

R_L = lower discount rate

R_U = upper discount rate

2.5.7 Management of forests for a single or perpetual series of like rotations

The question of sustainability in plantation forestry has two components. There are the general or broad issues of whether using land and devoting resources to tree plantations is a sustainable activity from the economic, the environmental or from the social sense. Is such development unsustainable or is it a threat rather than a help to people's livelihoods and way of life? These, and related issues, are important and fundamentally depend on national policies governing plantation development, understanding their impacts, and ensuring full public participation in the process. They contribute to what is labeled 'broad sense' sustainability (Price, 1989).

Narrow-sense' sustainability, is largely a silvicultural and forest management issue. The question raised is that can tree plantations be grown indefinitely for rotation after rotation on the same site without serious risk of reduction in site quality or in crop yield? More specifically, can their long-term productivity be assured, or will it eventually decline over time? These questions are pertinent owing to the increasing reliance on plantation forestry, which are also scientifically challenging since previous centuries trees and woodlands were seen as 'soil improvers' and not 'impoverishers'. Are today's silvicultural and management practices more damaging because of shorter rotations and the high timber yields achieved, typically 2-4 times that of natural forest
increment? And, of course, are developments such as tree breeding, targeted fertiliser application, and sophisticated manipulation of stand density, along with rising atmospheric carbon dioxide, likely to lead to crop yield improvement, while they disguise evidence of genuine site degradation or increasing risk of damaging attacks from pests and diseases (FAO, 2000).

A stand-level financial model analyzed the unit cost of production for alternate rotation lengths based upon the plantation's investment and operating costs and resulting biomass yields. The single rotation NPV calculation has a focus on assessing the returns to management activities and ignores the primary asset responsible for timber production, land. In 1849, Martin Faustmann proposed a method to calculate an estimate of the value of the land asset. Land Expectation Value (LEV, soil expectation value, bare land value) provides an estimate of the value of land when its most valuable use is forestry. An assumption of the method is that forestry will continue to be the most profitable use of the land in the future, so returns from timber rotations after the initial one are explicitly considered in the assessment of land value.

According to Faustmann, land’s value in forestry sector can be measured by determining the present value of a perpetual series of net revenue payments associated with a series of perpetual forest rotations. The future value of the first payment received at the end of the first rotation. (Faustmann, 1849).

2.5.8 Sensitivity Analysis

Accurately or precisely identifying, indicator for valuing, and comparing costs and benefits is always a problem. Future costs and benefits cannot be measured, but only estimated. Due to these a degree of uncertainty surrounds every estimated value. Information is nearly always limited with of low quality. For this reason, a major function of economic analysis is to test the sensitivity of selected measures of project worth to changes in assumption concerning inputs and outputs and the values attached to them (Hull, 1980). Sensitivity analysis can be used for several purposes (Hull, 1980): to illustrate differences in the attractiveness of a particular technology for farmers facing different prices, for example, for labor; to indicate the relative stability of an intervention and the risks associated with adoption; to define priorities for data collection, by noting the sensitivity of returns to certain inputs, outputs or prices; to show how input or output subsidies might influence the profitability of the practice, and to show how the implicit or financial discount rate chosen affects profitability.
CHAPTER THREE

STUDY AREA

3-1 Introduction

3.1.1 Location

Al Gadarif State extends over 71,621 km², bordered in the east by the Ethiopian Frontier, in the south and the west by River Rahad, and in the North East by the Atbara River, (Statistics Department, Al Gadarif State, 2009), map1.

Map 1. Geographical map of Al Gadarif State

Source: National Geographic Society (2011)
The study was carried out on *A. seyal* plantations at Wad El Basheir Forest Reserve, southwest of EL Hawata locality, at a distance of about 9 Km from Hawata town. Geographically it is located between latitudes 13° 30’ & 13° 33’ N and longitudes 34° 35’ & 34° 40’ E. The forest was reserved in 1952 with gazette number 840. The total area of the forest is about 3461.22 hectares, (Statistics Department, Al Gadarif State, 2009). The topography of Wad El Basheir Forest Reserve is slightly flattened, with presence of some depressions in the central and northern part of the forest. The forest area is mostly covered with hard dark cracking clay soil, (Statistics Department, Al Gadarif State, 2009). The inhabitants in the villages around the forest are enjoying the private of collect the small dry branches, twigs as fire wood; fruits, leaves, barks and roots for local medicine and other possible materials for building their local homes. (Statistics Department, Al Gadarif State, 2009). The forest is considered as a natural range particularly in the dry seasons from March to May, so grazing and browsing are rights for all livestock owners in forest area, while grazing is prevented in the areas where the new regenerations are established (Statistics Department, Al Gadarif State, 2009). Administratively, the whole area of the forest is divided into working circles mainly artificial plantation in the northern part of the forest which consists of 13 compartments, and the natural forest in southern part of the forest Map 2, (Statistics Department, Al Gadarif State, 2009). In terms of economic and land use activities, the year 2009 was the starting point in preparation of working plan for sustainable management of the forest to drive more economical, social and environmental benefits from the forest, in addition to protection and conservation of the vegetation cover in and the forests around the area (Statistics Department, Al Gadarif State, 2009). Table 3.1 displays subdivisions, establishment dates and compartment areas in Wad El Bashir Forest Reserve.
Map. 2 Compartmentation of Wad El Basheir Forest Reserve

Source: Faculty of Forestry, U. of K.
Table 3.1 Compartment areas and establishment times in Wad El Bashir forest Reserve.

<table>
<thead>
<tr>
<th>Compartment No</th>
<th>area/hectare</th>
<th>Year of establishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1124.2</td>
<td>Natural part</td>
</tr>
<tr>
<td>2</td>
<td>277.8</td>
<td>1998</td>
</tr>
<tr>
<td>3</td>
<td>164.7</td>
<td>1998</td>
</tr>
<tr>
<td>4</td>
<td>143.6</td>
<td>1997</td>
</tr>
<tr>
<td>5</td>
<td>292.5</td>
<td>1987</td>
</tr>
<tr>
<td>6</td>
<td>164.5</td>
<td>1997</td>
</tr>
<tr>
<td>7</td>
<td>160.9</td>
<td>1997</td>
</tr>
<tr>
<td>8</td>
<td>154.9</td>
<td>1996</td>
</tr>
<tr>
<td>9</td>
<td>101.3</td>
<td>1992</td>
</tr>
<tr>
<td>10</td>
<td>200.6</td>
<td>1988</td>
</tr>
<tr>
<td>11</td>
<td>210.4</td>
<td>1995</td>
</tr>
<tr>
<td>12</td>
<td>75.6</td>
<td>1998</td>
</tr>
<tr>
<td>13</td>
<td>196.1</td>
<td>1991</td>
</tr>
<tr>
<td>14</td>
<td>126.4</td>
<td>1993</td>
</tr>
</tbody>
</table>

Source: FNC (2009)
3.1.2 Topography and soils

The general landscape of Al Gadarif State is characterized by the undulating surface and hilly areas, with highly fertile clay soils in the central, southern and western part, and a higher precipitation is with mountain woodland savannas near the Ethiopian border. (Statistics Department, El Gadarif State, 2009). The region is a flat plain, with almost no relief other than small, scattered hills and seasonally flowing water courses. The principal soil type throughout the region is vertisols. Other soils, which occupy small fractions of the area, include a mixture of alluvial clays, silts, and sands of varying depths on the banks of the seasonal rivers, and rocks, stones, and gravels in some sites, (Statistics Department, Al Gadarif State, 2009).

The State is characterized by the presence of various soil types; the most important being the southern central clay plain which covers most of the State areas. This soil is heavy cracking clay with dark grey or dark brown color. However, the areas far from the river banks are covered with soils known as "Karab" and include the slope of the Ethiopian plateau and hills. These soils are clay while others are sandy (Statistics Department, Al Gadarif, 2009).

3.1.3 Climate

According to the study of climatic zones of Sudan 2009, Al Gadarif State is classified under tropical sub-humid region, The State is characterized by the high solar radiation during the rainy seasons; sun light energy is enormous and amounts to 17.5 mega joule/m²/day (Khartoum Meteorological Station, 2009). The mean maximum temperature is not greater than 35 C°, and the mean minimum temperature is not less than 20C° during the rainy season.

The highest temperature occurs in April where the mean daily maxima is (42.14 C°), and (41.8 C°) in May as the second mean daily maxima. January is recorded as the coldest month with mean daily minima (17.78 C°) and (19.47 C°) in December as the second mean daily minima (Figure 3.1), (Khartoum Meteorological Station, 2009). A considerable change in mean daily temperature occurred in the rainy period from June to the end of October due to the high relative humidity.
Fig. 3.1 Monthly maximum and minimum temperatures (2009).

Source: Khartoum Meteorological Station (2009)
Al Gadarif State is characterized by heavy rainfall. The rainy season begins in April and extends to November, with peak months being July-September, with averages of 140.49 and 103.94 mm/month for the mentioned months, respectively (Figure 3.2), (Khartoum Meteorological Station, 2009).

Fig. 3.2 Mean monthly Rainfall with month’s (2009).

Source: Khartoum Meteorological Station (2009)
The average relative humidity (R.H.) during the dry season is less than 50%, and increase to 80% in the wet season. August shows the highest mean relative humidity (72.73%), followed by September and July with (66.9%) and (63.00%) respectively, RH start decreasing gradually till December. Figure 3.3 displays mean monthly wind speed (km/h). The lowest mean relative humidity is recorded during March (21.91%) and April (19.07%) (Figure 3.4).

Fig. 3.3 Mean monthly wind speed (Km/h)

Source: Khartoum Meteorological Station (2009)
Fig. 3.4 Mean monthly relative humidity (2009)

Source: Khartoum Meteorological Station (2009)
3.1.4 Vegetation Cover

Wad El Bashir Forest Reserve is considered as one of most important dry land forest within El Hawata forest circle’s. It provides many products for local populations such as firewood, building bolus, charcoal and conservation and protection of soil. The natural vegetation cover of the forest consists of many species; the dominant ones are Acacia seyal var. seyal, mixed with A. seyal var. fistula, A. mellifra A. senegalensis, Balanites aegyptiaca. Harrison and Jackson (1958) classified the natural vegetation of the study area as an Acacia seyal and Balanites aegyptiaca woodland Savannah. On the clay plain Acacia seyal, Balanites aegyptiaca, Ziziphus orthacantha and Acacia senegal are the dominant trees.

Common grasses include Cymbopogon nervatus, Aristida mutabilis and Cteniumeelegans. In the drainage depressions also occur Hyparrhenia rafa, Hyparrhenia hitra and Longohocarus laxiferrus. The vegetation on the higher stonier land is less affected by human influences. On shallower soils the trees of Lannea stumper, Acacia campyla-canthaand, Combretum hartmannianum are exited. Sorghum grasses, Cymbopogon spp. and spurious grass species dominate areas of fallow or abandoned crop-land (SKAP, 1992).

This natural vegetation has largely been destroyed in the course of widespread clearance for mechanized crop cultivation, extensive burning and shifting cultivation, and only scattered fragments remain. The vegetation is marked by clear intra-annual changes. There is no recent reliable and comprehensive data for the vegetation of the study area, and the few surveys carried out in the past have become outdated because of the dramatic changes in the area. However, despite these changes sufficient traces of the natural vegetation remain (Statistics Department, Al Gadarif State, 2009). Map 3 displays vegetation cover of the Sudan (before subdivision). MAP 4 shows Sudan geography.
Map 3: Vegetation cover of the Sudan

Source: FAO (2001)
3.1.5 Population

The human population of Al Gadarif State belongs to many ethnic groups, most of whom have a recent history of settlement in the region. (Statistics Department, Al Gadarif State, 2009). Al Gadarif State remained an unpopulated region (supposedly as a consequence of the presence of VL) until recently, when mechanized agriculture cleared vast areas of woodland. Originally, the area was first exploited by nomadic tribes that visited the main rivers during the dry season and traveled north to the Butana region at the onset of rain. The first settlers in the area were the Fellata people, who migrated from the Kano region of Nigeria in 1923–1929. (Statistics Department, Al Gadarif State, 2009). These were then followed by Masaleet, Hausa, Fur, and other West African people who came as laborers in the mechanized agriculture schemes, which were first established at the end of the 1950s and beginning of the 1960s. Further settlement, particularly along the Atbara and Rahad Rivers, followed the continued expansion of mechanized agriculture in this region. According to the most recent estimate, Gadarif State has a total population of 1,137,642 people (Statistics Department, Al Gadarif State, 2009).

3.6 Land use types

Agriculture is the main economic activity, followed by livestock rising in the traditional seasonal transhumance pattern. Gum tapping, collecting and trading forest products and charcoal making are other traditional forms of economic activity. Thus, the people derive their income from various combinations of the three main forms of land-use: agriculture, grazing, and forest exploitation. Mechanized rain fed crop production, has considerably reduced the land available for small-holder farm and for grazing (Glover, 2005). Elmoula (1985) stated that the traditional pattern of land-use has been profoundly changed by population growth.
Map 4: Geographical map of the Sudan

Source: National Geographic Society (2011)
CHAPTER FOUR

MATERIAL AND METHODS

4.1 Data collection

Two methods of data collection were used. Growth and yield data were collected through temporary sample plots and market-related data was collected through interviews to key informants and from secondary sources of data as will.

4.1.1 Growth and yield data

Data concerning tree growth and yield was obtained from systematic sampling covering all ages present in the forest. Five percent sampling intensity were used. Sample plots were distributed 100 m apart along survey lines and 200 m apart between lines. With a radius of circular plots of 17.8 m, the area of a sample plot was approximately 0.1 ha. A total of 364 sample plots were taken. In each sample plot the following variables were assessed: tree count, diameter at breast height (dbh) of all trees and top height of trees (with largest, medium and smallest dbh). Table 4.2 shows number of compartments surveyed, crop age, survey lines and number of sample plots.
Table 4.1: Compartments and ages at Wad El basher forest reserve.

<table>
<thead>
<tr>
<th>Compartment no.</th>
<th>Age (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
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<tr>
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<tr>
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<td>16</td>
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</tr>
<tr>
<td>13</td>
<td>21</td>
</tr>
<tr>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>22</td>
</tr>
</tbody>
</table>

Source: FNC (2009)
Table 4.2 Number of compartments surveyed, crop age, survey lines and number of sample plots.

Table 4.2: Crop age, survey lines and number of sample plots.

<table>
<thead>
<tr>
<th>Number</th>
<th>Compartment</th>
<th>Age</th>
<th>Number of sample plot line</th>
<th>Number of Sample plots</th>
</tr>
</thead>
<tbody>
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<td>12</td>
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<td>49</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>14</td>
<td>4</td>
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</tr>
<tr>
<td>3</td>
<td>11</td>
<td>15</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>18</td>
<td>7</td>
<td>47</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>21</td>
<td>5</td>
<td>58</td>
</tr>
<tr>
<td>6</td>
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<td>83</td>
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<tr>
<td>7</td>
<td>2</td>
<td>23</td>
<td>2</td>
<td>70</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>364</td>
</tr>
</tbody>
</table>
4.1.2 Estimation of form factor

Three trees with small, medium and large diameter at breast height (dbh) were selected in each of the seven crop ages. Total heights and dbh of this trees were measured while standing. Volume of standing trees was calculated using formula 9 according to Taylor (1962).

Is:

\[ V_t = S \times h \times f \] ........................(9)

\[ V_t = \frac{\pi}{4} \times dbh^2 \times h \times f \] ........................(9)

Where:

\( V = \) volume \( (m^3) \)

\( t = \) age in years \( (t = 1, 2 \ldots n) \).

\( S = \) breast height sectional area \( (m^2) \).

\( h = \) height of tree \( (m) \)

\( f = \) form factor

The 21 trees were felled and cut into 1-meter long logs. Small-end and large-end diameters of each log were measured using a caliper. Log volume \( (m^3) \) was calculated for each log using Smalian formula (Taylor, 1962) presented in equation 10.

\[ V_i = \frac{1}{2} \times (S_0 + S_t) \times h \] ..............................(10)

Where:

\( V_i = \) volume of the log \( m^3 \)

\( S_0 \) and \( S_t = \) sectional areas of the two ends \( m^2 \).

\( h = \) the length of the log \( m \)
The volumes of all logs of each tree were added together to yield the true stem volume. Form factor was calculated as the ratio of the volume of the stem to the volume of the cylinder. It was estimated using equation 11 according to Taylor (1962).

\[ f = \frac{V_t}{V_c} = \frac{V_t}{s \times h} \quad (11) \]

Where:

- \( f = \) form factor.
- \( V_t = \) tree volume in \( m^3 \)
- \( V_c = \) cylinder volume in \( m^3 \)
- \( s = \) each tree basal area at breast height in \( m^2 \).
- \( h = \) each tree height in m

### 4.1.3 Estimation of volume of wood per unit area

Volume of standing trees (\( m^3 \) ha\(^{-1} \)) was estimated using formula 12 (Taylor, 1962).

\[ V = S \times h \times f \times N \quad (12) \]

Where:

- \( V = \) the timber volume.
- \( S = \) the breast height basal area.
- \( h = \) the trees height.
- \( f = \) the form factor.
- \( N = \) number of trees per unit area
4.1.4 Estimation of mean annual increment

Mean Annual Increment (MAI) expresses biological growth in terms of volume produced per area per year, averaged across the stand as forest property and over the life of the stand (Jacobson, 2008), MAI is simply the average volume production per year for a forest will known age, The MAI (m³/ha) is the total volume per acre divided by the age of the stand at that time. It was calculated using equation 13 (Leuschner, 1984).

\[ MAI = \frac{Y_A}{A} \] (13)

Where:

MAI = mean annual increment.
A = stand age.
Y = yield, or volume of wood at age A.

Current Annual Increment (CAI) is the increase determined by annual measurements in tree volume at a particular age with standing volume. On the basis of current volume and with the aid of the MAI, the real return value achieved in the future were normally be discounted by large amount. Forecasts of future volumes were made using equation 14 according to Gunter and Haney (1984).

\[ V_n = V_0 \times (1+i)^n \] (14)

Where:

\( V_n \) = future value at year n
\( V_0 \) = present value
i = annual interest rate
n = number of years

Calculation of Periodic Annual Increment (PAI) in m³/ha was calculated using equation 15 according to Leuschner (1984).
\[ PAI_{A} = \frac{Y_{A+n} - Y_{A}}{n} \] ..........(15)

Where:

PAI = periodic annual increment.

\( A = a + 0.5n \).

\( A = \) stand age.

\( N = \) number or year between observation

\( Y = \) yield of wood harvested at age \( A \).

### 4.1.5 Estimation of wood volume

Present wood volume and MAI (\( m^3/ha \)) were linked forward and backward to give an estimate of volume at different group ages, the equation used was:

\[ V_n = V_0 \pm (1 + MAI) \cdot n \] ...............(16)a

\[ V_n = V_0 \pm MAI \cdot n \] ...............(16)b

Where:

\( V_n = \) future volume

\( V_0 = \) present volume.

\( N = \) number of years.

\( MAI = \) mean annual increment.

(Use plus (+) sign to estimate future volumes and use (-) to estimate past volumes).
4.2 Fuel wood production, marketing and policy data

The data concerning production and marketing, and forest policy related to fire wood from *Acacia seyal* were obtained through market surveys and questionnaires. The questionnaires were addressed to three stakeholders, i.e. FNC staff, fuel wood producers /traders trade unions and commercial banks. Because of the similar nature of the data to be revealed and the small number of institutions targeted, resort was made to question minimum number of key informants in each case. *The questionnaire to FNC staff* meant to reveal information on rotation age, method of sale of Talh wood and justification for that, accepted minimum price SDG/m$^3$ and to generate data on market price of fuel wood and cost of establishment and management operations. Two representatives of FNC staff were questioned. Appendix 1 displays questionnaire addressed to FNC.

The questionnaires addressed to fuel wood producers /trader's trade union was used to obtain random information on taxes, fees, royalties levied on Talh fuel wood, constraints in production and marketing of Talh fuel wood and information on cost of felling, loading, unloading, transportation to destinations including (taxes and fees), and potential improvements in production and marketing. About 10% (n=3) of trade union current membership (35) were questioned. Appendix 2 displays questionnaire addressed to fuel wood producers /traders trade union.

The questionnaire to commercial banks was meant to reveal information about finance fuel wood production projects and profit margins Sudan. Agricultural Bank in Al Hawata and Al Gadarif were inquired. Appendix 3. displays questionnaire addressed to commercial banks.

4.3 Profitability of fuel wood production from *Acacia seyal*

4.3.1 Net Present Value

The criterion of net present value (NPV) was used to assess the profitability of fire wood production from *Acacia seyal* planted for single and perpetual rotations. NPV (SDG fd$^{-1}$) of a single rotation were calculated using equation 17.
\[ NPV_i = \sum_{t=1}^{T} B_t \cdot \frac{1}{(1+i)^t} - \sum_{t=1}^{T} C_t \cdot \frac{1}{(1+i)^t} \]  

(17)

Where:

\( B_t = \) Benefit at time \( t \)

\( C_t = \) Cost at time \( t \)

\( T = \) the length of the production or rotation.

Klemperor (1996), addressing the willingness to pay for land per unit area, ignoring taxes and assuming perpetual rotations presents equation 18. which was used to estimate NPV of management of \( Acacia seyal \) at Wad EL Bashier Forest Reserve (taking compartment 8 as example) for rotation of 20 years for the production of firewood in perpetuity.

Is:

\[ \text{WPL} = \frac{\sum_{y=0}^{t} R_y (1 + r)^{(t-y)} - \sum_{y=0}^{t} C_y (1 + r)^{(t-y)}}{(1 + r)^t - 1} + \frac{a - c}{r} \]  

(18)

Where:

\( \text{WPL}_\infty = \) willingness to pay for land per unit area

\( R_y = \) revenue in year \( y, \) $/unit area

\( C_y = \) cost in year \( y, \) $/unit area

\( t = \) rotation age

\( y = \) an index for years from 0 to \( t \)

\( r = \) real interest rate, percent/100

\( a = \) equal annual revenue, $/unit area

\( c = \) equal annual cost, $/unit area
4.3.2 The Internal Rate of Return (IRR)

Internal Rate of Return (IRR) for firewood production was estimated using equation 8 in page 25 chapter two.

4.3.3 Sensitivity analysis

To assess the sensitivity of profitability of firewood production from A. seyal in a single rotation some changes in basic production assumptions were made. First, reduction of annual discount rate from 12% to 7%, second, increase of price per m³ of firewood harvest from SDG 52.0 to 60.0. Third, adoption of thinning at ages 6 and 10. Finally, reduction of rotation age from 20 to 15 years.
CHAPTER FIVE
RESULTS AND DISCUSSION

5.1 Institutional and policy factors related to production and marketing of fire wood

5.1.1 Operations

Responses to the questionnaire of the FNC staff revealed the followings:

? Operations and unit costs: Different silvicultural and management operations and their unit cost according to current practice are shown in table 5.3.

? Methods of offering timber: The method used by FNC to offer timber from thinning and final cut for sale is the tender method where firewood is sold standing.

? Taxes and fees on firewood: Responses showed that a number of payments are levied on firewood. They include taxes paid to tax chamber (of about 5.5 SDG per m3), Zakat paid to Zakat chamber (2 SDGm3). Market fees are paid to the administration of crops market (about 5.8 SDGm3) and administrative fees paid to localities (about 2.8 SDGm3). A return paid to FNC was about 10.0 SDG per standing cubic meter of firewood.

? Firewood consumption centers: Firewood is consumed inside and outside the state, at national and international markets (e.g. Saudi Arabia). The main method of transport of firewood to consumption areas is road transport using trucks that carry in average 50 cubic meter (stacked).

? Finance: Results showed that FNC finances firewood production from its internal financial resources.

? Constraints to firewood marketing (Policy and marketing):

Responses to the questionnaire showed that there are several constraints to firewood marketing. The main obstacles that limit production and marketing of firewood produced from plantation forests of Acacia seyal are:

1 – Imposition of different types of payment by a non-forest institutions (Locality, Crops markets, Taxes, Zakat, … etc.) on firewood.

2 – High cost of production of firewood at public forests and competition with firewood produced from private forests that is offered at comparatively lower prices

3 – Availability of low-cost fire wood produced from Mesquite (Prosopis spp.).

4- A difficult and lengthily ratification processes.
5 – The scarcity of workers during establishment period as it coincides with the production season of agricultural cash crops

5.2 Growth and yield data

5.2.1 Estimation of form factor

Figure 5.1 displays calculated form factor for *A. seyal* for crop ages present in Wad El Basheir Forest Reserve at 2010. The mean estimates were 0.62, 0.57, 0.53, 0.55, 0.66, 0.62 and 0.56 for age 12, 14, 15, 18, 21, 22 and 23, respectively.

![Fig 5.1 Form factor of Acacia seyal](image)

**Fig. 5.1 Scatter plot of form factor of Acacia seyal at Wad El Basheir Forest Reserve**

The present estimates of form factor range are closely scattered when compared to that of Elmaleeh (2004) who estimated a lower and higher ends of form factors of *A. seyal* of 0.22% and 0.68 %. Eltayib (2011) reported comparable results.
Table 5.1 Number of trees, wood volume and MAI

<table>
<thead>
<tr>
<th>Age Year</th>
<th>Area fd</th>
<th>DBH cm</th>
<th>B.A m²</th>
<th>HT m</th>
<th>No./fd</th>
<th>VOLUME m³ fd⁻¹</th>
<th>MAI m³ fd⁻¹</th>
<th>VOLUME m³/comp</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>166.01</td>
<td>10.42</td>
<td>0.01</td>
<td>6.96</td>
<td>142</td>
<td>16.33</td>
<td>1.36</td>
<td>1129.55</td>
</tr>
<tr>
<td>14</td>
<td>156.12</td>
<td>9.21</td>
<td>0.008</td>
<td>8.34</td>
<td>282</td>
<td>26.22</td>
<td>1.87</td>
<td>1705.61</td>
</tr>
<tr>
<td>15</td>
<td>212.06</td>
<td>7.34</td>
<td>0.005</td>
<td>6.12</td>
<td>187</td>
<td>8.37</td>
<td>0.56</td>
<td>739.57</td>
</tr>
<tr>
<td>18</td>
<td>102.10</td>
<td>8.95</td>
<td>0.007</td>
<td>6.38</td>
<td>126</td>
<td>8.35</td>
<td>0.46</td>
<td>355.21</td>
</tr>
<tr>
<td>21</td>
<td>197.70</td>
<td>8.46</td>
<td>0.006</td>
<td>6.53</td>
<td>172</td>
<td>11.94</td>
<td>0.57</td>
<td>983.38</td>
</tr>
<tr>
<td>22</td>
<td>202.20</td>
<td>10.01</td>
<td>0.009</td>
<td>6.98</td>
<td>243</td>
<td>25.63</td>
<td>1.17</td>
<td>2159.33</td>
</tr>
<tr>
<td>23</td>
<td>280.01</td>
<td>10.21</td>
<td>0.009</td>
<td>7.83</td>
<td>218</td>
<td>26.22</td>
<td>1.01</td>
<td>3059.09</td>
</tr>
<tr>
<td>Mean</td>
<td>9.23</td>
<td>0.008</td>
<td>7.02</td>
<td>196</td>
<td>17.58</td>
<td>1</td>
<td>1447.39</td>
<td></td>
</tr>
<tr>
<td>Std</td>
<td>1.1</td>
<td>0.002</td>
<td>0.8</td>
<td>56</td>
<td>8.34</td>
<td>0.51</td>
<td>929.27</td>
<td></td>
</tr>
<tr>
<td>C.V.%</td>
<td>11.02</td>
<td>21.522</td>
<td>10.6</td>
<td>11</td>
<td>18.46</td>
<td>20.01</td>
<td>518.12</td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>7.34</td>
<td>0.005</td>
<td>6.12</td>
<td>126</td>
<td>8.35</td>
<td>0.46</td>
<td>355.21</td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>10.42</td>
<td>0.01</td>
<td>8.34</td>
<td>282</td>
<td>26.22</td>
<td>1.87</td>
<td>3059.09</td>
<td></td>
</tr>
</tbody>
</table>

Mean stocking density of *Acacia seyal* at Wad El Basheir Forest Reserve was calculated as 196 within a range of 282 – 126 trees/fd. This stocking is in agreement with that prescribed by NFTA (1994) who state that for poles and fuel wood production in a 20 year rotation in Sudan thinning after 10 and 14 years reduce stocking to 675 and 450 stems fd⁻¹, respectively. The relatively high CV% (11%) indicates the existence of high variability in stocking at young as well as older crops. Stocking of present crop ranges between a minimum of 126 stems per feddan at age 18 to 282, 243 and 218 trees per feddan at ages 14, 22 and 23, respectively.

The growing stock wood volume for ages 12, 14, 15, 18, 21, 22, 23 ranges between 8.35 – 26.22 m³ fd⁻¹ while the mean annual increment for those ages ranges from a 0.46 – 1.87 m³ fd⁻¹, with high MAI corresponding to crops with high stocking density. Minimum and maximum mean volumes (m⁻¹ fd⁻¹) of 8.35, 8.37 and 26.22, respectively, showed high variation in wood stocking relation ship with ages. This variation may be attributed to trees per unit area due to application of prescribed
selection felling (compartment age 14 and 15) or to illegal felling which is common at compartments located at forest boundaries and easily accessible (compartment age 12) (Eltayib, 2011).

5.2.3 Estimation of past and future wood volumes using MAI

Based on current stocking and assuming constant MAI, projection of future volume yields variations in standing wood volume (m\(^3\) fd\(^{-1}\)). At age 20, for instance, estimates of final standing wood volumes are 4.8, 11.07, 2.54, 2.89, 2.92, 5.72 and 5.13 m\(^3\) fd\(^{-1}\). The mean standing wood volume of 11.92 at age 20 is comparatively higher than that stated by Vink (1989) and agrees well with NFTA (1994). Figure 5.2 shows estimation of volume of A. seyal wood.

**Fig 5.2 Estimation volume of A. seyal**

![Fig. 5.2 Estimated volume (m\(^3\) fd\(^{-1}\)) of Acacia seyal](chart)
5.3 Financial profitability of Firewood production

5.3.1 Physical input and output table

Table 5.3 displays physical input and cost elements for production of firewood from *Acacia seyal*.

**Table 5.3 Inputs costs of firewood production from *Acacia seyal* (SD.G/td)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Operation</th>
<th>Unit</th>
<th>Quantity</th>
<th>Cost</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Land rent/purchase</td>
<td>fd</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Land preparation</td>
<td>Md/fd</td>
<td>2</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Seeds</td>
<td>Kg/fd</td>
<td>1.5</td>
<td>4.5</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Seed sowing</td>
<td>Md/fd</td>
<td>2</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>1st weeding</td>
<td>fd</td>
<td>1</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Opening fire line (200m/fd)</td>
<td>fd</td>
<td>1</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Supervision</td>
<td></td>
<td></td>
<td>1.17</td>
<td>1.17</td>
</tr>
<tr>
<td></td>
<td><strong>Sum</strong></td>
<td></td>
<td></td>
<td><strong>83</strong></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2nd weeding</td>
<td>fd</td>
<td>1</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Supervision</td>
<td></td>
<td></td>
<td>1.17</td>
<td>1.17</td>
</tr>
<tr>
<td></td>
<td><strong>Sum</strong></td>
<td></td>
<td></td>
<td><strong>29.17</strong></td>
<td></td>
</tr>
<tr>
<td>3-5</td>
<td>Supervision</td>
<td></td>
<td></td>
<td>1.17</td>
<td>1.17</td>
</tr>
<tr>
<td>6</td>
<td>Improvement thinning</td>
<td>fd</td>
<td>2</td>
<td>12</td>
<td>24.00</td>
</tr>
<tr>
<td></td>
<td>Supervision</td>
<td></td>
<td></td>
<td>1.17</td>
<td>1.17</td>
</tr>
<tr>
<td></td>
<td><strong>Sum</strong></td>
<td></td>
<td></td>
<td><strong>25.17</strong></td>
<td></td>
</tr>
<tr>
<td>7-9</td>
<td>Supervision</td>
<td></td>
<td></td>
<td>1.17</td>
<td>1.17</td>
</tr>
<tr>
<td>10</td>
<td>Commercial thinning</td>
<td>Fd</td>
<td>2</td>
<td>14</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Supervision</td>
<td></td>
<td></td>
<td>1.17</td>
<td>1.17</td>
</tr>
<tr>
<td></td>
<td><strong>Sum</strong></td>
<td></td>
<td></td>
<td><strong>29.17</strong></td>
<td></td>
</tr>
<tr>
<td>11-19</td>
<td>Supervision</td>
<td></td>
<td></td>
<td>1.17</td>
<td>1.17</td>
</tr>
<tr>
<td>20</td>
<td>Harvesting</td>
<td>m³</td>
<td>2</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Supervision</td>
<td></td>
<td></td>
<td>1.17</td>
<td>1.17</td>
</tr>
<tr>
<td></td>
<td><strong>Sum</strong></td>
<td></td>
<td></td>
<td><strong>1.17</strong></td>
<td></td>
</tr>
</tbody>
</table>
Production cost includes material cost (e.g. seeds) and labour cost (e.g. seeds sowing, land preparation, 1st weeding, 2nd weeding and cost of opening fire and inspection lines). The total revenues included the revenue from intermediate thinnings and from harvest at the end of rotation. Output at the end of rotation is estimated at 52 m$^3$/feddan. Market price was 60 SD.G. per standing m$^3$.

5.4 Estimation of returns to land for firewood production from firewood production from a single rotation of *Acacia seyal* plantations

Table 5.4 shows cash flow and NPV from firewood production from *Acacia seyal* single 20-year rotation, 12% annual discounting rate, without thinning.

**Table 5.4 Financial net present value (SD.G./feddan) for firewood production from *A. seyal* (Compartment 8)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total costs</th>
<th>Total benefits</th>
<th>DF at 12%</th>
<th>PVC at12%</th>
<th>PVB at12%</th>
<th>NPV at12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83.000</td>
<td>0</td>
<td>0.893</td>
<td>74.107</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>29.000</td>
<td>0</td>
<td>0.797</td>
<td>23.119</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3-19</td>
<td>1.170</td>
<td>0</td>
<td>0.797</td>
<td>6.641</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1.170</td>
<td>821.600</td>
<td>0.104</td>
<td>0.121</td>
<td>85.173</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td></td>
<td></td>
<td>103.99</td>
<td>85.17</td>
<td>-18.82</td>
</tr>
</tbody>
</table>
Table 5.5 shows net present value (SD.G/feddan) of firewood production for all compartments without thinning at annual discounting rate of 12%.

Table 5.5 Financial Net Present Value (SD.G/feddan) for firewood production from *Acacia seyal* plantations without thinning

<table>
<thead>
<tr>
<th>Compartment</th>
<th>Volume (m³/feddan)</th>
<th>NPV @ 12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td></td>
<td>SD.G.</td>
</tr>
<tr>
<td>3</td>
<td>11.56</td>
<td>-41.67</td>
</tr>
<tr>
<td>8</td>
<td>15.8</td>
<td>-18.82</td>
</tr>
<tr>
<td>11</td>
<td>4.69</td>
<td>-78.71</td>
</tr>
<tr>
<td>9</td>
<td>3.89</td>
<td>-83.02</td>
</tr>
<tr>
<td>13</td>
<td>4.76</td>
<td>-78.33</td>
</tr>
<tr>
<td>10</td>
<td>9.75</td>
<td>-51.43</td>
</tr>
<tr>
<td>2</td>
<td>9.74</td>
<td>-51.48</td>
</tr>
</tbody>
</table>

The calculation of financial NPV of firewood production from *Acacia seyal* plantation for a rotation of 20 years at 12% discounting rate as currently practiced was negative for all compartments. This result is a reflection of the low wood volume per unit area at harvest, poor producers’ price of firewood, high cost of production, long rotation, or absence of early income because there is no thinning in current management system. Using the base scenario, the wood volume required to breakeven is 19.3 m³ fd⁻¹ given the present costs and prices.
5.5 Estimation of NPV per feddan per perpetual rotation

Table 5.6 Estimation of NPV for fire wood production in perpetual at 20 years rotation without thinning at discount rate 12%.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total cost</th>
<th>Total income</th>
<th>Net income</th>
<th>$I-C^{(1+i)^{(t-j)}}$</th>
<th>$(1-C)(1+1)^{t-j}$</th>
<th>$(1+1)^{t-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>C</td>
<td>I</td>
<td><code>I-C</code></td>
<td>(1+i)^{(t-j)}</td>
<td>(1-C)*(1+1)^{t-j}</td>
<td>(1+1)^{t-1}</td>
</tr>
<tr>
<td>0</td>
<td>83.0</td>
<td>0.0</td>
<td>-83.00</td>
<td>8.61</td>
<td>-714.86</td>
<td>-114.86</td>
</tr>
<tr>
<td>1</td>
<td>29.2</td>
<td>0.0</td>
<td>-29.17</td>
<td>7.69</td>
<td>-224.32</td>
<td>-35.72</td>
</tr>
<tr>
<td>2</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>6.87</td>
<td>-8.03</td>
<td>-1.17</td>
</tr>
<tr>
<td>3</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>6.13</td>
<td>-7.17</td>
<td>-1.17</td>
</tr>
<tr>
<td>4</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>5.47</td>
<td>-6.40</td>
<td>-1.17</td>
</tr>
<tr>
<td>5</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>4.89</td>
<td>-5.72</td>
<td>-1.17</td>
</tr>
<tr>
<td>6</td>
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<td>0.0</td>
<td>-1.17</td>
<td>4.36</td>
<td>-5.11</td>
<td>-1.17</td>
</tr>
<tr>
<td>7</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>3.90</td>
<td>-4.56</td>
<td>-1.17</td>
</tr>
<tr>
<td>8</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>3.48</td>
<td>-4.07</td>
<td>-1.17</td>
</tr>
<tr>
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<td>3.11</td>
<td>-3.63</td>
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<td>-2.90</td>
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</tr>
<tr>
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<td>-1.17</td>
<td>2.21</td>
<td>-2.59</td>
<td>-1.17</td>
</tr>
<tr>
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<td>-1.17</td>
<td>1.97</td>
<td>-2.31</td>
<td>-1.17</td>
</tr>
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<td>-1.17</td>
<td>1.76</td>
<td>-2.06</td>
<td>-1.17</td>
</tr>
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<td>-1.17</td>
<td>1.57</td>
<td>-1.84</td>
<td>-1.17</td>
</tr>
<tr>
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<td>-1.17</td>
<td>1.40</td>
<td>-1.64</td>
<td>-1.17</td>
</tr>
<tr>
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<td>-1.17</td>
<td>1.25</td>
<td>-1.47</td>
<td>-1.17</td>
</tr>
<tr>
<td>18</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>1.12</td>
<td>-1.31</td>
<td>-1.17</td>
</tr>
<tr>
<td>19</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>1.00</td>
<td>-1.17</td>
<td>-1.17</td>
</tr>
<tr>
<td>20</td>
<td>1.17</td>
<td>821.60</td>
<td>820.43</td>
<td>0.89</td>
<td>732.53</td>
<td>-271.9</td>
</tr>
</tbody>
</table>

NPV per feddan -35.7
Table 5.6 shows NPV (SDG/fd) of *Acacia seyal* crop managed for 20 years for firewood production in perpetuity at 12% annual discounting rate. Reduction of discounting rate to 7% per year improved NPV per feddan to 125.4 in table 5.7 bellow.
Table 5.7 Estimation of NPV for fire wood production in perpetual at 20 years rotation without thinning discount rate 7%.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total cost</th>
<th>Total income</th>
<th>Net income</th>
<th>(1+i)^t - 1</th>
<th>(I-C)*(I+I)^t-j</th>
<th>(1+i)^t-j</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>83.0</td>
<td>0.0</td>
<td>-83.00</td>
<td>3.62</td>
<td>-300.17</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>29.2</td>
<td>0.0</td>
<td>-29.17</td>
<td>3.38</td>
<td>-98.59</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>3.16</td>
<td>-3.70</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>2.95</td>
<td>-3.45</td>
<td></td>
</tr>
<tr>
<td>4</td>
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<td>0.0</td>
<td>-1.17</td>
<td>2.76</td>
<td>-3.23</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.17</td>
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<td>-1.17</td>
<td>2.58</td>
<td>-3.02</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>2.41</td>
<td>-2.82</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>2.25</td>
<td>-2.64</td>
<td></td>
</tr>
<tr>
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<td>1.17</td>
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<td>-1.17</td>
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<td></td>
</tr>
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<td>-1.17</td>
<td>1.97</td>
<td>-2.30</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>1.84</td>
<td>-2.15</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>1.72</td>
<td>-2.01</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>1.61</td>
<td>-1.88</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>1.50</td>
<td>-1.76</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>1.40</td>
<td>-1.64</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>1.31</td>
<td>-1.53</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>1.23</td>
<td>-1.43</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>1.14</td>
<td>-1.34</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>1.07</td>
<td>-1.25</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>1.17</td>
<td>0.0</td>
<td>-1.17</td>
<td>1.00</td>
<td>-1.17</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1.17</td>
<td>821.60</td>
<td>820.43</td>
<td>0.93</td>
<td>766.76</td>
<td>328.2</td>
</tr>
</tbody>
</table>

NPV per feddan 125.4
5.6 Sensitivity analyses of returns to land for firewood production from a single rotation of *Acacia seyal* plantations

Sensitivity of returns to land, expressed as NPV per feddan, due to change in annual discounting rate, adoption of thinning, increase firewood price at harvest and reduction of rotation.

5.6.1 Decrease of annual discounting rate

Table 5.8 shows effect of the annual discounting rate on financial (NPV) for firewood production *A. seyal* (single 20-year rotation, without thinning at annual discounting rate of 7%) taking compartment 8 as a model.

**Table 5.8 Effect of reduction of discounting rate on Net Present Value of firewood production from *A. seyal* plantation**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total costs</th>
<th>Total benefits</th>
<th>DF at 7%</th>
<th>PVC at 7%</th>
<th>PVB at 7%</th>
<th>NPV at 7%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83.000</td>
<td>0</td>
<td>0.935</td>
<td>77.570</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>29.000</td>
<td>0</td>
<td>0.873</td>
<td>25.330</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3-19</td>
<td>1.170</td>
<td>0</td>
<td></td>
<td>11.38</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1.170</td>
<td>821.600</td>
<td>0.258</td>
<td>0.302</td>
<td>212.32</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td></td>
<td></td>
<td>113.18</td>
<td>212.32</td>
<td>99.14</td>
</tr>
</tbody>
</table>

The calculation of financial (NPV) of firewood production from the first rotation of *Acacia seyal* plantations managed at 20-year rotation at 7% annual discounting rate without thinning operations reveals negative financial NPVs for firewood production for compartments 3, 8, 9, 10 and 2. While The table of compartments display positive NPVs indicating positive responses to the decrease in discounting rate. Relative to the basic scenario lowering annual discounting rate converts negative returns to land for four compartments to profitable ones with positive NPV per feddan. This result implies that for firewood production to be financially profitable at the present production characteristics, finance at a low annual profit margin is a necessity.
Table 5.9 Effect of reduction in discounting rate on Net Present Value of firewood production from *A. seyal* plantations (all compartments).

<table>
<thead>
<tr>
<th>Compartment</th>
<th>Volume</th>
<th>NPV at 7%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>m³/ feddan</td>
<td>without thinning</td>
</tr>
<tr>
<td>3</td>
<td>11.56</td>
<td>42.16</td>
</tr>
<tr>
<td>8</td>
<td>15.8</td>
<td>99.14</td>
</tr>
<tr>
<td>11</td>
<td>4.69</td>
<td>-50.16</td>
</tr>
<tr>
<td>9</td>
<td>3.89</td>
<td>-60.91</td>
</tr>
<tr>
<td>13</td>
<td>4.76</td>
<td>-49.22</td>
</tr>
<tr>
<td>10</td>
<td>9.75</td>
<td>17.84</td>
</tr>
<tr>
<td>2</td>
<td>9.74</td>
<td>17.71</td>
</tr>
</tbody>
</table>

Taking Compartment 8, an example, with NPV of -18.8 and +99.14 at 12% and 7% annual discount rates respectively, IRR of the basic scenario was estimated as 11.2% using equation 8.
5.6.2 Adoption of thinning:

Response to financial net present value (SD.G./feddan) of firewood production from a single rotation of A. seyal at annual discounting rate of 12% to the adoption of thinning was done for compartment 8 (Table 5.10) and for all compartments (Table 5.11).

Table 5.10 Influence of thinning on financial net present value (Compartment 8)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total costs</th>
<th>Total benefits</th>
<th>DF at 12%</th>
<th>PVC at 12%</th>
<th>PVB at 12%</th>
<th>NPV at 12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83.000</td>
<td>0</td>
<td>0.893</td>
<td>74.107</td>
<td>0</td>
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</tr>
<tr>
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<td>29.000</td>
<td>0</td>
<td>0.797</td>
<td>23.119</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3-5</td>
<td>1.170</td>
<td>0</td>
<td>0.712</td>
<td>0.833</td>
<td>0</td>
<td></td>
</tr>
<tr>
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<td>1.170</td>
<td>23</td>
<td>0.507</td>
<td>0.593</td>
<td>12</td>
<td></td>
</tr>
<tr>
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<td>0</td>
<td>0.322</td>
<td>0.377</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.170</td>
<td>31</td>
<td>1.671</td>
<td>1.121</td>
<td>85.173</td>
<td></td>
</tr>
<tr>
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<td>0</td>
<td>1.671</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1.170</td>
<td>821.600</td>
<td>0.104</td>
<td>0.121</td>
<td>85.173</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>103.99</td>
<td>106.97</td>
<td>2.98</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.11 Effect of thinning on Financial Net Present Value (all compartments)

<table>
<thead>
<tr>
<th>Compartment No</th>
<th>Volume (m³/feddan)</th>
<th>NPV at 12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>11.56</td>
<td>-26.15</td>
</tr>
<tr>
<td>8</td>
<td>15.8</td>
<td>2.98</td>
</tr>
<tr>
<td>11</td>
<td>4.69</td>
<td>-71.5</td>
</tr>
<tr>
<td>9</td>
<td>3.89</td>
<td>-77.4</td>
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<tr>
<td>13</td>
<td>4.76</td>
<td>-71.76</td>
</tr>
<tr>
<td>10</td>
<td>9.75</td>
<td>-38.59</td>
</tr>
<tr>
<td>2</td>
<td>9.74</td>
<td>-34.77</td>
</tr>
</tbody>
</table>
5.6.3 Increase in firewood price at harvest
An increase of price from 52 to 60 SDG at rotation age was observed. Table 5.12 shows the effect of price increasing at harvest on returns to land for firewood production at annual discounting rate of 12% without thinning in compartment 8, as an example.

Table 5.12 Effect of price increasing at harvest on returns to land (Compartment 8)

<table>
<thead>
<tr>
<th>Volume (m³/feddan)</th>
<th>Price</th>
<th>NPV (SDG/feddan) i= 12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.8</td>
<td>52</td>
<td>-18.82</td>
</tr>
<tr>
<td>15.8</td>
<td>60</td>
<td>-5.71</td>
</tr>
</tbody>
</table>

Table 5.13 Response of NPV to price increasing for firewood at harvest on returns to land (all compartments)

<table>
<thead>
<tr>
<th>Compartment</th>
<th>Volume</th>
<th>NPV i= 12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>m³/ feddan</td>
<td>(SDG/feddan)</td>
</tr>
<tr>
<td>3</td>
<td>11.56</td>
<td>-32.08</td>
</tr>
<tr>
<td>8</td>
<td>15.8</td>
<td>-5.71</td>
</tr>
<tr>
<td>11</td>
<td>4.69</td>
<td>-74.82</td>
</tr>
<tr>
<td>9</td>
<td>3.89</td>
<td>-80.83</td>
</tr>
<tr>
<td>13</td>
<td>4.76</td>
<td>-74.38</td>
</tr>
<tr>
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<td>9.75</td>
<td>-43.34</td>
</tr>
<tr>
<td>2</td>
<td>9.74</td>
<td>-43.40</td>
</tr>
</tbody>
</table>

The results implies that even such an increase in the price per unit of firewood was not big enough to attach profitably the current management system of Acacia seyal plantations. Other cost factors, including silvicultural operation and protection, as well as low wood volume per unit area, are more responsible for the negative NPV per unit area.
5.6.4 Reduction of rotation

Estimation of financial net present value (SD.G./feddan) without thinning at rotation 15 for firewood production for all compartments at discounting rate 12%

Table 5.14 displays reaction of (NPV) (SD.G./feddan) of firewood production at discounting rate 12%, without thinning for a reduction of rotation to 15 years (all compartments).

Table 5.14 Effect of reduction of rotation length on NPV (all compartments).

<table>
<thead>
<tr>
<th>Compartment No</th>
<th>Volume (m³/feddan)</th>
<th>NPV at 12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>8.63</td>
<td>-21.23</td>
</tr>
<tr>
<td>8</td>
<td>11.81</td>
<td>8.98</td>
</tr>
<tr>
<td>11</td>
<td>3.52</td>
<td>-69.78</td>
</tr>
<tr>
<td>9</td>
<td>2.93</td>
<td>-75.38</td>
</tr>
<tr>
<td>13</td>
<td>3.56</td>
<td>-69.4</td>
</tr>
<tr>
<td>10</td>
<td>7.23</td>
<td>-34.53</td>
</tr>
<tr>
<td>2</td>
<td>7.62</td>
<td>-30.83</td>
</tr>
</tbody>
</table>

The calculation of financial NPV (SD.G./feddan) for firewood production from Acacia seyal plantation at a rotation of 15 years and at 12 % discounting rate, the resulted in negative of financial NPV (SD.G./feddan) without current operation thinning shows negative results except compartments (8) shows a positive financial NPV of (8.98) (Table 5.14) The negative NPV indicative that the sum of the present value of annual revenues is less than the sum of the present value of costs. This result could be explained by the the poor producers’ price for firewood, which reflected in low producers’ revenue or due absence of early income from thinning in study area.
Table 5.15 shows reaction of Net Present Value (SD.G/feddan) of firewood production at discounting rate 12%, without thinning for a reduction of rotation to 15 years (compartment 8).

Table 5.15 Effect of reduction in rotation length on NPV SD.G/feddan).

<table>
<thead>
<tr>
<th>Year</th>
<th>Total costs</th>
<th>Total benefits</th>
<th>DFat 12%</th>
<th>PVC at12%</th>
<th>PVB at12%</th>
<th>NPV at12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83.000</td>
<td>0</td>
<td>0.893</td>
<td>74.107</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>29.000</td>
<td>0</td>
<td>0.797</td>
<td>23.119</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3-14</td>
<td>1.170</td>
<td>0</td>
<td>0.712</td>
<td>4.945</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1.170</td>
<td>614.120</td>
<td>0.183</td>
<td>0.214</td>
<td>112.197</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td></td>
<td></td>
<td>103.22</td>
<td>112.2</td>
<td>8.98</td>
</tr>
</tbody>
</table>

Compared to a rotation of 20 years (table 5.4) adoption of shorter rotation of 15 years converted NPV to positive proofing the land use as financial profitable.
CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

• Firewood production from *Acacia seyal* in Wad El Bashier Forest Reserve is not profitable at current practices because of the relatively low wood volume per unit area at harvest, combined with high production cost.

• As wood is offered for sale standing, the study concludes that weeding, opening of fire lines and thinning are the main cost centers of firewood production at the current management system.

• The methods followed by FNC to offer timber at final harvest are theoretically satisfactory but there are several administrative and managerial costs associated with firewood marketing. These are partially responsible for poor marketing of firewood (high sale price/unit).

The current management system of *A. seyal* plantations for the production of firewood is challenged with a number of institutional and marketing constraints that need to be addressed in order for the business to flourish.

6.2 RECOMMENDATIONS

The study recommends that:

• Management of *Acacia seyal* forests needs to adhere strictly to the silvicultural and planning for the production of firewood. Financial profitability depends on the presence of satisfactory stocking density.

• As a land use, management of forest lands for the production of wood products needs to be more competitive. Management of *Acacia seyal* for the efficient production of charcoal to generate added values to local as well as national economies need to be addressed.

• Further study to be conducted to evaluate the non-wood products and services offered by *Acacia seyal* forest ecosystem.
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APPENDICES

Appendix 1. Questionnaire targeting Forest National Corporation

 позволяет الله الرحمن الرحيم
 جامعة الخرطوم
 كلية الغابات

استبيان: الهيئة القومية للغابات

يقوم طالب الدراسات العليا: سليمان يوسف علي، بجمع معلومات عن اقتصاديات انتاج وتسويق حطب
الحريق من غابات الغابات المزروعة، للراجي الأسهام في هذا البحث والإعلاء بالإجابات الصحيحة.

المنطقة/دائرة غابات:

المؤسسة التعليمية:

1. ما هي نوع العمليات التي تمت عند تأسيس غابات الطحل بود البشير؟
   1. ازالة دقل ( )
   2. مساحة ( )
   3. حفظ خطوط تار ( )
   4. انتاج حطب حريق ( )
   5. نموذج فتح ( )
   6. تسويه نزاعات ( )
   7. تحقير الأرض ( )
   8. جمع البذور ( )
   9. شراء البذور ( )
   10. ( )
   11. ( )
   12. ( )

2. ما هي تكاليف العمليات الفلاحية التي تتم عند زراعة الغابة؟
   2.1 تكلفة/ أجرة الأرض؟ ( جن./الدان )
   2.2 كيف تم تحضير الأرض؟ ( جن./الدان )
   2.2.1 كم هو تكلفة تحضير الأرض؟ ( جن./الدان )
   2.3 ماهي مواد التأسيس:
   2.3.1 ماهي مصادر البذور/الشتلل ( الهيئة )
   2.3.2 السوق ( جن./الدان )
   2.4 كم هو سعر البذور/الشتلل؟ ( جن./الدان )
   2.5 ماهي كيفية تحضير الأرض؟ ( كجم )
   2.5.1 كم تم زراعي البذور/الشتلل؟ ( البصل )
   2.5.2 هل تجتمع عملياً التحضير والزراعة مع بعض؟ ( )
   2.5.3 ماتكلفة الأرض المستخدم في تحضير الأرض؟ ( )
   2.5.4 لم ينجب الكمية؟ ( )
   2.5.5 كم هي تكلفة الشتلل؟ ( جن./الدان )
   2.5.6 ما هي تكلفة الشتلل بالبصل؟ ( )
   2.6 هل خضعت لعمليات ازالة حشائش؟ ( )

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2.6.1 كيف يتم إزالة الحشائش؟

2.6.2 في أي عمر يتم إزالة الحشائش؟

2.6.3كم عدد مرات إزالة الحشائش؟

2.6.4 في المتوسط كم تكلفة إزالة الحشائش؟

3 هل هناك أي عمليات شيخ تم داخل غابات الطلح المزرعة؟ نعم ( ) مصليحاً ( ) بالأجرة

3.1 كيف يتم التعاقد لعملية الطلح؟

3.2 في أي عمر يتم عمليات الطلح؟

3.3 كم عدد مرات الطلح؟

3.4 في المتوسط كم تكلفة الطلح؟

القلابة الأولى: 

( ) جنيه/المتر

( ) جنيه/المتر م³(مقطوع)

القلابة الثانية: 

( ) جنيه/المتر

( ) جنيه/المتر م³(مقطوع)

القلابة الثالثة: 

( ) جنيه/المتر

( ) جنيه/المتر م³(مقطوع)

3.5 كيف يتم بيع نتائج انخاب العش؟ 1. وافق ( ) 2. مقطوع ( )

3.6 ما هو متوسط الانتاج من عمليات الطلح (م³/الفد؟

القلابة الأولى ( )

القلابة الثانية ( )

القلابة الثالثة ( )

3.7 ما هو سعر المتر المكعب الناتج من عملية الطلح؟ ( ) جنيه/م³

( )

4 هل تم فتح خطوط النار؟ نعم ( ) لا ( )

4.1 كم طول خطوط نار الغابة؟ ( ) كم

4.2 كم مرة فتح خطوط النار؟ ( ) سنوات ( ) كل 2 سنة ( ) غير محدد

4.3 كم من السنوات يستمر فتح خطوط النار؟ ( )

4.4 كيف يتم عملية فتح خطوط النار؟ ( ) بالعمالة ( ) ألياً ( )

4.5 هل تم فتح خطوط تنفيش؟ نعم ( ) لا ( )

5.1 كم طول خطوط تنفيش الغابة؟ ( ) كم

5.2 كم مرة فتح خطوط التنفيش؟ ( ) سنوات ( ) كل 2 سنة ( ) غير محدد

5.3 كم من السنوات يستمر فتح خطوط التنفيش؟ ( )

5.4 كيف يتم عملية فتح خطوط التنفيش؟ ( ) بالعمالة ( ) مصليحاً ( ) بالأجرة

5.5 كيف يتم التعاقد لعملية الطلح؟ ( ) جنيه/كم

5.6 في المتوسط كم تكلف فتح خطوط التنفيش؟ ( ) جنيه/كم

6 كم طول دورة انتاج حطب الحريق في غابات الطلح المزرعة؟ ( ) سنة
6.1 ما هي الطريقة المتبعه لعرض اخشاب الطلح؟
1. عطاءات ( )  2. مزادر ( )  3. اتفاقيات خاصة ( )  4. أخرى ( )

6.2 ما هي الطريقة المتبعه لبيع انتاج الاختشاب في غابات الطلح المزروعة؟
1. واقف ( )  2. مقطع ( )

6.3 كم تكلفه القطع؟ ( جن/م )

6.4 كممنتج، هل للهيئه سعر ادنى مقبول لبيع انتاج حطب الحريق من شلخ غابات الطلح المزروعة؟
( ) نعم ( ) لا

6.5 كم؟ ( جن/م )

6.6 كممنتج، هل هناك سعر ادنى مقبول لبيع انتاج حطب الحريق من غابات الطلح المزروعة بنهاية الدورة؟
( ) نعم ( ) لا

7 ما هو سعر استخدام حطب حريق الطلح؟ ( جن/م )

8 هل هناك اي دفعات او تكاليف أخرى مفروضة على حطب الحريق؟
1. ضرائب ( )  2. رسوم ادارية ( )  3. ذكاة ( )

9 كم يدفع للنمر المکعب من حطب الحريق الطلح؟
1. ضرائب ( )  2. رسوم ادارية ( )  3. ذكاة ( )

10 ما هي الجهة المستفيدة من هذه التكاليف؟
1. ضرائب:
2. رسوم ادارية:
3. عوائد:
4. ذكاة:
5. أخرى:

11 اين يستهلك معظم انتاج حطب حريق الطلح؟
1. محلي ( )  2. خارجي ( )

12 ما هي الوسيلة التي يتم بها ترحيل الانتاج؟
1. لوري ( )  2. شاحنة ( )

13 ما هي تكلفة ترحيل حطب الحريق محلية؟
1. لوري ( )  2. شاحنة ( )

14 ما هي تكلفة ترحيل حطب الحريق ملحية؟
1. لوري ( )  2. شاحنة ( )
15. ما هي تكلفة ترحيل طلب الحريق خارجية الخرطوم؟
( ) 1. لوفي ( ) 2. شاحنة ( ) 3. بطارح ( ) 4. متر مكعب ( ) 5. أخرى

16. ما هي تكلفة تصرف حطب الحريق؟
( ) 1. لوفي ( ) 2. شاحنة ( ) 3. بطارح ( ) 4. متر مكعب ( ) 5. أخرى

17. كم هو سعر بيع المتر المكعب في الخرطوم؟

18. ما هي مقتراحاتك لتحسين تسويق حطب الحريق؟

19. ما هي القوى العاملة في الاشراف على غابة ودالشير؟
( ) 1. عدد الغرايات/الحراس ( ) 2. عدد الملاحين ( ) 3. عدد خبراء الغابات
( ) 4. متوسط إجمالي المرتب الشهري ( )

20. في المانحة تستحوذ غابة ود البشير من وقت
( ) 1. ملاحظة الغابة؟ ( ) 2. خبير الغابة؟ ( ) 3. مفتش غابات الدائرة/القسم ( )
( ) 4. مساعد المدير لمصادر الغابات ( )

21. هل تدفع الهيئة القومية للغابات ضرائب، زكاة أو رسوم... استمع إلى الجملة ما تجاه توقع وتسويق حطب الحريق؟

( ) 1. ماهي ضريبة ( ) 2. رسوم ( ) 3. أخرى ( )

22. كيف تم مبلغ: الضريبة ( ) 1. الرسوم ( ) 2. أخرى ( )
( ) 3. دخل ( ) 4. مصرف بحري

23. في ركاب ماهي ابسط الاحتفاظ ببعض مراي الحث沸腾 حتى عمر متقدم (22 سنة) في غابة ود البشير؟

( ) 1. ( ) 2. ( ) 3. ( ) 4. ( )
24. أيهما أفضل إدارة غابات الطلح فنيًا لإنتاج حطب الحريق أم إنتاج الفحم النباتي؟

حقق حريق ( )
فحم نباتي ( )

 لماذا؟

1. 
2. 
3. 
4. 

25. في رأيك ما هي المعوقات التي تحد من تسويق إنتاج حطب الحريق من غابات الطلح المزروعة؟

1. 
2. 
3. 
4.
Appendix 2. Questionnaire targeting Trade Union of producers and traders of firewood

بسم الله الرحمن الرحيم
جامعة الخرطوم
كلية الغابات

استبيان: اتحاد منتجي وتجار حطب الحريق

يقوم طالب الدراسات العليا: سليمان يوسف محمد علي، بجمع معلومات عن اقتصاديات انتاج وتسويق حطب الحريق من غابات الطحل المزرعة، الرجاء الإسهام في هذا البحث بالإجابة بالأجابات الصحيحة.

الولاية: 
المدينة: 
الوظيفة/ المهنة: 

أ. الشغل:

1. هل نافست على انتاج عمليات شيخ تمت داخل غابات الطحل المزرعة؟ نعم ( )

( في حالة الإجابة ب: (لا) التوجه للسؤال 8 مباشرة )

2. كيف كانت طريقة تقديم ( ) عطاءات اتفاق مع الهيئة

3. في أي عمر تمت عمليات الشغل؟ ( ) سنة

4. كيف كانت طريقة تقدير كمية الإنتاج?

i. متر 3 وافق قبل القطع ( )

ii. متر 3 مقطع ومرصوص داخل الغابة ( )

5. كيف كانت طريقة المقاولة؟

( ) متر مكعب مقطع ومرصوص داخل الغابة

( ) متر مكعب مقطع ومرصوص على حط النار

( ) متر مكعب مقطع ومرحل الي المستودع

6. شراء الإنتاج في المتوسط كم كلفة شيخ المتر المكعب؟

1. الامام الصغيرة (0-10 سنة) جنح/متر 3

2. الامام الكبيرة (10 سنة) جنح/متر 3

7. ما هو سعر المتر المكعب الناتج من عملية الشغل؟ جنح/متر 3

b. الإنتاج النهائي:

8. ما هي الطريقة المتبعة لبيع الإنتاج النهائي من احشاب غابات الطحل المزروعة؟

( ) وافق ( ) مقطع

9. كيف كانت طريقة التقدم لشراء الإنتاج؟ ( ) عطاءات ( ) اتفاق مع الهيئة
10. ما هو سعر آخر عطاء لحطب حريق الطحلب؟ ( ) جنيه/م³

11. كم تكلفة الفعل للملت المكعب؟ ( ) جنيه/م³

12. كم تكلفة الرص والتنزيل للملت المكعب؟ ( ) جنيه/م³

13. كتعذر حطب، هل هناك سعر أعلى مقبول لديك لشراء المنتج النهائي حطب الحريق من غابات الطحلب مثلها في 2010؟ نعم ( ) لا ( )

14. كم للمتل المكعب؟ ( ) جنيه/م³

15. ما هي أنواع الدفعات أو التكاليف الأخرى على حطب الحريق؟

2. ضرائب ( ) رسوم إدارية ( ) عوائد ( ) أخرى ( ).

16. كم يدفع للمتل المكعب من حطب الحريق الطحلب؟

2. ضرائب ( ) رسوم إدارية ( ) عوائد ( ) بأخرى ( ).

ما هي الجهة المستفيدة من هذه التكاليف؟

6. ضرائب:

7. رسوم إدارية:

8. عوائد:

9. أخرى:

18. بتن يستنكل انتاج حطب حريق الطحلب؟

2. محلي ( ) خارجي ( )

ما هي الوسيلة التي يتم بها ترحيل المنتج؟

1. لوسي ( ) شاحنة ( ) بئان ( )

ما هي تكلفة شحن حطب الحريق؟

1. لوسي ( ) شاحنة ( ) بئان ( )

ما هي تكلفة ترحيل حطب الحريق محلية؟

1. لوسي ( ) شاحنة ( ) بئان ( )

ما هي تكلفة بئان الحريق خارجيا، الخرطوم؟

1. لوسي ( ) شاحنة ( ) بئان ( )

ما هي تكلفة تفرغ حطب الحريق؟

1. لوسي ( ) شاحنة ( ) بئان ( )

كم هو سعر بيع المتل المكعب في الخرطوم؟

24. في مرايا ما هي المعرفة التي تحدد من تسويق انتاج حطب الحريق من غابات الطحلب؟
٢٦. ما هي مقترحاتك لتحسين تسويق حطب الحريق؟

٢٧. في رأيك ما هي اسباب الاحتفاظ ببعض مرابع الطلح حتى عمر متقدم (١٠) سنة في غابة ود البشیر؟

٢٨. ايهما افضل ادارة غابات الطلح فنبا لانتاج حطب الحريق ام انتاج الفحم النباتي؟

٢٩. لماذا؟
Appendix 3. Questionnaire targeting banks

بسم الله الرحمن الرحيم
جامعة الخرطوم
كلية الغابات

استبيان: المصارف

يقوم طالب الدراسات العليا: سليمان يوسف محمد علي، بجمع معلومات عن اقتصادية إنتاج وتسويق حطب
الحريق من غابات الطلخ المزروعة. الرجاء الإسهام في هذا البحث بالأدلة بالاجابات المناسبة.

المدينة:
المحقق/المهنة:

1. هل يقدم بنك …… تمويل الانتاج الزراعي بشكل عام؟
   ( ) نعم ( ) لا

2. ما هي صيغ التمويل الأكثر استخداما لتمويل الانتاج الزراعي؟
   1. ( ) 2. ( ) 3. ( )

3. هل هناك أي تجربة تمويل من بنك …… لمشروعات:
   1. ( ) 2. ( ) 3. ( )

4. في حالة الإجابة نعم: كم متوسط هامش الأرباح/السنة؟
   ( )

5. في حالة الإجابة لا: ما هي الأسباب؟
   1. ( ) 2. ( ) 3. ( ) 4. ( )

6. حتى تتمكن من المنافسة على تمويل من بنك …… لمشروعات التشجير والوقود المطلوب مؤسياً؟
   i. ( ) ii. ( ) iii. ( ) iv. ( )
7. ما هي العوامل التي بموجبها يتم منح التمويل من البنك؟

1. طول فتره المشروع
2. معدل المخاطرة
3. طول فترة السماح

متوسط هامش الأرباح/السنة
General plate 1: Artificial plantation of Wad El Basheir Natural Forest Reserve (Photographer: Suliman Yusif, 2009).
General plate 2: Natural plantation of Wad El Basheir Natural Forest Reserve (Photographer: Suliman Yusif, 2009).
Seeds of *Acacia seyal Var. seyal*