CARBON STORAGE POTENTIAL OF TREES OUTSIDE FORESTS UNDER PRIVATE AND COMMUNAL TENURE REGIMES IN NG'IRESI VILLAGE, ARUMERU DISTRICT TANZANIA

BY

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ABSTRACT

Though people are getting benefits by favour of ToF in form of lumber, firewood, fruits honey and such products, little has been documented on their potential in timber supply, carbon sequestration and storage. This study was carried out to determine carbon storage potential of Trees outside Forests (ToF) that fall on private and communal tenure regimes in Ng'iresi village, Arumeru district, Tanzania. The village was stratified into 5 main strata; trees around homesteads, agroforestry, woodlots, natural springs, and trees growing in line plantings (along borders of farm blocks, village roads and "Songota" river and its tributary known as "Maridadi"). Trees were measured for diameter at breast height (dbh) and total height for the computation of stand parameters. In addition trees basic densities were obtained through laboratory analysis of the tree cores taken at dbh point. Data on ToF establishment costs (site preparation and planting costs), management costs and revenue accrued from sale of tree products was established based on market prices. The results show that ToF occupied 56% of total area of village land (326 ha). Student's t-test revealed that ToF under communal tenure regime stored significantly higher amount of carbon (p= 4.35E-08) averaged at 40.35 tC/ha than for private tenure regime estimated at 8.16 tC/ha. The stock parameters of communal tenure regime are higher than for private tenure regime presumably due to type of management in the former which favours less harvesting of trees so as to conserve the natural springs. ToF under communal tenure regime have shown higher and positive land expectation value due to presence of springs which are conserved. It is worth investing on communal ToF land (especially around natural springs/water sheds) so as to get extra benefits including carbon storage benefits.

DECLARATION

I, Chamalindi Bugingo, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has never been submitted nor concurrently being submitted for a higher degree award in any other University.

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DEDICATION

To my late father Mr. Deogratius Bugingo Muriga and my mother Mrs Francisca Bugingo Muriga who lost their ample time as well as little reasonable resources but gained credit on shaping me in the world of elites. May the almighty God bless them incessantly.

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LIST OF ABBREVIATION AND SYMBOL

AGB	Above ground biomass
ARRCO	Arusha Region Regional Commissioners Office
BA	Basal area
BAF	Basal area factor
BGB	Below ground biomass
BLV	Bare land value
C	Carbon
CBD	Climate Change and Biodiversity synergies
Cm	Centimetre
CO_2	Carbon dioxide
Dbh	Diameter at breast height

DOM	Dead organic matter
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resource Assessment
G	Basal area per hectare
GHG	Green House Gases
GPS	Geographical Positioning System
IPCC	Intergovernmental Panel on Climate Change
ITTO	International Tropical Timber Organization
LEV	Land Expectation Value
LIS	Line Intersect Sampling
m.a.s.l	Metre above sea level
MAI	Mean Annual Increment
Mg	Mega gram
N	Number of stems per hectare
NAFORMA	National Forestry Monitoring and Assessment
NFV	Net Future Value
NTR	Net Timber Revenue
PMO	Prime Minister’s Office
RALG	Regional Administration and Local Governments
SBSTA	Subsidiary Body for Scientific and Technological Advice
SEV	Soil Expectation Value
SUATF	Sokoine University of Agriculture Training Forest –Olmotonyi
tC	Tone of Carbon
TM	Thermatic mapper
ToF	Trees outside Forests
UNEP	United Nations Environmental Programme

UNFCCC	United Nations Framework Convention for Climate Change
URT	United Republic of Tanzania
V	Volume per hectare

CHAPTER ONE

INTRODUCTION

1.1 Background Information

In order for one to undertake a Trees outside Forests (ToF) inventory, definitions of tree, TOF and forest must be succinctly and objectively defined. The definitions selected will determine whether trees are outside or in forest land and should or should not be included in the inventory (Lund, 1999). The following definitions of various concepts are worth put forward, as far as this study is concerned.

Trees" include palms, bamboos, canes, shrubs, bushes, plants, poles, climbers, seedlings, saplings, and the re-growth thereof, all ages and all kinds and any part (URT, 1998; 2002), that are able to reach a height of 2- 5 m at maturity." According to FAO (2001a), a tree is defined as woody perennial with a single main stem, or in the case of coppice with several stems, having a more or less definite crown. It includes: bamboos, palms and other plants meeting the above criterion.

ToF are defined as trees on land not defined as forest and other wooded land (FAO, 1998; 2010). Based on this definition, ToF would comprise: (i) trees on land that fulfil the requirements of forest and other wooded land except that the area is less than 0.5 ha ; (ii) trees able to reach a height of at least 5 m at maturity *in situ* where the stocking level is below 5 percent; (iii) trees not able to reach a height of 5 m at maturity *in situ* where the stocking level is below 20 percent ; (iv) trees on boundaries, scattered trees and woodlots less than 0.5 ha. (v) permanent tree crops such as fruit trees and coconuts; (vi) trees in shelterbelts and riparian buffers of less than 20 m wide and area of 0.5 ha (FAO, 1998).

A forest is an area of land with at least 10% tree crown cover, naturally grown or planted and or 50 % or more shrub and tree regeneration cover and includes all forest reserves of whatever kind declared or gazetted and all plantations (URT, 2002). However, this definition found in Tanzania forest act does not provide both area and height of trees constituting a forest. UNFCCC (2001) defines "Forest as a minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 per cent with trees having the potential to reach a minimum height of 2-5 metres at maturity in situ.

The UNFCC definition of a forest is a baseline that nations, organizations and projects could coin their forest definitions. UNEP/CBD (2001) and FAO (2006) define forest as a land area of more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*). The term forest excludes tree stands urban parks, gardens and agricultural production systems, for example fruit plantations and agro-forestry systems (FAO, 2007). A new definition of forest has been proposed for Tanzania. 'Forest' means an area of land with at least 0.05 hectares, with a minimum tree crown cover of 10% or with existing tree species planted or natural having the potential of attaining more than 10% crown cover, and with trees which have the potential or have reached a minimum height of 2.0 meters at maturity in situ (URT, 2011).

FAO (1998) defines other woodlands to include shrub cover and forest fallow. Shrubs are "woody perennial plants, generally of more than 0.5 m and less than 5 m in height on maturity and without a definite crown. This definition thus embraces all low-growing woody formations.

Globally, total forest area in 2010 is estimated to be just over 4 billion hectares, corresponding to an average of 0.6 ha of forest per capita (FAO, 2010). The total area of other wooded land is estimated to be at least 1.1 billion hectares, equivalent to 9 percent of the total land area (ibid). According to FRA 2010, the forest area in Africa was estimated close to 675 million ha. This accounts for about 17% of global forest area and 23% of the total land area in the region (FAO, 2010).

The total area of land covered by forests in Tanzania is estimated at 35.3 million ha, of which 18.3 million ha is gazetted as forest reserves, 0.96 million ha is proposed forest reserves and 16.04 million ha is unreserved forest (URT, 2008). By 2007, Arumeru district had an estimated forest reserved area of 16 638.40 ha. This makes 18% of the region's total forest area of 92 336 ha (URT-PMO, 2008). A recent study on TOF has revealed their distribution at a global scale that about 46% of the agricultural land in the world (more than 1 billion ha) has tree cover of more than 10% (Zomer *et al.*, 2009). The total area of other wooded land with tree cover was estimated at 79 million ha, but is undoubtedly much higher as information availability was limited (FAO, 2010).

TOF may occur in state tenure regime (ITTO,2009), private tenure regime (Kleinn, 2001;FAO,2009), communal tenure regime (Eboh, 1999; Lund, 1999; Nair and Tieguhong, 2004; Akinnifesi *et al.,* 2006) and open access tenure regime when communal tenure break due to weakened forces of collective control and intensifying competition by individual community members (Eboh,1999). However, Lund (1999) argues that ToF are often found on private lands or communal lands and they may be grouped into two main classes, those that are part of the human environment (farms, urban areas) and those that are found in a natural setting (savannas, shrublands etc.).

Kleinn *et al.,* (2001) stresses that most of the ToF land which is under human management is under private ownership of smallholders**.**

During the 1980s and 1990s, ToF, began to be viewed in terms of their contribution to the environment. It is becoming increasingly clear that the future of trees in Africa is on farmland and other areas outside forests (FAO, 1999). It has been reported that the number of trees on farms is increasing (FAO, 2005) while forests are still being severely degraded. Interestingly, there is evidence that the increase in on-farm tree numbers occurs in areas where population densities are high and farm size is very small (Leakey, 2010). From a local perspective, there may be more interest in maintaining and improving ToF than forest lands especially if the improvement will benefit the farmers and the local community (Lund, 1999). As carbon storage potential of ToF will be known and mechanisms set at hand, tree owners can enjoy the carbon benefits at a global market.

1.2 Problem Statement and Justification

Tenure changes and increased pressure on forest resources, has resulted into establishment of ToF (Lund, 1999). Though people are getting benefits by favour of ToF in form of lumber, firewood, fruits honey and such products, little has been documented on their potential in timber supply, carbon sequestration and storage. It is believed that ToF contain more total wood biomass (Holmgren *et al.,* 1994), hence large carbon stocks (van Noordwijk *et al.,* 2009), because more land is involved (Holmgren *et al.,* 1994). Conversely, this could be proved by a concomitant assessment of carbon storage potential for both Trees inside Forests and ToF in a particular region. However, in most countries, this is not the case as ToF are poorly reported in most of official national statistics used to support national decision-making and policy.

Generally, the basic information such as location, number, species, spatial organization, biomass, growth and production is often lacking. ToF are thus most often ignored in land-use planning and development policies (FAO, 2010).

Ever since attention had increased overtime on carbon trading and mitigating climate change, an enormous need on good accounts of all possible carbon sources and sinks is of no dodging. This study focused on carbon storage potential for ToF, not only because it was a forgotten treasure to be accounted on its carbon storage and other uses but also due to what Holmgren *et al.* (1994) asserted ToF as the ones most likely to be used by local farmers and villagers. It was thus found very imperative, to study on ToF whose benefits and costs are reflected in the daily life of most people in rural scenery.

This research work was anticipated to focus on ToF found under private and communal tenure regimes which are solely found in the study village. Karmann and Lorbach (1996) reveal that different tenure regimes have different impact on tree, tree products and natural resource management. In this particular case, carbon storage potential in the study village might be influenced by management of each tenure regime. The carbon stored in ToF might serve both as an added value to land on which ToF are growing and an incentive to local people who would get income through selling carbon. They will thus get motivation to plant more ToF. Understanding carbon stock of ToF under private and communal tenure regimes would bring awareness and enlighten both policy and decision makers on incorporating the ToF carbon values in development land use planning.

1.3 Objectives and Hypotheses

1.3.1 General objective

The main objective of this study was to assess carbon storage potential of Trees Outside Forests under private and communal tenure regimes in Ng'iresi village landscape in Arumeru district.

1.3.2 Specific objectives

i. To identify and determine areas of land occupied with ToF under private and communal tenure regimes in the study village.
ii. To identify the species composition of ToF under private and communal tenure regimes in the study village.
iii. To estimate stocking of the ToF under private and communal tenure regimes in the study village.
iv. To compare stocks of ToF under private and communal tenure regimes in the study village.
v. To determine the value of land added by carbon stored in ToF under private and communal tenure regimes

1.3.3 Hypotheses

The first null hypothesis: There is no significant difference in carbon storage potential of ToF between private and communal tenure regimes in the study village.

The second null hypothesis: The variation in carbon storage potential coming from communal and private tenure regimes is the same.

1.4 Conceptual Framework

ToF fall under different tenure regimes. This study features private and communal tenure regimes. Among other characteristics, and like their counterparts in the forests, ToF are concerned with carbon capture and storage. Hairiah *et al.* (2001) argue that farmers deal with the reality of aboveground biomass. In this study, only the above ground carbon stock of ToF was quantified. It is believed that carbon storage potential differs in the two tenure regimes as management of trees in both regimes might be different. It is argued that, once carbon is quantified and farmers get income through carbon sale, consequently the value of the land harbouring ToF will increase. This study gives a concept that stakeholders and especially farmers would be paid for storing carbon in their trees. Another concept rests to the basis of all stakeholders involved in carbon management being liable to pay for releasing carbon from any pool or source concerned. It is hypothesized that carbon stored in ToF would increase the value of land on which they grow. Fig.1 shows the conceptual framework of this study.

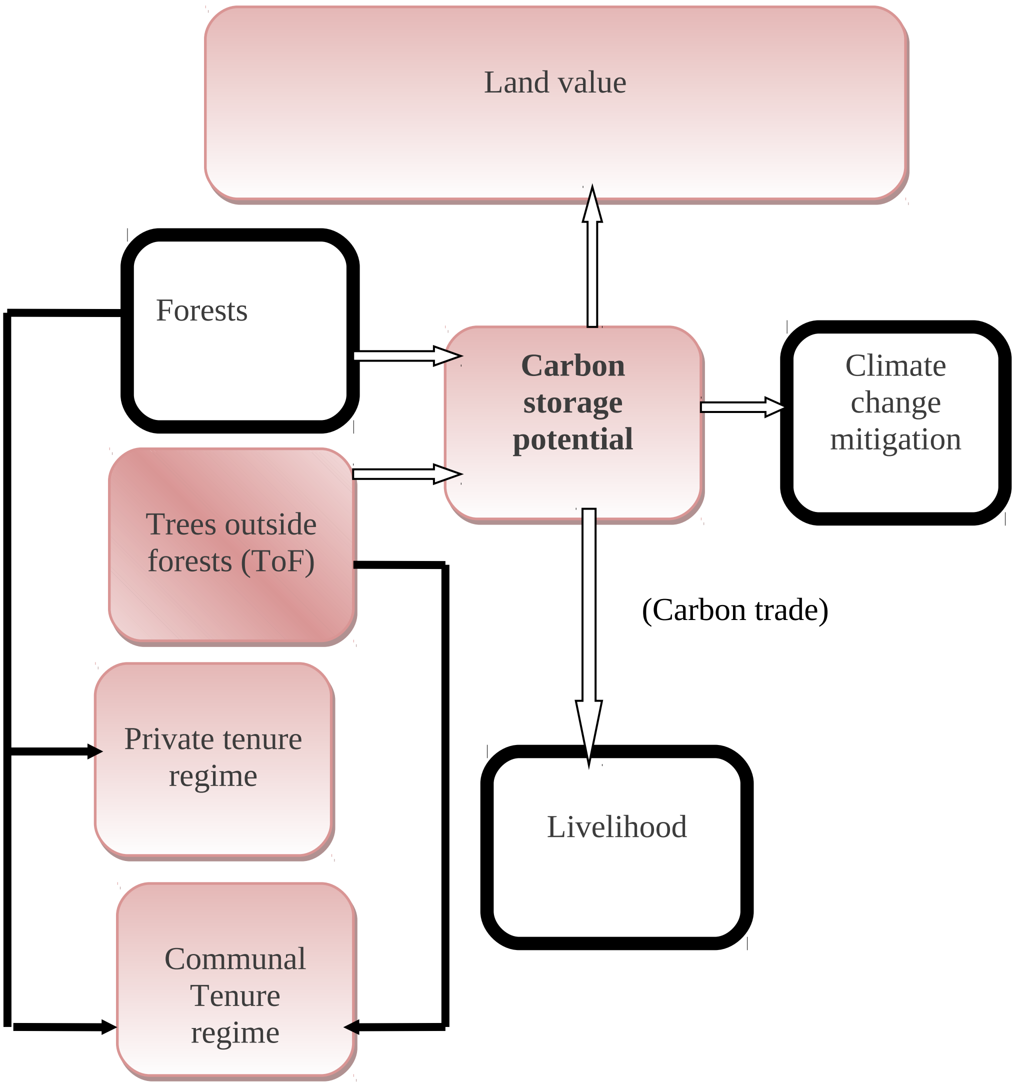

Figure 1: Conceptual framework.

CHAPTER TWO

LITERATURE REVIEW

2.1 Trees Outside Forests (ToF)

According to Alexandre *et al.* (1999), ToF may be productive; such as orchards, and trees in fields and other agroforestry systems, or protective; such as trees with an ecological or landscaping function. ToF may be ornamental; such as trees around houses, and in parks and towns (FAO, 1998; Alexandre *et al.*, 1999). In spatial terms, they may be scattered discontinuously on farmland and pasture, or growing continuously in line-plantings along roads, canals and watercourses, around lakes, or in small aggregates with a spatial continuum such as clumps of trees, sacred woods, and urban parks (FAO, 1998; Alexandre *et al.*, 1999 and Kleinn, 1999).

The terms agroforestry and ToF may in some cases be used by scholars as if they are synonymous. According to Asamoah-Boateng (2003) ToF is different from agroforestry. The later is the intentional growing of trees and shrubs in combination with crops or forage, which may or may not include animals. In agroforestry, spacing of trees and crops are systematic. Agroforestry is always man made. ToF on the other hand can be manmade or natural. Additionally agroforestry has little diversity while diversity of ToF especially *in natural setting can be high. It follows that all agroforesry trees qualify as* ToF but not all ToF are agroforestry. Also in defining ToF, land use should be taken into consideration.

2.1.1 ToF species composition

Literature on species composition of ToF under different tenure regimes elsewhere in the world is scant due to fewer studies made for ToF compared to forests (FAO, 2010). Some studies report the following species composition of ToF. A study by Pandey (2002) on ToF under private tenure regime, in the Haryana state, India reveals TOF composed of Eucalyptus spp, *Acacia nilotica*, *Prosopis* spp and *Dalbergia sissoo* in their decreasing order of abundance respectively. In Nakuru and Nyandarua districts in Kenya, Njuguna *et al.*, (1998) report ToF in farms composed of several species dominated by *Eucalyptus spp*, *Cupressus lustanica*, *Tarchonathus camphorates, Citrus sinensis, Acacia mearnsii, megalocarpus, Prunus domestica, Dovyalis Caffra, Grevillea robusta* and *Citrus limon.* On his study in Sudani, Glen (2002) in Sudani reported ToF to compose mainly *Acacia balanites*, *Combretum spp* and *Terminalia spp.*

2.1.2 ToF and tenure

Tenure systems define who owns and who can use what resources for how long, and under what conditions. Customary tenure systems are determined at the local level and are often based on oral agreements. Statutory tenure systems are applied by governments and are codified in state law. Public lands administered by government typically include all forests in the legal forest estate that are owned and administered exclusively by the government and that are not designated for use by communities or indigenous peoples. Public lands designated for use by communities and indigenous peoples are lands set aside on a semi-permanent but conditional basis. Private lands owned by communities or indigenous people refer to forest lands where rights cannot be unilaterally terminated by a government without some form of due process and compensation (ITTO, 2009). Moreover, tenure security is crucial for carbon sequestration projects. Tenure insecurity may affect carbon sequestration projects in three different ways. Inability of suppliers to make credible commitments to supply carbon offsets is a good example (Gutman, 2003). Also more powerful people may confiscate land occupied by poor people. It is likely the poor may not receive benefits from carbon sales (Kerr *et al*., 2006).

The legal basis for land tenure in Tanzania is derived from two basic laws. Both laws, the Land Act and Village Land Act state that all land in Tanzania is public land and the president holds in trust for all citizens. The president delegates the power to designate, adjudicate and modify land tenure status to the Commissioner for Lands (Akida and Blomley, 2007).

According to Karman and Lorbach (1996) different tenure regimes have different impact on tree, tree products and natural resource management. The type of tenure regime affects inventory/assessment of ToF. ToF under private ownership offer poor physical access due to presence of multitude of tree owners to deal with in the inventory than for ToF under communal tenure regime (Lund, 1999).

2.1.2 ToF inventory/assessment

The terms assessment and inventory are used interchangeably in most of the projects reviewed. A clear distinction between the two might be made. Kleinn (2000) describes the inventory as the process of quantitative and qualitative identification of a resource, where as assessment consists of situating the data thus obtained and attributing values to the specific resource. Lund (1998) stresses that once an object is assessed we can begin to estimate or weigh its significance, importance and value.

Bellefontaine *et al.* (2002) states that, as for ground measurements, sampling arrangements designed for forests are not really suitable for the territorial distribution of ToF.

Forest resource assessment is even more crucial for ToF, which are complex for their spatial distribution, highly diversified in terms of use and function, and highly sensitive to interaction with people (Bellefontaine *et al.*, 2002). While these characteristics indicate what a rich and complex resource this is, they also show how very hard it is to establish a qualitative and quantitative assessment on it. An essential first step in assessing trees ToF is to address their peculiarities. A review of existing or needed tools and methods is the first requirement. A classification which can lead to authentic integrated land management at the country level is essential, and the next step is to make a clear distinction between aspects of land cover and aspects of land use, a frequent stumbling-block in such exercises (Bellefontaine *et al.*, 2002).

The tools and methods of ToF assessment are neither specific nor new, what is more original is the way they are combined and implemented. The fundamental thing in this process is to combine two approaches: biophysical analysis and socioeconomic analysis. Large-scale aerial photographs are good for describing the spatial distribution of ToF formations. Satellite data are a little harder to use for mapping this resource, which tends to be spread over a wide area (Bellefontaine *et al., 2002*). Kleinn (1999) points out the following major difficulties in assessing ToF. The problems of definition and classification, distinction between land use and land cover, data sources, “planar geometry” of the resource, presentation in maps, models, omnipresence, and who shall do it.

Inventory on ToF had been conducted through conventional forest inventory methods. Other ToF inventories have based upon estimates from small surveys and interviews but the reliability of such results is uncertain (Rawat *et al*., 2002). In Kenya, Legiliso-Kiyapi (2002), undertook inventory of ToF involving aerial photos and ground survey and revealed that aerial photos are useful at the stage of defining the sample, but are not reliable for estimating ToF biomass. Assessment methodologies which combine remote sensing techniques with ground verification offer good results (ibid), though the assessment should draw much more on participatory methodologies (Legiliso-Kiyapi, 2002; Yossi and Malé, 2002). Glen (2002) based on the Sudan experience, suggested that satellite imagery without good ground verification can produce misleading results.

On their study on ToF in Philippines, Sales *et al.* (2005) found that biomass and carbon density values are found to vary with age, type of species, site conditions and silvicultural treatments applied in the stand. The carbon density value of the farm ranged from 0.98 to 63.94 MgC/ha. Giri (2004) argued that ToF assessment can be better done while we use both ground base tree measurements as well as remote sensing tools. Line Intersect Sampling (LIS) method and Landsat TM Satellite image classification with maximum likelihood algorithm were used for field measurements and spatial distribution of ToF in Yombo and Chasimba villages of Tanzania. According to this scholar, ToF in the study area contained mean volume 50 m^3/ha.

Sangeda *et al.* (2001) conducted a study on ToF in Nkweshoo village in Moshi but focused on determination of suitable shape and plot size for estimation of ToF. Their study revealed that plots measuring 20 x 250 m are statistically most suitable for estimation of parameters in ToF of Machame, Moshi-Tanzania and other areas with similar conditions. Tanzania is currently implementing its National Forest Monitoring and Assessment (NAFORMA). The programme aims to take stock of all tree resources including ToF. Due to the large scale nature of NAFORMA however, it is unlikely the results will be useful at project level (Malimbwi, R.E. personal communication, 2009).

2.2 Carbon Capture, Storage and Emission

Carbon pools are components of the ecosystem that can either accumulate or release carbon and have classically been split into five main categories: living above-ground biomass (AGB), living below-ground biomass (BGB), dead organic matter (DOM) in wood, DOM in litter and soil organic matter (SOM) (Brown, 2002; MacDicken, 1997; Ogle *et al*., 2005; IPCC, 2006; Lui and Hani, 2009). According to Brown (2002), a carbon source is a carbon pool from which more carbon flows out than flows in: forests can often represent a net source (rather than sink) of carbon due to the processes of decay, combustion and respiration. A carbon sink is a carbon pool from which more carbon flows in than out: forests can act as sink through the process of tree growth and resultant biological carbon sequestration (Brown, 2002). According to Rohit (2006), Carbon sequestration is the process of removing excess carbon dioxide (CO_2) from the atmosphere (3.67 ton of CO_2 = 1 ton of sequestered carbon). Claasen and Molehart (2009) asserted that carbon sequestration potential is the amount of carbon that could be sequestered (held) within farmland in response to financial incentives generated by a GHG offset market. In the broadest sense, carbon sequestration potential can be estimated as the total number of farmland hectares where emission reduction practices could be applied, multiplied by an estimate of the amount of carbon sequestration per hectare (Claasen and Molehart, 2009). Renting carbon in forests assumes that landowners have the property right for the carbon stored on their land and that they are able to sell the annual rental equivalent of holding the carbon out of the atmosphere for each year they store it. When landowners harvest their forests some dead wood remains on the site and is assumed to decompose immediately. The remaining wood is assumed to move into either saw timber or pulpwood (Sohngen and Brown, 2006).

Additionally, since ToF are revealed to be potential in storing carbon, incentives to carbon storage could result into lengthened rotational periods (Sohngen and Mendelsohn, 2003). However, leaving trees (Forests and ToF) unmanaged and building up large carbon stores in tree biomass could pave way to risk of catastrophic events such as fire, strong winds and even insect outbreaks that might cause large CO_2 emissions (Kurz *et al.*, 2008). Carbon is present in different natural systems in the environment including oceans, fossil fuel deposits, the terrestrial system and atmosphere (Jana *et al.*, 2008). The greatest proportion of global carbon is in the ocean that contain 39 out of the 48 Tera ton (Tt) of Carbon (1 tera ton = 10^{12} ton = 10^{18} gram). Fossil is the next largest stock of carbon that accounts for only 6 Tt. According to Loutfy and Juhany (2009), Forests at present a significant global carbon stock. Global forest vegetation stores 283 Gt (gigatons = a billion metric ton) of carbon in its biomass, 38 Gt in dead wood and 317 Gt in soils (top 30 cm) and litter. The total carbon content of forest ecosystems has been estimated at 638 Gt for 2005, which is more than the amount of carbon in the entire atmosphere.

However most of the anthropogenic activities impact on terrestrial ecosystems. A major proportion of the carbon and nutrients in terrestrial ecosystems is found in the tree component (Jana *et al.*, 2009). Carbon is extracted from the atmosphere (carbon sequestration) in form of carbon dioxide through the process of photosynthesis and stored as biomass in different parts of the trees (in terrestrial ecosystems) for a very long period of time (Hairiah *et al.*, 2001; Jana *et al.*, 2008; 2009). Once trees die, the biomass becomes a part of the food chain and enters the soil as soil carbon. If the biomass is burnt up, the carbon is re-emitted into the atmosphere as Carbon dioxide and is free to move in the carbon cycle (Jana *et al.*, 2008).

At final felling a major part of the biomass is taken out of the forest. The harvested stem wood is converted into forest products from pulpwood and sawn timber (Backéus *et al.,* 2005). Forest products have two major climate benefits. Firstly, carbon is stored outside the forest. The longer the lifetime of a forest product the longer the carbon is kept out of the atmosphere. Secondly, forest products can replace more energy-demanding materials like cement, steel and plastics made from fossil oil. After the lifetime of the products, wood can be recycled, burned for energy or placed in landfills (Backéus *et al.,* 2005). Olsson *et al.,* (2005) asserted that application of fertilizer in forestland is usually a cost-effective way to increase trees production, which eventually increases carbon sequestration/storage in both above and below ground biomass.

According to FAO (2010), the world's forests contain 600 Gt of biomass (above-ground and below-ground) and about 67 Gt of dead wood. The decrease in total biomass stock is mainly a result of the loss of forest area. Again, the world's forests store more than 650 billion ton of carbon (tC), 4% in the biomass, 11% in dead wood and litter, and 45% in the soil. Globally carbon stocks are decreasing as a result of the loss of forest area; however the carbon stock per hectare has remained almost constant for the period of 1990s to 2010s. According to these estimates, the World's forest is therefore a net source of emissions due to the decrease in total forest area. Trees on agricultural landscapes represent a globally important carbon stock (Zomer *et al.*, 2009). Management of trees in agro-ecosystems such as ToF can mitigate green house gas (GHG) emissions under the Kyoto Protocol (Pandey, 2002a). ToF also act as reservoirs and potential sources of carbon. According to the Intergovernmental Panel on Climate Change (IPCC), carbon fixation from reduced deforestation, forest regeneration, and intensified planting and agroforestry practices would amount to the equivalent of 12-15% of CO_2 emissions from fossil fuels from 1995-2050 (FAO, 2001b).

2.3 Estimation of Aboveground Biomass

The accurate estimation of tree biomass is crucial particularly for the global carbon cycle. The estimation of the total above-ground biomass (AGB) with accuracy sufficient to establish the increments or decrements in carbon stored in the trees is increasingly important (Hofstad, 2005; Basuki *et al.*, 2009). The use of local allometric equations for estimating tree stocking, for areas with similar geographical and vegetation type is recommended in the literature (Brown, 2003; IPCC, 2003). To reduce the need for destructive sampling, biomass can be estimated from an easily measured property such as stem (dbh), and the use of allometric equations (Hairiah *et al.,* 2001; Timothy *et al.,* 2007). However, the estimation of tree biomass by combination of dbh and height as independent variables is often superior to dbh alone (Timothy *et al.*, 2007).

2.4 Sampling Design, Shape and Size of Sample Plots

MacDicken (1997) asserts that for carbon inventory purposes, stratified random sampling yields more precise estimates than simple random sampling and systematic sampling. Most commonly, the sample plots may be laid in form of circular, square, rectangle and strip shapes (Malimbwi and Mgeni, 1990; Philip, 1994). When large plots are desired, it is suggested to use rectangular plots as it might not be easy to demarcate large circular plots. The circular plots are recommended for use only when small plots are desired (Malimbwi and Mgeni, 1990). Size and shape are the two general characteristics of sampling units. Effectiveness in representing variation is achieved by large sampling units although they are more expensive to identify and measure than the small units. The choice of sampling units depends on size and shape of sample plots, easy of boundary definition, effectiveness of the unit in representing the variation in the population, the convenience and costs. In contrast for a given sampling fraction a larger number of smaller units will provide a more precise estimate than fewer larger units (Philip, 1994).

2.5 Land Expectation Value (LEV) Calculation

LEV calculates the value of bare land in perpetual timber production and is useful to value both even aged tree stands and uneven-aged tree stands that are cut periodically (Straka and Bullad, 2006). The LEV criterion is also called “Soil Expectation Value (SEV)” and “Bare Land Value (BLV)”, because many applications assume the cashflow stream begins with bare land (Ibid).

2.5.1 LEV calculation for mature even aged and premature even aged stands

i. LEV calculation for even aged management

Nyvold *et al*., (2005) gave a formula for estimating LEV of even aged management:

LEV $= NPV[\frac{(1+i)^t}{((1+i)^t-1)}]$

Where: NPV =Net present value given by formula:

NPV $= \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t}$

Where: B_t = benefit in year t,

C_t = Cost in year t,

r = Discount rate,

n = Number of years specific tree species are expected to store carbon

Straka and Bullad (2006) come out with another formula for estimating LEV for even aged management as:

$$\text{LEV} = \frac{NFV}{(1+i)^t - 1}$$

Where: LEV =Land expectation value,

NFV =Net future value of one timber rotation,

$$\text{NFV} = (\sum_{t=1}^{n} B_t - C_t) * ((1+i)^t)$$

t = Length of timber rotation,

i = Interest rate expressed as a decimal

ii. LEV calculation for pre-mature even aged stands

A method using LEV, can clearly establish the value of immature timber. The value of immature timber stand is calculated based on the following formula.

$$V_m = \frac{NV_t + LEV}{(1+i)^{t-m}} - LEV \quad \text{(Straka and Bullad, 2006).}$$

Where: V_m = Value of m-aged timber stand,

m = Age of the immature stand,

NV_t = Net value of the income and costs associated with the immature stand between year m and rotation age t.

With this formula LEV is subtracted to obtain V_m because, with LEV included we have the value of land and timber. When we subtract LEV we have the value of immature stand of timber only.

2.5.2 Valuing uneven-aged tree stand using LEV criterion

Uneven aged tree stands contain trees of various ages. Usually "mature" trees are selectively harvested on a cycle of some sort. The tract may be harvested annually, removing a small timber volume each year off each hectare; or, perhaps, timber volume is removed every years. In this case, the value of the land and timber must be estimated concurrently and cannot be separated. Unless all the trees are cut, bare land never exists under uneven-aged management. In effect, discounted cash flow is used to value a perpetual timber production factory. The simplest case is when an annual income stream is produced. This is a perpetual annual annuity situation. The standard equation is given as:

LEV = a/i (Straka and Bullad, 2006).

Where: a = Net annual income generated,

i =Interest rate, expressed as a decimal

The other situation takes place when net timber revenue occurs on a periodic basis, for example every other year or every 5 years. The standard LEV calculation is appropriate in this case. Note that annual management and property tax costs are subtracted from net timber revenue using the future value of a terminating annuity formula. LEV is calculated as:

$$LEV = \frac{NTR - [a \times (1+i)^c] - 1}{(1+i)^c - 1}$$ (Straka and Bullad, 2006).

Where: LEV =Land expectation value,

NTR =Net timber revenue received every c years,

a =Annual management and property tax costs,

c =Number of years in a cutting cycle,

i =interest rate expressed as a decimal

2.5.3 Financial compensation value of tree land owners

According to Huan and Kronrad (2001), it is not known who would or would not practice intensive forest management prior to being given financial compensation. For landowners who already intensively manage their forest land, their financial loss due to changing timber harvest schedules to maximize carbon sequestration is calculated by subtracting the SEV with carbon management maximizing Mean annual Increment (MAI) from the SEV and without carbon management maximizing SEV(ibid). The difference between SEVs is termed the ‘financial compensation value’ for landowners who are maximizing SEV and are willing to participate in a program of carbon maximization management. For landowners who have unstocked land, this value is used as the economic incentive to motivate landowners to convert unstocked lands into managed forest lands for the purpose of carbon sequestration (Huang and Kronrad, 2001).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area Description

3.1.1 Location of the study site

The study was conducted in Ng'iresi village in Arumeru District in Arusha, Tanzania. It is located about 6.5 km east of Arusha Town. The village is found at the windward side of mount Meru 4 562 m.a.s.l) at an approximate grid reference $36^0$42'50''E; $31^0$9'36''S and $30^0$20'S; $36^0$45'00''E (Fernandes *et al.,* 1984). The village borders Mount Meru Forest to the north and Oldadai village to the south. It also borders Ebangata village and Songota River to the east. To the west the village borders Olgilai village and Kivesi Mountain (Ng'iresi village executive officer, personal communication, 2010). Topography of the village is undulating is undulating. Fig. 2 shows the location Map of the village.

3.1.2 Soils and climate

Soils are originating from volcanic ash varying from Mollic Fluvisols to Alic Andosols. Ng'iresi village lies in the climatic zone of sub-humid highlands and rainfall reaches to 2000 mm annually. The temperature ranges from 12 to 30°C (Kaihura *et al*., 1998). Rainfall pattern in the village is bimodal. It experiences long rain season from March to May and short rains from November to December (Fernandes *et al.,* 1984). The village is among the areas in Arumeru district where land scarcity is a big challenge.

3. 1.3 Flora, fauna and aves

The flora, fauna and aves in the study area are reported as observed during the survey in this study.

3.1.3.1 Flora

Permanent tree crops planted are *Grevillea robusta* (silk oak), *Pinus patula* (pine), *Cupressus lustanica* (cypress), *Olea capensis* (east african olive), *Ficus cycomorus* (sycamore fig), *Markhamia lutea* (bell bean tree), and many others. Fruit trees like *Citrus cinensis* (orange), *Citrus limon* (lemon), *Citrus reticullata* (tangelin), *Annona squamosa* (custard apple), *Annona muricata* (custard apple), *Mangifera indica* (mango), *Persea americana* (ovacado), *Carica papaya* (pawpaw) and *Punica granatum* (pomegranate) are found in the village. Other plants include C*offea robusta*, *Saccarum spontaneum* (sugarcane), *Musa* spp. (banana), *Soranum tubarosum* (irish potato), *Phaseolus spp* (bean), *Ipomoea batatas* (sweet potatoes), *Zeya mays* (maize), *Manihot esculenta* (cassava), *Oxytenanthera abyssinica* (common bamboo), *Pasiflora edulis* (passion fruit), *Sorghum bicolor* (sorghum), *Panicum miliaceum* (common millet), *Arachis hypogaea* (groundnut), *Allium sepa* (onion), *Lycopersican esculentum* (tomato), *Lagenaria siceraria* (gourd), *Cucumis sativus* (cucumber), *Citrullus lanatus* (water melon), *Cucurbita species* (pumpkin), *Spinacia oleracea* (spinach), *Physalis ixocarpa (*mnavu in swahili) and *Hibiscus esculentus* (okra) (Personal observation, 2010).

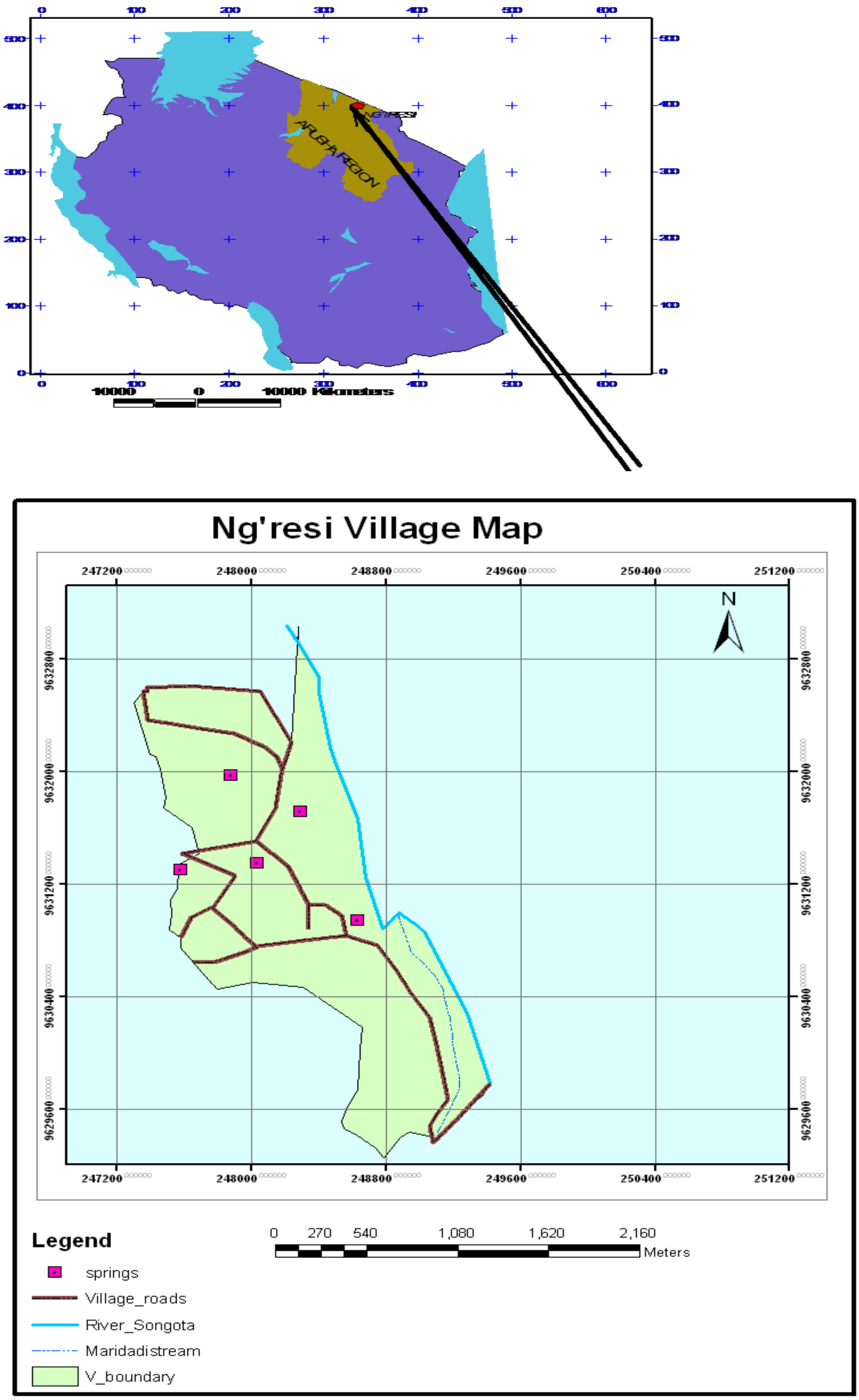

Figure 2: Map of study village.

3.1.3.2 Fauna

The fauna found in Ng'ilesi village are *Cercopithecus pygerythrus* (vervet monkey), *Papio cynocephalus* (baboon) and *Potamochoerus larvatus* (bush pig) which are coming from Kivesi Mountain forest and Mount Meru forests especially during dry seasons (Ng'iresi village executive officer, personal communication, 2010). Other fauna include *Cryptomys hottentotus* (mole-rat), S*accostomus campestris* (pouched mouse) which like the above animals destruct farmers' crops (Ng'iresi village executive officer, personal communication, 2010). Some domestic animals kept in the village are *Bos taurus* (cattle), *Capra hircus (*goat), *Ovis aries* (sheep), *Potamochoerus parvifolia* (domestic pig), *Felis catus* (cat), *Canis familiaris* (dog), and *Equus asinus* (donkey) (Personal observation, 2010).

3.1.3.3 Aves

Some villagers keep *Gallus domesticus* (domestic fowls*)*, *Guttera pucherani (*guinea fowl, kanga in Swahili), *Anas platyrhncha* (domestic duck) and *Anser domesticus* (domestic goose). *Anas sparsa* (water ducks) are found in Songota River. *Accipiter tachiro* (kipanga in swahili) and *Ciccaba woodfordi* (bundi in swahili), are also found in the village (Personal observation, 2010).

3.1.4 Drainage

The village is drained with Songota River and its tributary known as "maridadi." The River never dries up and originates from Meru Forest reserve. The village has five (5) natural springs that also never dry up. The springs are under communal management of the people found in each hamlet but are supervised by village environmental committee (Ng'iresi village executive officer, personal communication, 2010). The springs are

Lesendu (found in Kimerok hamlet), Ngoikaa (found in Ngoikaa hamlet), Mbayani and Engichoru (found in Oltoroto hamlet) and the fifth spring is known as Manina (which is found in Olaivolos hamlet). The fifth hamlet known as Achi has no natural spring. The water from the five springs is drawn for domestic uses while water from Songota River and maridadi stream is in addition used for irrigation purposes (Ng'iresi village executive officer, personal communication, 2010).

3.1.5 Population and economic activities

The population of people in this village is estimated at 4 114. The inhabitants are mostly farmers of "Waarusha" tribe. Most of the women and sometimes children, in this village are engaged in firewood business. It is a common practice to see women carrying bunch of firewood to sell in town. The demand for firewood and other wood products is high both for household and industrial use in Arusha municipality (Ng'iresi village executive officer, personal communication, 2010).

3.2 Methods

3.2.1 Pilot survey and sampling design

A reconnaissance survey was carried out in the village prior to the major inventory. Among others, different tenure regimes and land use categories were identified. The village was found to be featured with 5 main categories of land occupied with ToF and two tenure regimes, private and communal. The land occupied with ToF was categorised as; trees around homesteads, agroforestry, woodlots, natural springs, and trees growing in line plantings (along borders of farm blocks, village roads and "Songota" River and its tributary known as "Maridadi"). In this study, the land occupied with ToF was classified as five major strata found in the village.

Stratified random sampling was used to obtain number of sampling units. Village boundary tracking was done using a GPS to obtain both map and area of the village. The total village land was estimated to be 326 ha. Land occupied by ToF was estimated to be 182 ha as shown in Table 1. Blocks/units falling in each stratum were identified and their areas were measured as indicated in Table 1. Then a pilot survey was done in each stratum/substratum whereby two sample plots were established at random. In each plot basal area was measured using relascope (with BAF of 1). The basal areas obtained were used to estimate the variance in tree stocking (Table 1).

The variance obtained, allowed an estimation of the number of sampling units that were needed to carry out a major inventory. The number of sampling units needed for a major inventory was calculated as shown below using the formula;

$$n = \frac{N\sum N_i S_i^2}{\frac{N^2E^2}{t^2} + \sum N_i S_i^2} \quad \text{(Malimbwi, 1997)}$$

Where: n =number of sampling units required for a major inventory.

N_i =area of a given stratum,

N =total area of all strata,

t = expression of confidence that true average is within the estimated range,

E = Allowable error and

S_i^2 =variance for a given stratum

In this study the allowable error (E) was decided to 0.4078 m^2/ha, being 10% of mean basal area per ha which was estimated to 4.078 m^2/ha. The expression of confidence that true average is within the estimated range (t) was taken as 2.

The number of sample plots (n) was estimated as:

$$n = \frac{181.90 * 422.200}{\frac{181.90^2 * 0.4078^2}{2^2} + 422.200}$$

=42.71

Thus n ≈ 43 plots

The number of sampling units needed to be allocated to each stratum/sub-stratum was thus calculated using the method of optimum allocation as indicated in the formula:

$$N_i = \left(\frac{N_i S_i}{\sum N_i S_i}\right) n \quad \text{(Malimbwi, 1997).}$$

Where: n = total number of sample plots need for a major inventory in this case

The summary of number of sample plots calculated for each stratum/substratum is shown in Table 2 below). After computation, it was found that the number of plots that was optimally allocated to stratum number five (tress around natural springs) would have been one. Increasing the allowable error (E) above 0.4078 m^2/ha, i.e. greater than 10% of mean basal area per hectare would have resulted to getting few sample plots On the other hand, decreasing the allowable error (E) below 0.4078 m^2/ha, i.e. less than 10% of mean basal area per hectare would have resulted to getting many sample plots and consequently more than one plot might have been optimally allocated to stratum number five. But with only one plot for trees around springs, there would be zero (1-1) degrees of freedom and no statistics at all. To avoid this, two plots were allocated for springs in place of one.

3.2.2 Data collection

3.2.2.1 Size and shape of plots

As mentioned earlier, in their study Sangeda *et al.* (2001) found that rectangular plots measuring 20 x 250 m are statistically the most suitable for assessing ToF. The study intended to use plots of such size. However, it was not possible to establish 20 x 250 plots for line-plantings (riverine trees, roadside plantation and for trees bordering other crops). Thus for roadsides and riverine tree plantings, plot sizes used were laid at 10 m x 100 m on each side of the road and/or river as suggested by Prasad *et al.*, (2001). Other line-plantings which measured less than 100 m length (like ToF bordering farms/other crops in one side) a plot chosen at random was established at 10 m times available length. For ToF bordering crops in many sides their plot size were taken by summation of; 10 m x length of each side.

It was found that most of the strata/sub-strata were scattered throughout the village land. Establishing, for example a 20 x 250 m in a particular stratum/substratum could have caused some part of an established plot falling/overlapping in the premises of another stratum/sub-stratum as there were no very close and same a farm/land use category so that such plot size could be easily established by joining two or more units. In this study the areas of 43 sampled plots ranged from 0.05 ha to 0.5 ha and the average sample plot measured 0.2 ha. Table 3 below indicate the size and shape and stratum/substratum in which sample plots were found.

Table 1: Variance in tree stocking from basal area recorded from five strata

S/n	Stratum	Sub-stratum	Area (ha)	G (m^2/ha)	Mean G (m^2/ha)	S^2
1	Homestead plantation	-	64.31	2,3.5	2.75	1.13
2	Agroforestry	-	47.6	5,3.5	4.25	1.13
3.1	Trees in line-plantings	Trees bordering other crops in one side	11.1	4.5,2	3.25	3.13
3.2		Trees bordering other crops in four sides	19.71	6,4.5	5.25	1.13
3.3		Roadside plantation	16.8	4.5,1	2.75	6.13
3.4		Trees along Songota River and its branch (maridadi)	10	3,6.5 2,3.5	3.75	3.75
4	Woodlots	-	11.08	14,10	12	8
5	Trees around springs	-	1.3	7,3	5	8
Total area of ToF			**181.90**			

Table 2: Number of plots optimally allocated in each stratum /substratum

Stratum /Sub. Stratum no.	Stratum/Sub-stratum		Area	No. of plots	Plot nos.
1	Homestead plantation		64.31	11	1,2,3,4,5,6,7,8,9,10,11
2	Agroforestry		47.6	8	19,20,21,22,23,24,25,26
3.1	Line plantings	Trees bordering other Crops in one side	11.1	3	16,17,18
3.2		Trees bordering other crops in four sides	19.71	4	27,28,29,30
3.3		Roadside plantation	16.8	7	31,32,33,34,35,36,37
3.4		Trees along Songota River and its branch (maridadi)	10	3	13,14,15
4	Woodlots		11.08	5	38,39,40,41,42
5	Trees around springs		1.3	2	12,43
Total			**181.9**	**43**	

Table 3: Size, area and shape of each sample plot

Strat.	Sub Strat.	Plot no.	Plot Size (m)	Plot Area (ha)	Plot Shape	Strat.	Sub Strat.	Plot no.	Plot Size (m)	Plot Area (ha)	Plot Shape	Strat.	Sub Strat.	Plot no.	Plot Size (m)	Plot Area (ha)	Plot Shape
Hsd.		1	40*50	0.20	Rect*	Line*	Bd 1s	16	10*60	0.06	Strip	Line*	Bd 4s	30	28*80	0.22	Rect*
Hsd.		2	30*50	0.15	Rect*	Line*	Bd 1s	17	10*50	0.05	Strip	Line*	Road	31	10*100*2	0.20	Strip
Hsd.		3	40*25	0.10	Rect*	Line*	Bd 1s	18	10*80	0.08	Strip	Line*	Road	32	10*100*2	0.20	Strip
Hsd.		4	25*40	0.10	Rect*	Agrfor		19	20*250	0.50	Rect*	Line*	Road	33	10*100*2	0.20	Strip
Hsd.		5	40*50	0.20	Rect*	Agrfor		20	40*50	0.20	Rect*	Line*	Road	34	10*100*2	0.20	Strip
Hsd.		6	20*50	0.10	Rect*	Agrfor		21	25*80	0.20	Rect*	Line*	Road	35	10*100*2	0.20	Strip
Hsd.		7	25*40	0.10	Rect*	Agrfor		22	40*50	0.20	Rect*	Line*	Road	36	10*100*2	0.20	Strip
Hsd.		8	20*50	0.10	Rect*	Agrfor		23	30*50	0.15	Rect*	Line*	Road	37	10*100*2	0.20	Strip
Hsd.		9	20*50	0.10	Rect*	Agrfor		24	80*50	0.40	Rect*	Wlot		38	20*50	0.10	Rect*
Hsd.		10	40*50	0.20	Rect*	Agrfor		25	60*50	0.40	Rect*	Wlot		39	25*40	0.10	Rect*
Hsd.		11	40*50	0.20	Rect*	Agrfor		26	20*250	0.50	Rect*	Wlot		40	20*250	0.50	Rect*
Spring		12		0.40	Non*	Line*	Bd 4s	27	15*60	0.15	Rect*	Wlot		41	40*50	0.20	Rect*
Line*	Rrne	13	10*100 *2	0.20	Strip	Line*	Bd 4s	28	15*40	0.11	Rect*	Wlot		42	60*70	0.42	Rect*
Line*	Rrne	14	10*100 *2	0.20	Strip	Line*	Bd 4s	29	30*40	0.14	Rect*	Spring		43		0.10	Non*
Line*	Strm	15	10*100 *2	0.20	Strip												

Key: Hsd → Household; Line*→ Line-plantings; Rrne → Riverine; Rect*→Rectangular; Wlot→Woodlot; Agrfor →Agroforestry

Bd 1s and Bd 4s→ Trees bordring crops in 1 side and 4 sides respectively; Strat. →Stratum; Non*→ Not regular; Plot 27-30(Plot area obtained by multiplying 10 m*2(Length + Width of given plot)

3.2.2.2 Sampling frame

The size of sampling frame for each stratum/substratum consisted of five units of spring, 19 blocks of woodlot, 627 blocks of homestead and 190 blocks of agroforestry. The sampling frame for line-plantings involved; 84 strips of 10 x 100 m from approximately 8.403 km total length of the eight identified roads in the village, 196 blocks of trees bordering other crops in four sides, 137 strips of trees bordering other crops in single side and 50 strips of 10 x 100 m from approximately 5 km total length of the Songota River plus Maridadi stream.

3.2.2.3 Layout of plots

The sample plots were laid in each stratum at random. ToF blocks of different sizes and falling in different strata and tenure regimes were identified during pilot survey and given a number. The numbers of ToF units belonging to same stratum/sub-stratum were put in a basket and after a through shake; picking was done at random to represent a plot that was inventoried. For this case each and every plot was chosen equiprobable of the other. Frequency of picking a number from the basket depended on the number of plots that were needed in each stratum. All trees in a selected plot were measured.

3.2.2.4 Measured variables in plots

Tree measurements made include dbh ≥ 5cm typically measured at 1.3 m above ground using a calliper. Heights of standing trees were measured using hypsometers. Trees dbh of all trees and height of sample trees (mostly trees with smallest, medium and largest diameter) were measured directly in the plots. Equally, dbh and height of the odd trees found in sampled plots were measured directly in the plots. Odd trees included few standing trees (with very short height compared to the dbh size e.g. a tree with dbh of 28cm and height of 4 m). They appeared to be either decapitated by man or other agents.

It was found important to measure both their dbh and height directly to avoid over estimation of height by a regression model that was to be fitted later. Additionally, sampling of odd trees was not neglected because they also contribute to carbon storage potential. Elevation and location of points (eastings and northings) were done using GPS. Data were filled in data sheet as indicated in Appendix 1.

Bryce (1967) shows basic density of various tree species. Basic densities of only 14 out of 59 tree species sampled were found in Bryce (1967). Increment borer was used to extract cores (at dbh point) of 45 trees (out 59 identified) whose basic density was not indicated in Bryce (1967). Laboratory data was collected by analysis of the 45 wood cores to obtain basic density. Appendix 2 shows the basic density of all 59 trees sampled in this study.

3.2.2.5 Data collection for LEV calculation

Data on ToF establishment costs (site preparation and planting costs), management costs and revenue accrued from sale of tree products was established based on market prices. Carbon price (based on market price) was also used in land valuation. Two sources were taken into account for establishing economic costs for ToF management. These included a scan of literature and available costs data from forest enterprises offices especially SUATF a part of Mount Meru forest (which appears west of Ng'iresi village). Data collected for LEV calculation are shown in Table 4.

Table 4: Data collected for LEV calculation

S/N	Category	Value
1	Site preparation cost	67 774 Tshs/ha
2	Seedlings cost	100 Tshs/seedling
3	Planting cost	67 774 Tshs/ha
4	Thinning cost	101 631 Tshs/ha
5	Weeding(twice a year) cost	112 924 Tshs/ha
6	Pruning cost	62 108 Tshs/ha
7	Clear felling cost	2 240 Tshs/m^3
8	Sawing cost	22 982 Tshs/m^3
9	Transport cost	62 926 Tshs/m^3
10	Pole price	600/m
11	Firewood price	1 5000/m^3
12	Lumber price	163 691 Tshs/m^3
13	Carbon price	US$ 10/tC
14	Carbon emission price	US$ 10/tC

Conversion factor:

1 m^3 of pole (4m length, 17cm diameter) is made up of 12 pole pieces

3.2.3 Data analysis

3.3.3.1 Estimation of tree stock (basal area, volume, biomass and carbon)

i) Basal Area (BA) and Tree volume

Basal area was estimated using the general formula for calculating basal area of trees. Tree volume was estimated using the formula:

Tree Volume =Basal area*Height*form factor (estimated at 0.5).

Tree dbh and heights of sample trees were used to fit a height dbh equation that was used to estimate heights of trees not measured in the field. The dbh height model fitted was;

$$H = 0.5022dbh+5.1001 (R^2 = 0.69, n = 186).$$

Whereby:

H = Height (m)

dbh = diameter at breast height(cm)

R^2 = coefficient of determination

n = number of observations

ii) Estimation of biomass and Carbon

The tree biomass was estimated as a product of total tree volume and its wood basic density (Appendix 3) as suggested by (Negi *et al*, 2003; Munishi and Shear, 2004). Carbon was estimated using the formula; Carbon (kg) = 0.49 x Biomass (kg) (MacDicken 1997 and Brown, 2003).

iii) Plot and stand parameters

Plot parameters were estimated as a summation of all tree stock values in a plot. Stand parameters were estimated as a ratio of plot parameter to plot area. i.e

$$\text{Stand parameter} = \text{Plot}\left(\frac{parameter}{area(ha)}\right)$$

Where; parameter = tree count, BA,volume, biomass and carbon

3.2.3.2 Comparing stock values between state and private tenure regimes

Student's t-test was used to compare the estimated carbon data between private and communal tenure regimes. The F-test was used to check whether or not similar variation of stock values existed between the private and communal tenure regimes. It should be noted that F-test was conducted prior to running the t-test. The reason behind was to have a good idea on which t-test to use. F-test proved that variances in stock values of the two tenure regimes were statistically not different (Table 5). Thus decision was made on the use of a paired t-test assuming equal variance as an appropriate test to compare the means of stock values between private and communal tenure regimes. The analysis was done by using statistical analysis in MS Excel.

Table 5: Comparison of variances for the 5 parameters sampled in the 2 tenure

Parameter	**Private** (n=41plots)Mean	**Communal** (n=2 plots)Mean	**p-valueCalculated**	**Status**	**Ruling claim**
N	229	295	0.91	P>0.05	no significant difference in variation
G	4.19	16.72	0.20	P>0.05	no significant difference in variation
V	32.95	176.16	0.12	P>0.05	no significant difference in variation
B/ha	16.64	82.35	0.43	P>0.05	no significant difference in variation
C/ha	8.1549	40.3499	0.43	P>0.05	no significant difference in variation

3.2.3.3 Valuation of land under ToF

Costs and revenues (as explained in section 3.2.2.6) together with expected revenue from sale of carbon (carbon quantified x carbon price) was used to estimate value of land under ToF in terms of LEV. Since ToF in the study village were un-even aged , the appropriate formula for LEV was used as suggested by Straka and Bullad (2006). The LEV was calculated with help of formula;

LEV $= \frac{a}{i}$ (Straka and Bullad, 2006)

Where: a = Net annual income generated,

i = Interest rate, expressed as a decimal

The details of this formula are found in section 2.5.2

CHAPTER FOUR

RESULTS

This study was carried out with the objectives of: identifying and determine areas of land occupied with ToF under private and communal tenure regimes in the study village; identifying the species composition of ToF under private and communal tenure regimes in the study village; estimating stocking of the ToF under private and communal tenure regimes in the study village; and determination of the value of land added by carbon stored in ToF under private and communal tenure regimes.

4.1 Areas of Land Occupied with ToF under Private and Communal Tenure Regimes in the Study Village

The total land area in the studied village was 326 ha. Results from this study show that the area of land occupied by ToF is about 56% of the total village land area. Plate 1 shows general view of the village. Plate 2 shows identified five main categories of land occupied with ToF in the study village. The categories are:

- Homestead plantation: Trees appearing in the villagers residences and especially around house premises
- Trees in mix with other crops (agroforestry): Trees appearing in farms mixed with other crops such as banana, maize, beans and such crops.
- Trees in line-plantings: Trees appearing in lines along village roads, river, stream and farm borders:

- Roadside plantation: Trees appearing along sides of wide ways connecting different parts of the village
- Riverine trees: Trees appearing along the sides of large natural stream of water in the village (trees along Songota River and its branch (Maridadi)
- Boundary trees: Trees planted along borders of farms to encompass other crops either on one side or four sides

* Woodlots: Trees appearing in the premises of a piece of land (at mostly 0.5 ha) set aside for growing trees particularly for firewood, building poles, lumber and such uses
* Trees around springs: Trees appearing at the premises of village land where water is naturally flowing from the underground

The first four categories fall under private tenure regime while the last falls under communal tenure regime. In terms of land area, ToF under private tenure regime accounted for 99% of ToF land and about 55% of total village land while those under communal tenure accounted for 1% of ToF land and about 0.4% of the whole village land. This finding is supported by Kleinn *et al.* (2001) and Pandey (2008) who asserted that most of the ToF land which is under human management falls in private ownership of smallholders.

Plate 1: General view of the village

Trees bordering other crop

Agroforestry

Trees along Songota River

Roadside plantation

Trees around homestead

Woodlot

Trees around springs

Plate 2: View of ToF categories /strata

4.2 Species Composition of ToF under Private and Communal Tenure Regimes in the Study Village

The species composition in the five strata is as follows; Stratum one (homestead) composed of 41 different tree species, stratum two (agroforestry) 15 tree species, stratum three (line-plantings) 24 tree species, stratum four (woodlot) 16 tree species and stratum five (springs) composed of 17 tree species (Appendix 3). The 15 tree species encountered in agroforestry are higher than eight tree species recorded by Mugasha (2009). A total of 59 tree species were identified in this study and are higher compared to number of species reported for ToF project (2000) in Cañas, Guanacaste where pasture bordered by trees constituted 40 tree species but 69 tree species were enumerated for pasture not bordered with trees. Also this study reports higher number of species than 11-40 ToF species in fields in Mali enumerated by Yossi and Kouyaté (2002). The number of tree species enumerated in this study is higher compared to 20 species reported in ToF study in Mali by Kojwang and Chakanga (2002). Additionally Glen (2002) in Sudani reported lower species composition estimated at 33 tree species.

ToF were found richer in species, likely due to deliberate planting of different tree species, most especially category of ToF around homesteads so as to meet different uses as would be deemed necessary.

As indicated in Appendix 3, seven species were distributed in all five strata. These are *Grevillea robusta, Croton macrostachyus, Jakaranda mimosifolia, Markhamia lutea, Persea americana, Pinus patula* and *Rauvolvia caffra.* In communal tenure regime, the dominant tree species was *P.americana* (Fig.3). The reason for its dominance is probably due to what Holding (2004) reported that fruit trees like *P.americana* previously grown as a source of fruits, was now also being converted to timber and firewood for commercial purposes in the lower zones of Kenya.

G. robusta was a dominant species in private tenure regime (Fig.4). Kweka *et al.* (2007) observed that ninety six percent (96%) of the farmers who grow trees do so for business and/or for financial security. *G. robusta* found to dominate the village probably due to its recognized potential in increasing farmers' income in terms of timber, poles, firewood, and fodder. The species also provide shade due to its less competition with adjacent crops.

Literature reveals that *G. robusta* was both most abundant and as the single most readily traded species grown on farms (Holding and Njuguna, 2004). Ngayambaje and Mohren (2011) report that most farmers in Rwanda use *G. robusta*, to demarcate farm and plot boundaries, stabilization of roads and windbreaks. In addition to fuelwood, the species is also used for construction poles and timber. *G. robusta* is used as a windbreak tree presumably due to fact that the tree may grow high enough (at favourable conditions) and its spreading branching system protect other plants from mechanical damage by strong wind, high rates of transpiration and surface evaporation. Munishi (2007) on his study on distribution and diversity of ToF in the southern sides of Mount Kilimanjaro found that *G. robusta* was commonest tree species found at the area. Apart from the above opinions on the popularity of *G. robusta*, also its popularity might be caused by probability of leaf litter from the plant to naturally fertilize the soil.

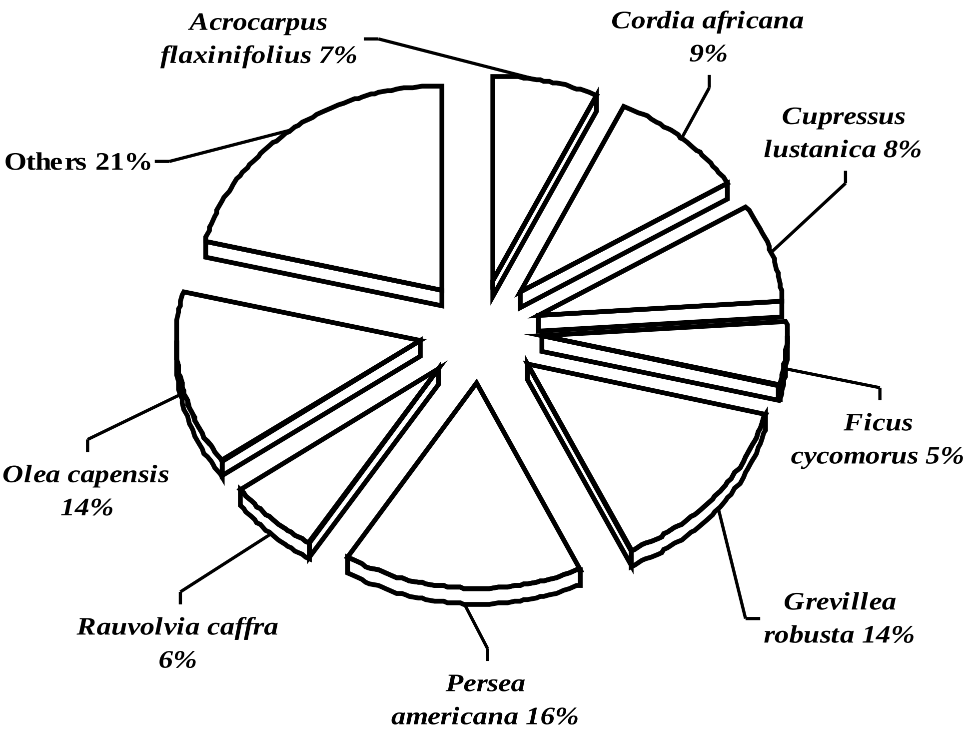

Figure 3: Species dominance in communal tenure regime in Ng’iresi village.

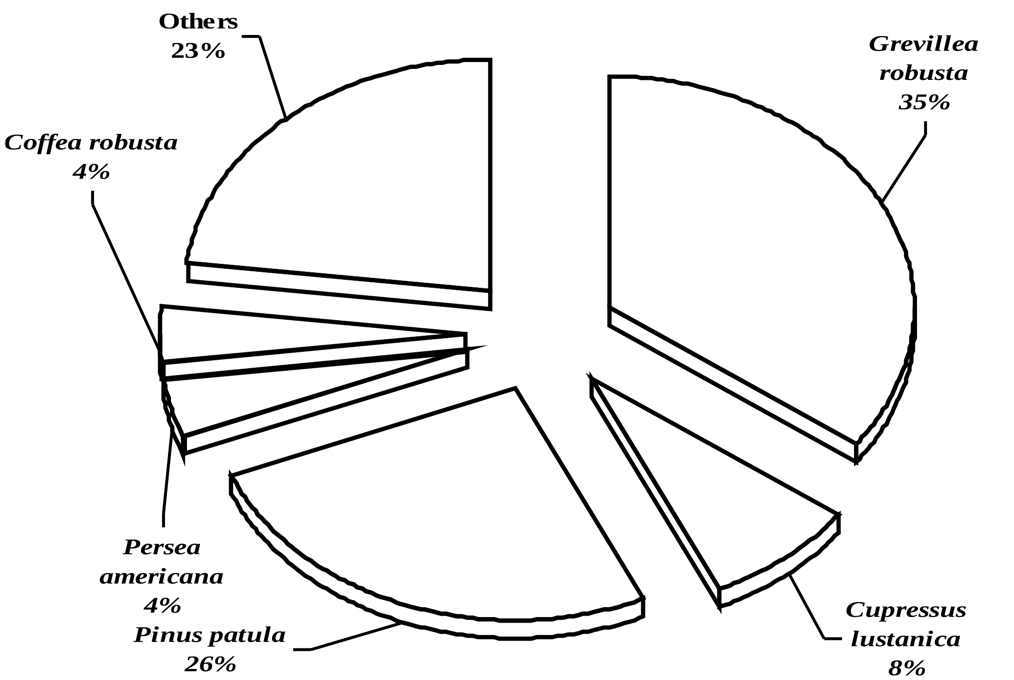

Figure 4: Species dominance in private tenure regime in Ng'iresi village.

4.3 Estimating and Comparing Stocking of the ToF under Private and Communal Tenure Regimes in the Study Village

Table 6 shows the forest stocking levels in terms of number of stems, basal area, volume and carbon per hectare for the five categories of ToF in the studied village. Table 7 compares these stocking levels between communal and private regimes.

Table 6: Socking levels of the five strata observed in this study

Stratum	N	G	V(m^3/ha)	Biomass (t/Ha)	Carbon (t/Ha)
1	192 ± 25	4.07 ± 0.58	30.41 ± 4.60	14.41 ± 1.84	7.06 ± 0.90
2	149 ±43	2.57 ± 0.52	18.06 ± 4.94	8.73 ± 1.89	4.28 ± 0.92
3	211 ± 29	4.56 ± 0.61	39.72 ± 7.06	20.53 ± 3.49	10.06 ± 1.70
4	497 ± 134	5.79 ± 0.75	39.29 ± 6.02	21.02 ± 2.80	10.30 ± 1.37
5	295 ± 75	16.72 ±2.65	176.16 ±31.3	82.35 ± 9.85	40.35 ± 4.83

4.3.1 Number of stems per hectare (N)

Results in Table 6 show that the average density of trees was highest in stratum four compared to other strata. This stocking is also higher compared to 400 stems/ha reported by Munishi *et al.* (2004). Stratum two (agroforestry) had the lowest tree density (about 149 stems/ha) for provision of enough space for other crops in the system. The tree density in the strata one (trees around homesteads) was estimated at 192 stems/ha and the figure is higher than what was reported by Pandey (2002b) in state of Kerala India where homesteads contained 113 trees/ha. Also this study reports higher tree stocking than 180 trees/ha, in home gardens reported by Rawalt *et al*. (2002). Strata three (trees in line plantings) had 211 stems/ha which can be compared with 250 stem/ha of trees in hedgerows, reported by Bertomeu (2006).

Table 7: Comparison of mean for the five parameters sampled in the two tenure regimes

Parameter	Mean 1 Private	Mean 2 Communal	P value	/test statisticCalculated	t-valuetabulatedCritical/	Ruling claim
N	229	295	0.60	-0.53	2.02	mean 2 not significantly greater than mean 1
G	4.1892	16.7176	2.57E-09	-7.58	-2.02	mean 2 significantly greater than mean 1
V	32.9455	176.1597	1.9E-10	-8.40	-2.02	mean 2 significantly greater than mean 1
Biomass/ha	16.6427	82.3466	4.35E-08	-6.74	-2.02	mean 2 significantly greater than mean 1
Carbon/ha	8.1549	40.3499	4.35E-08	-6.74	-2.02	mean 2 significantly greater than mean 1

Though number of stems per hectare was statistically not different (P = 0.6) between private and communal tenure regimes (Table 7), on aggregate the average stems per hectare in private tenure regime are lower (229 stems/ha) compared to communal regime (stratum five) with 295 stems/ha. This is because stratum five (trees around springs) composed of standalone trees while other strata are composed of trees mixed with other crops. Due to owner's free access for ToF under private tenure, trees might be highly exposed to harvesting than for ToF under communal tenure regime where access is restricted by community members.

The overall mean tree density of ToF in the study village was estimated at 232 stems/ha. This can be compared with findings by Njuguna *et al.* (1998) on tree farms in Kenya who reported tree density of 250 trees/ha. In their study on ToF, Sangeda *et al*, (2001) reported lower tree density than this study ranging from 47 ± 4 stems/ha to 67 ± 6 stems/ha. ToF Project (2000) reported lower mean tree density in pasture bordered by trees and one not bordered by trees estimated at seven and nine trees/ha respectively. Another comparison, is made to Yossi and Kouyaté (2002) who studied a ToF in Mali and came up with stocking density of 8-20 stems/ha in village fields which had been cultivated over a long period of time. A ToF study done by Mhirit and Et-Tobi (2002) in Morocco, reports stocking of carob tree (*Ceratonica siliqua L.*) of estimated at 16 stems/ha.

The mean tree density distribution for private tenure regime was highest in dbh class (5cm-20cm) about 198 stems/ha and most negligible in dbh class (>60 cm) about 0.22 stems/ha (Fig. 5). Likewise, in communal tenure regime the mean tree stocking was found highest in dbh class (5 cm to 20 cm) about 156 stems/ha and lowest in dbh class (>60 cm) about 3 stems/ha as indicated in Fig. 6.

Distribution of number of stems/ha in the strata under communal tenure regime (natural spring) follows a reversed J-shaped trend as expected for a naturally grown forest with active regeneration and recruitment (Philip 1994). This is not the case with the strata under private tenure regime where most of the trees are not naturally grown.

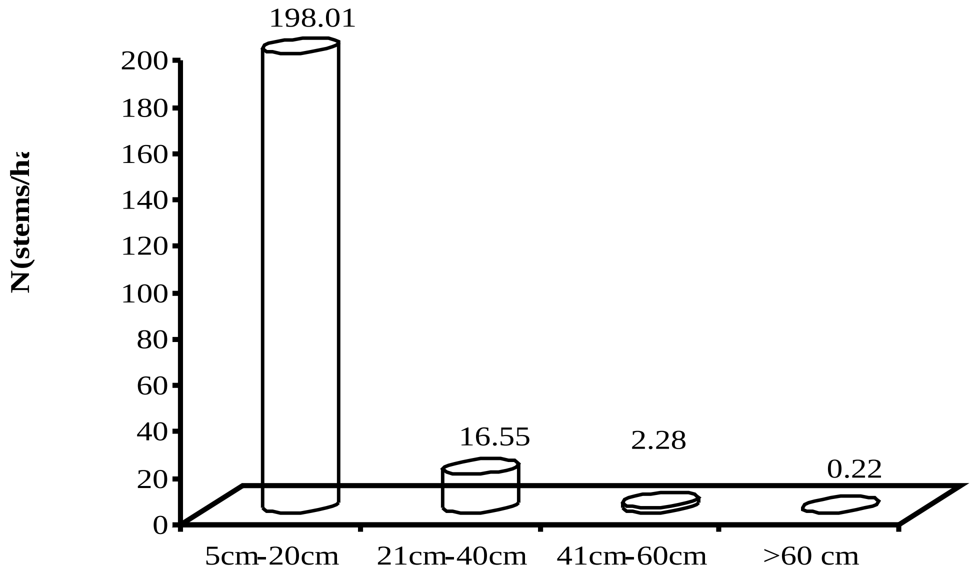

Figure 5: Distribution of number of stems/ha for private ToF tenure regime in Ng'iresi village.

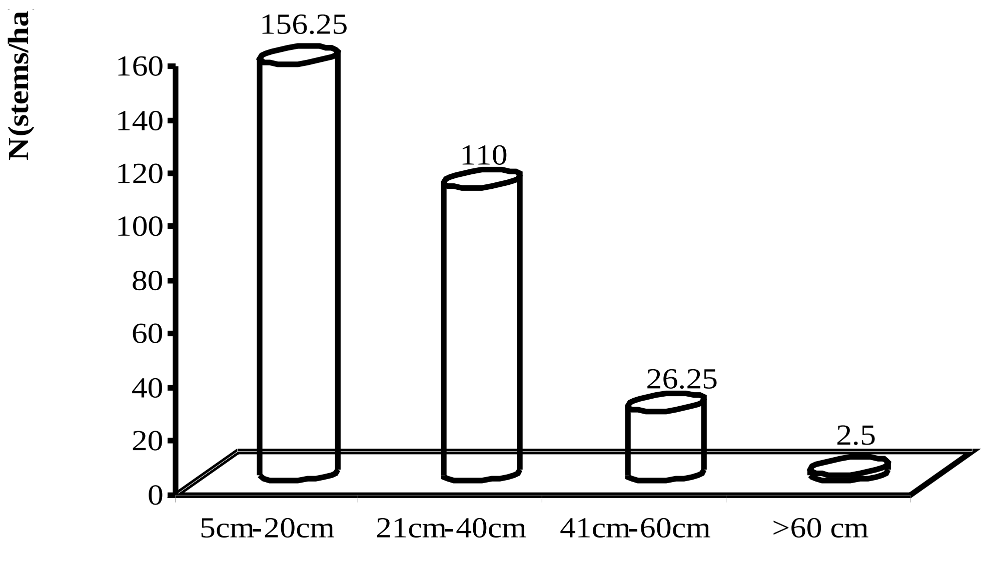

Figure 6: Distribution of number of stems/ha for communal ToF tenure regime in Ng'iresi village.

4.3.2 Basal area, Volume and Carbon per hectare

4.3.2.1 Basal area

Results reveal that average basal area was highest in stratum five while stratum two had the lowest basal area (Table 6). Based on the types of tenure regimes, average basal area per hectare was statistically higher (P= 2.57E-09) in communal tenure regime than for private tenure regime (Table 7). These values are within the range reported by Sangeda *et al*. (2001) on ToF where basal area was found to vary between 4.12 ± 1.01 to 8.61 ± 3.00 m^2/ha. However the basal area for communal tenure regime is higher due to dense population of large trees as pointed out in section 4.3.1.

Fig.7 and 8 below show mean basal area distributions in the four dbh classes for the two tenure regimes. Basal area in communal tenure regime was higher in dbh class 21 cm to 40 cm while dbh classes “5cm to 20 cm” and “60 cm” contained trees with least basal area. For the private tenure regime, basal area was high in dbh class of 5cm to 20 cm (about 1.98 m^2/ha) almost equal to that of dbh class of 21 cm to 40 cm (about 1.88 m^2/ha) and lowest in dbh class (>60 cm) estimated at 0.12 m^2/ha.

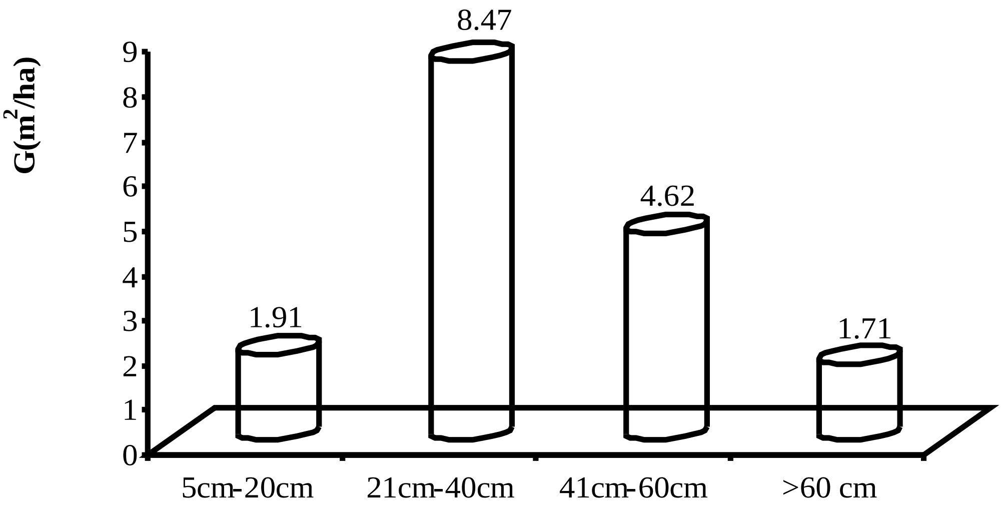

Figure 7: Distribution of basal area/ha for communal ToF tenure regime in Ng'iresi village.

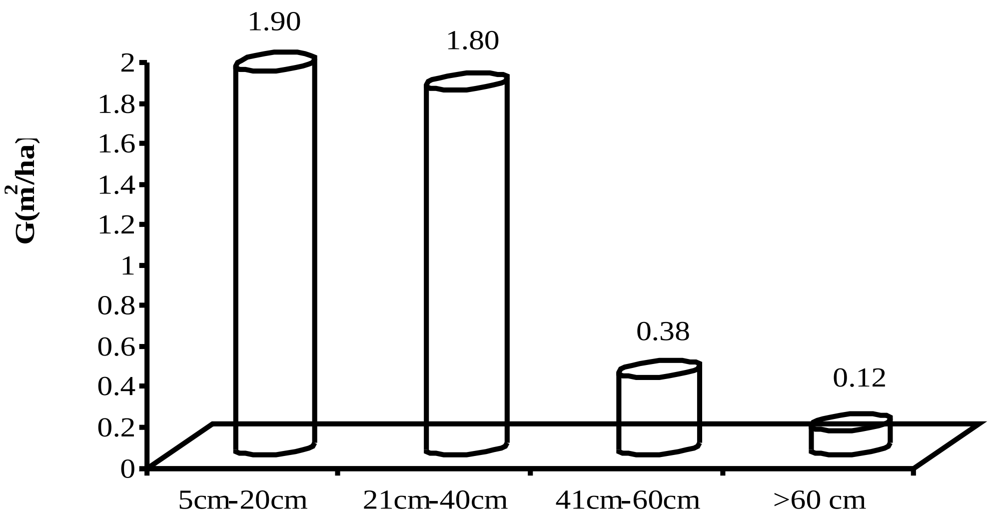

Figure 8: Distribution of basal area/ha for private ToF tenure regime in Ng'iresi village.

4.3.2.2 Volume per hectare

It was observed that the volume per hectare was highest in stratum five (trees along springs) and lowest in stratum two (agroforestry). ToF around springs showed highest volume due to tendency of people not to frequently remove trees around water sources avoiding disturbing the ecosystem around the watersheds, the practice that would have fostered drying of springs. Stratum three (trees in line plantings) and four (trees in woodlots) had almost equal volume per hectare (Table 6). The volume per hectare in stratum one (homestead) of 30.41 m^3/ha is within the range reported Kumar *et al.* (1994) where volume of home gardens ranged from 6.6 to 50.8 m^3/ha. Additionally this study reports higher volume than 26.6 m^3/ha reported by Pandey (2002b) in homesteads of Kerala state, India. Volume of trees in line plantings is lower compared with 69 m^3/ha of hedge rows reported by Bertomeu (2006) in Philipines.

The volume per hectare was statistically higher (P = 1.9E-10) in communal tenure regime 176.16 m^3/ha than for private tenure regime 32.95 m^3/ha (Table 7) due to presumably trees with larger diameter observed in communal tenure than private tenure regime. These values are almost consistent with ToF volume in Machame ranging from 43.92 ± 12.22 m^3/ha to 104.68 ± 48.44 as reported by Sangeda *et al.* (2001). Furthermore, volume reported in this study is higher than 19.9 m^3/ha reported by Njuguna *et al.* (1998) and lower than 50 m^3/ha of ToF reported by Giri (2004) in Chasimba village Tanzania.

Results show that the diameter class “21 cm to 40 cm” for private regime contained trees with highest volume while diameter class “>60 cm” contained trees with lowest volume (Appendix 7 and Fig.9). For communal tenure regime highest volume were contained in dbh class “21 cm to 40 cm” but lowest in dbh class “5 cm to 20 cm” (Appendix 7 and Fig.10).

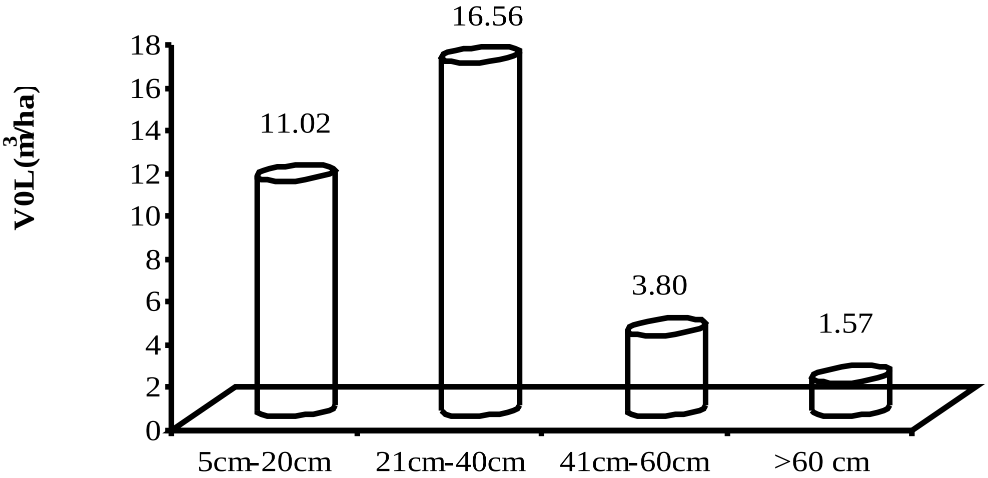

Figure 9: Distribution of volume/ha for private ToF tenure regime in Ng'iresi village.

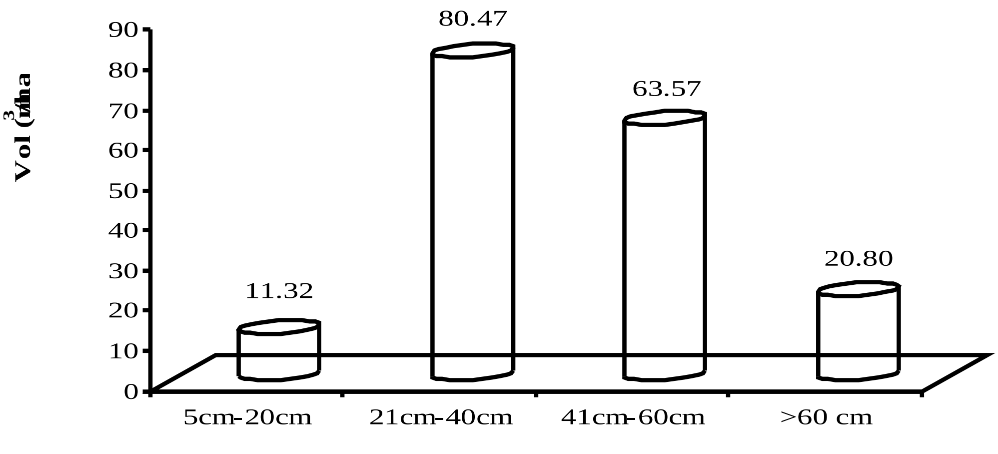

Figure 10: Distribution of volume/ha for communal ToF tenure regime in Ng'iresi village.

4.3.2.3 Carbon per hectare (tC/ha)

Results show that, stratum five (trees along springs) contained the highest mean carbon per hectare while stratum two (agroforestry) had the lowest carbon per hectare followed by stratum one (homestead). Stratum three (trees on line plantings) and four (woodlot) had almost the same values for carbon per hectare (Table 6). The average carbon per hectare was statistically higher (P=4.35E-08) in communal tenure regime than in private tenure regime. These values are within the range reported in Philippines tree farms by Sales *et al.* (2005) where carbon figures ranged from 0.98 MgC to 63.94 MgC/ ha.(1 Mg=1 ton=10^6 g). In his study Mugasha (2009) reported that ToF contain 56 tC/ha out of 155 tC/ha stored in agroforestry systems (soil, herbs, litter, banana and trees) in Matombo village Tanzania. A study done by Seeberg-Elverfeldt *et al. (*2009) reported that the net carbon accumulation in three agroforestry systems to ranged from 62 to 67 tCO_2e/ha (=17 to 18 tC/ha as 3.67 tCO_2e=1 tC).

For communal tenure regime highest mean carbon values were falling in diameter class “21 - 40 cm” and lowest in diameter class “5 - 20 cm” (Fig.11) estimated to an average of 2.97 tC/ha. Results reveal further that diameter class “21- 40 cm” in private tenure regime contained highest mean carbon per hectare while lowest values were indicated in diameter class “>60 cm” (Fig.12). Fig. 11 and 12 below show the carbon distribution in the four diameter classes for the two tenure regimes. More details of stocking values are indicated in Appendices 4, 6, 7 and 8.

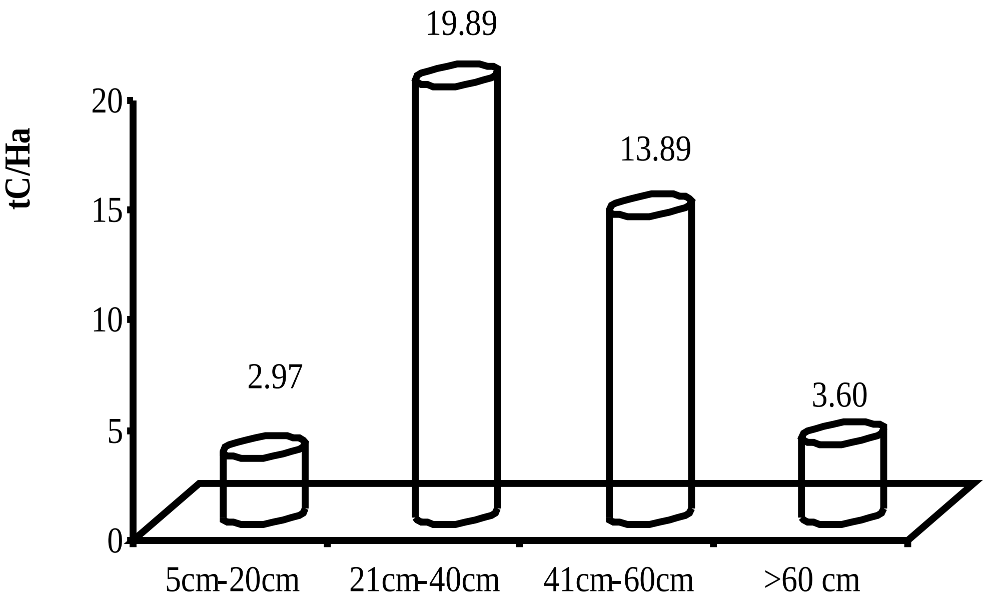

Figure 11: Distribution of carbon/ha for communal ToF tenure regime in Ng'iresi village.

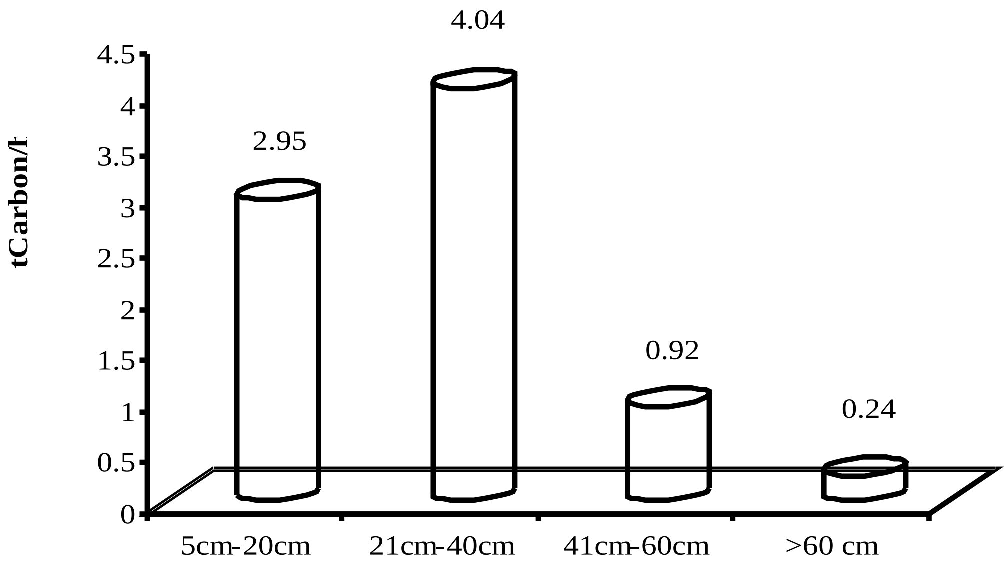

Figure 12: Distribution of carbon/ha for private ToF tenure regime in Ng'iresi village.

4.4 Value of Land Harbouring ToF (in Terms of LEV) in the Study Village

4.4.1 ToF LEV under carbon management

As shown in Section 4.3.2.3, ToF under communal tenure regime had higher carbon store estimated at an average of 40.35 tC/ha compared to that of private tenure regime estimated at 8.40 tC/ha. Also the carbon figures for communal tenure regime were statistically higher and different from that of private tenure regime. It is therefore argued that communal tenure regime maximizes land value due to higher value of carbon stored.

This study assumed that tree owners' reserve the property right to sell carbon stored in their lands annually (for standing trees). Another assumption rests on the principle that after harvesting tree owners are paid for carbon stored in wooden fixtures such as poles, furniture and other wood products. These have also included in LEV computation (Appendices 9 and 10). This study assumed also that stakeholders in the carbon trade are supposed to pay for releasing carbon in the atmosphere through burning wood materials (firewood, sawdust) and materials left to decompose freely in their farms/lands. Carbon cost/price is considered to vary from one region to another and from country to country (Shin, *et al,* 2007). Several studies report on carbon costs in different countries. Economic modelling done by Muray *et al*. (2009) in USA reveals global carbon prices estimated at US$10-US$30 per metric ton of CO_2. Niles *et al.* (2002) used carbon costs ranging from US$1-US$ 100/tC in his study for developing countries. In this study cost for carbon emission and price of carbon were assumed to be equal (Backéus *et al,* 2005). The carbon price was assumed at US$ 10 adopted from the above studies by assuming the same social economic conditions. All computations of LEV in both communal and private tenure regime were done at 10% interest rate.

When removal of trees is done, average amount of products that would be obtained are indicated in Table 8: The computation was adapted from assortment table of forest produce obtained in SUATF Management plan (2002-2007)

Table 8: Average value of tree products when trees are cut down

Woodproduct	Sawlog(%)	Chiplogs(%)	Poles(%)	Firewood(%)	Waste(%)
Average Value (%)	33.75	39.25	6.25	9.50	11.25

Table 9: Assortment table of timber produces in SUATF

Type of cutting	Sawlogs (%)	Chiplogs(%)	Poles (%)	Firewood (%)	Waste (%)
Clearfelling	80	5	0	8	7
Thinnings					
1st	0	52	20	10	18
2nd	5	66	5	12	12
3rd	50	34	0	8	8

The annual average volume of trees harvestable in each tenure regime in the study village was computed based on relating allowable cut from a SUATF as follows.

Area of SUATF=840 ha, allowable cut 7220 m^3/yr.

- The allowable cut for private tenure regime would be: TOF area under private tenure regime(180.6 ha) *(7220 m^3/yr) /(840)=1552.3 m^3/yr
- Accordingly, the allowable cut for communal tenure regime was estimated as: Area(1.3 ha) * (7220)/(840)=11.1738 m^3/yr

Assuming that the allowable cuts in private and communal tenure regimes were 1552.3 and 11.17 respectively then the amount of timber produce available per year from each tenure regimes were estimated as indicated in Table 10.

Table 10: Amount of tree produce obtained by cutting trees from each tenure regime

Tenure regime	Allowable cut(m^3/yr)	Volume of timber produce(m^3/yr) Sawlogs	Chiplogs	Poles	Firewood	Waste
Percentage		33.75	39.25	6.25	9.50	11.25
Private	1552.30	523.90	609.28	97.02	147.47	174.63
Communal	11.17	3.77	4.38	0.70	1.06	1.26

This study considered that sawlogs and chiplogs contributed to volume available for sawing. Also the study assumed that lumber, poles and saw dust (50% of sawdust) contribute to amount of carbon stored completely in these tree produce, while firewood and 50% of sawdust contribute to carbon re-emitted in the atmosphere (pollution) when the products are burnt. Another assumption put forward in this study was that 50% of wastes decompose and release carbon while remaining 50% is stored completely in soil. Experience at SUATF sawmill showed that when 1 m^3 of round wood is sawn, 40% of the product would be lumber, 40% slabs and 20% sawdust. The volume of forest produce indicated in Table 10 and Table 11 were converted to carbon equivalent as indicated in Appendix 11.

Results for total volume and carbon in the private and communal tenure regimes as illustrated under section 4.3.3 and 4.3.5 revealed that the ratio of total carbon to total volume in private and communal tenure regimes are 0.2471(1472.783/5949.949) and 0.2291(52.4549/229.0079) in that order. Thus the carbon equivalency for selected timber products were estimated by multiplying 0.2471 and 0.2291 with volumes of the respective timber produce from both private and communal tenure regimes respectively.

Table 11: Volume of lumber, slabs and sawdust obtainable after sawing sawlogs and chiplogs

Tenure regime	Volume available for sawmill (sawlog+chiplogs)	Lumber (40%)	Slabs (40%)	Sawdust (20%)
Private	1133.18	453.27	453.27	226.64
Community	8.16	3.26	3.26	1.63

It was shown that about 297.557 tC would be completely stored in; wooden fixtures in buildings and other structures (in form slabs and poles), soil (in form of waste and saw dust) and lumber (in form of furniture) taking consideration private tenure regime. For communal tenure regime the amount would be 2.226 tC. Again it was revealed that about 86.0163 tC and 0.6435 tC would be released to the atmosphere from private and communal tenure regimes through burning of firewood and sawdust.

Results from this study (at 10% discount rate and 10 US$ carbon price) have shown that the LEV was lower for private tenure regime amounting to Tshs.-826 050 883 (-4 573 925 Tshs/ha) the value equivalent to -472 029 US$ (-25 326US$/ha)(Appendix 9) than for community tenure regime estimated at Tshs. 5 370 255 (4 130 966 TShs/ha) the value equivalent to 3 069 US$(2 361 US$/ha) (Appendix 10). If carbon market is available, ToF under communal tenure regime would merit funding due to positive LEV.

4.4.2 TOF LEV without carbon management

At zero carbon prices and/or costs (a no carbon management option) LEV for private tenure regime was estimated at TShs. -1 052 520 922(-867 653 893 TShs/ha) the value equivalent to -725 877 US$ (-4 019 US$/ha). For communal tenure regime, LEV estimated at TShs. -3 556 118 (-2 735 476 TShs/ha) the value equivalent to - 2 453 US$

-1 887 US$/ha). These results prove that LEV for ToF is maximized under carbon management option. Thus, in this study, carbon stored in ToF is potentially influencing the land value in which they grow (Carbon stored in ToF have a positive contribution to LEV).

The results for LEV (-4 019 US$/ha for private and -1 887 US$/ha for communal tenure regime) in this study are lower compared to 2 279 US$ /ha LEV of *Gmellina* spp. tree hedge row (*Gmellina* hedge for maize) and 3 245/ha for maize mono-cropping as reported by Bertomeu (2006). However, with carbon management 2 035 US$/ha LEV of ToF under communal tenure regime is slightly lower to LEV of *Gmellina* tree hedge row. Also LEV in this study is relatively lower than LEV of tree farms estimated at US$ 3 634/acre (9 085 US$/ha) by Friday *et al.* (2000).

4.4.3 Financial compensation value for land owners

As described under section 2.5.3 financial loss due to changing timber harvest schedules to maximize carbon sequestration is obtained by;

Financial loss = (LEV with carbon management – LEV without carbon management)

Applying the information generated in this study:

Financial loss (Private tenure) = ((-25 326) - (-4 019)) US$/ha

= -21 307 US$/ha

Financial loss (Communal tenure) = ((2 361)-(-1 887)) US$/ha

= 4 248 US$/ha

As described earlier financial loss due to changing timber harvest schedules to maximize carbon sequestration is what is called ‘financial compensation value’ for landowners who are maximizing LEV and are willing to participate in a program of carbon maximization management. Since the value is higher for ToF under communal tenure regime (4 248 US$/ha) than for private tenure regime (-21 307 US$/ha), its interpretation is that when other factors are kept constant, farmers in communal tenure regime will fetch a better return when they economically set alternative course of actions that enhance a high but favourable amount of carbon storage. Alternatively it may be explained that farmers under communal tenure regime will have the good advantage to claim extra carbon benefits in terms of annual compensation benefits.

4.5.4 Sensitivity analysis

A sensitivity analysis was made (keeping other costs and prices constant and assuming that the US dollar exchange rate remains TShs. 1 750/US$1 as at early November 2011) by varying the price/cost for carbon at a range US$ 1 to US$ 100 (Table 12). The LEV for private tenure remained negative for the price of carbon below US$ 46.4750 but changed to positive for the price of carbon starting at US$ 46.4751. For communal tenure regime the LEV remained positive when price of carbon was above US$ 3.9838. This shows that LEV is sensitive to carbon prices.

However this study is limited in scope that in view of calculating LEV of ToF in the study area, it has not incorporated some cost/price elements in LEV computation. These include costs and benefits associated with non-wood tree products found in concomitant with ToF management. Lack of inclusion of such costs and/or revenues was due absence/inadequate empirical evidence related to them.

Table 12: LEV sensitivity to carbon price

Private tenure regime			Communal tenure regime		
Carbon price (US$)	**Net Revenue (TSHS)**	**LEV(Net Rev/0.1) (TSHS)**	**Carbon price (US$)**	**Net revenue (TSHS)**	**LEV(Net Rev/0.1) (TSHS)**
0	-105252092.2	-1052520922.2	0	-355611.8	-3556118.3
5	-93928590.3	-939285902.5	1	-266348.1	-2663480.9
10	-82605088.3	-826050882.9	3	-87820.6	-878206.1
30	-37311080.4	-373110804.2	3.5	-43188.7	-431887.4
40	-14664076.5	-146640764.8	3.9838	-2.9	-29.5
46.4749	-367.9	-3679.0	3.9839	6.0	59.8
46.475	-141.4	-1414.3	10	537025.5	5370255.5
46.4751	85.0	850.4	20	1429662.9	14296629.2
50	7982927.5	79829274.5	40	3214937.7	32149376.7
60	30629931.4	306299313.9	60	5000212.4	50002124.2
70	53276935.3	532769353.2	70	5892849.8	58928498.0
80	75923939.3	759239392.6	80	6785487.2	67854871.7
90	98570943.2	985709431.9	90	7678124.5	76781245.5
100	121217947.1	1212179471.3	100	8570761.9	85707619.2

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

This chapter draws conclusions and gives recommendations based on the results and discussions from this study.

5.1 Conclusions

This study has shown that ToF are found in two main categories of ownership, private and communal tenure regimes. A large area of land occupied by ToF around human environment falls in private tenure regime. In the studied village landscape, TOF appear in five main categories which are; trees in line plantings, agroforestry, homesteads, woodlots and natural springs. These ToF categories cover a large area (56% of total village land area of 326 ha) in rural scenery and are valuable to local farmers.

A total of 59 tree species were encountered in this study. The dominant tree species were *G. robusta* and *P.americana* in communal regime. The stock parameters of communal tenure regime are higher than for private tenure regime presumably due to type of management in the former which favours less harvesting of trees so as to conserve the natural springs. However, generally, the stock parameters (N, G, V, Biomass and Carbon) revealed in this study are consistent with findings of other ToF studies.

Definitely, carbon stored by ToF maximizes value of land on which they grow. It is evident that ToF under communal tenure regime have shown higher and positive land expectation value due to presence of natural springs which are conserved. Therefore, it is worth investing on communal ToF land (especially around natural springs/water sheds) so as to get extra benefits that will be accrued through carbon trade.

5.2 Recommendations

Based on the general field work and findings for this study, the following recommendations were worth given. Firstly, ToF should not be ignored in land-use planning and development policies at village level (and even at district and national levels) as they appear to cover a large area in rural setting.

Dominance of two species *G. Robusta* and *P. americana* in the study village imply that smallholders decisively plant them due to immense benefits they provide. While *G. Robusta* provides valuable timber *P. americana* provides edible fruits. In addition to these benefits, people should plant more ToF in order to increase chances of tapping extra benefits including carbon.

Due to working within objectives of sponsoring project under Tanzania-Norway NUFU programme, budget and time limitations it was not possible to study on many aspects of TOF. This study thus recommends the following areas for further study.

- Provided that the best methodologies in assessing TOF are inadequate and almost lacking emphasis should put on developing best methodologies for assessing TOF at a given locality. This study has in one way or another adapted some conversion factors/figures established from forest trees, due to lack of models that express TOF.

- More research work should be made on fitting growth and yield models for TOF. For trees planted in mix with other crops studies need to be done to help in determination of both best spatial and vertical formation of trees and other crops.
- Research should be done to compare TOF LEV with that of agriculture but the kind of comparable costs such as labour, discount rates, overhead percent, materials and such cost elements should be the same.

- Since this study has revealed *G.robusta* to dominate ToF further study should be done to ascertain why it is popular among other ToF species.

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APPENDICES

Appendix 1: Data collection form

Date:

Name of recorder:

Tenure regime:

Village name:

Plot No

Stratum Name:

Plot GPS locations: Eastings

Northings

Slope

Altitude

Trees DBH and height measurements

Spp Code	Scientific name	Local tree name	DBH (cm)	Height (m)

Appendix 2: Wood basic density of tree species identified in the study village

SPP CODE	BASIC DENSITY(KG/M^3)	SPP CODE	BASIC DENSITY (KG/M^3)
1	603	31	608
2	**689**	32	325
3	430	33	334
4	**545**	34	**609**
5	515	35	330
6	601	36	489
7	426	37	480
8	511	38	486
9	586	39	455
10	455	40	412
11	510	41	443
12	64	42	496
13	673	43	753
14	**449**	44	689
15	**609**	45	454
16	619	46	**529**
17	634	47	665
18	661	48	536
19	535	49	475
20	219	50	**423**
21	**545**	51	438
22	**721**	52	432
23	402	53	301
24	**465**	54	427
25	253	55	230
26	**801**	56	**705**
27	**609**	57	**550**
28	690	58	568
29	409	59	698
30	470		

*****values in bold: Basic density indicated in Bryce (1967) the rest were obtained by laboratory data collection through analysis of wood cores

Appendix 3: Species composition /checklist of ToF in the study village

Spp code	Botanical name	Local name	Gener*	Private	Com*	Hom*	Agro*	Line*	Wood*	Spring
1	*Acacia meansii*		√	√	X	X	x	X	√	X
2	*Acacia melanoxylon*		√	√	√		x	√	x	X
3	*Acrocarpus flaxinifolius*		√	√	√	√	x	√	x	√
4	*Albizia gummifera*	Mruka	√	√	X	X	√	√	x	√
5	*Anguelia madagascariensis*	Olmadanyi	√	√	X	X	√	X	x	X
6	*Annona muricata*	Topetope	√	√	X	√	x	X	x	X
7	*Annona squamosa*	Mstafeli	√	√	X	X	x	X	√	X
8	*Araucaria heterophyla*		√	√	X	√	x	X	x	X
9	*Basama abisinica*	Engiranguves	√	√	√	X	x	√	x	X
10	*Bridelia micrantha*	Olkujuk	√	√	√	X	x	√	x	√
11	*Callistemon speciousus*	Rasta	√	√	X	√	x	X	x	√
12	*Carica papaya*	Mpapai	√	√	X	√	x	X	x	X
13	*Casuarina cunninghamiana*		√	√	X	X	x	√	x	X
14	*Cedrera odorata*		√	√	√	√	x		x	X
15	*Celtis africana*	Olmatasya	√	√	X	X	x	√	x	√
16	*Citrus lemon*	Mlimao	√	√	X	√	x	X	x	X
17	*Citrus reticulate*	Chenza	√	√	X	√	x	X	x	X
18	*Citrus cinensis*	Mchungwa	√	√	X	√	x	X	x	X
19	*Coffea robusta*	Mkahawa	√	√	X		√	X	x	X
20	*Cordia Africana*	Mringaringa	√	√	√	√	√	√	x	X
21	*Croton macrostachyus*	Mfurufuru /Oloiyaviyav	√	√	X	√	x	√	√	√
22	*Croton megalocarpus*		√	√	X	√	√	X	x	X
23	*Cupressus goveniana*		√	√	X	√	x	X	x	X
24	*Cupressus lustanica*	Endarakwai	√	√	√	√	x	√	√	X
25	*Cussonia holstii*	Olmangalele	√	√	X	X	√	√	√	√
26	*Diospyros mespiliformis*	Engirerekuru	√	√	X	X	√	X	x	X
27	*Ekebergia capensis*	Olmukuna	√	√	X	X	√	X	x	X
28	*Eriobotyra japonica*	Silimanga	√	√	X	√	x	X	x	X
29	*Eucalyptus grandis*		√	√	X	√	x	√	√	X
30	*Eucalyptus maidenii*		√	√	X	√	x	X	√	X
31	*Eucalyptus saligna*		√	√	X	X	x	√	x	X
32	*Ficus sycomorus*	Mkuyu	√	√	√	X	x	√	x	X
33	*Ficus thonningii*	Leteti	√	√	X	X	√	X	x	√

spp code	Botanical name	Local name	Gener*	Private	Com*	Hom*	Agro*	Line*	Wood*	Spring
34	*Grevillea robusta*		√	√	√	√	√	√	√	√
35	*Jakaranda mimosifolia*	Jakaranda	√	√	√	√	√	√	√	√
36	*Leucaena leucocephala*	Kalianda	√	√	X	√	X	x	x	X
37	*Macaranga kilimandscharica*	Oljaninarok	√	√	X	x	X	√	x	X
38	*Maesa lanceolata*	Engaing`oorwa	√	√	√	√	X	√	x	√
39	*Mangifera indica*	Mwembe	√	√	X	√	X	x	x	X
40	*Markhamia lutea*	Bunduki	√	√	√	√	√	√	√	√
41	*Melia azedarach*		√	√	X	√	X	x	x	X
42	*Morus alba*	Mandela/ Olmandelai	√	√	X	√	X	x	x	X
43	*Olea capensis*	Loliondo /Ololoiondoi	√	√	√	√	X	√	√	√
44	*Olea europaea*	Mzeituni	√	√	X	√	X	x	√	X
45	*Persea Americana*	Mparachichi	√	√	√	√	√	√	√	√
46	*Pinus patula*		√	√	√	√	√		√	√
47	*Prunus persica*	Mfyulisi	√	√	X	√	X	x	x	X
48	*Psidium quajava*	Mpera	√	√	X	√	X	x	x	X
49	*Punica granatum*	Komamanga	√	√	X	√	X	x	x	X
50	*Rauvolvia caffra*	Oloichavukaliyan/ Msesewe	√	√	√	√	√	√	√	√
51	*Senna senguena*		√	√	X	√	X	x	x	X
52	*Senna spectabilis*		√	√	X	√	X	x	x	X
53	*Sesbania sesban*		√	√	X	x	X	x	√	X
54	*Solindea madagascariensis*	Embarivala	√	√	X	x	X	√	x	X
55	*Spathodea campanulata*		√	√	√	√	X	x	x	√
56	*Syzigium cuminii*	Mzambarau	√	√	X	x	X	√	√	X
57	*Terminalia superba*		√	√	X	x	X	x	x	X
58	*Thuja orietalis*		√	√	X	x	X	x	x	X
59	*Vepris simplicifolia*	Engilai	√	√	X	√	X	x	x	X

Where: Gener* =General checklist

Comm.* =communal checklist

Home* =Homestead checklist

Line* =line-plantings checklist

Wood* =woodlot checklist

√ and x = species sampled and species not sampled respectively

Appendix 4: Stocking values in the 43 plots

Tenure	Stratum no.	Plot no.	Plot area	N	G	V	Biomass (t/Ha)	Carbon (t/Ha)
	1	1	0.20	200	2.59	17.21	9.58	4.69
Private	1	2	0.15	107	1.73	12.80	7.52	3.69
Private	1	3	0.10	260	3.46	27.56	14.83	7.27
Private	1	4	0.10	240	6.96	33.92	13.70	6.72
Private	1	5	0.20	115	2.87	26.59	13.41	6.57
Private	1	6	0.10	290	6.28	45.38	19.25	9.43
Private	1	7	0.10	320	3.37	21.18	10.58	5.18
Private	1	8	0.10	210	6.52	59.70	27.28	13.37
Private	1	9	0.10	120	5.41	47.67	20.80	10.19
Private	1	10	0.20	195	3.98	30.61	14.61	7.16
Private	1	11	0.20	55	1.56	11.90	6.90	3.38
Mean(stratum 1)			**0.14**	**192**	**4.07**	**30.41**	**14.41**	**7.06**
Private	2	19	0.50	144	2.00	12.42	7.57	3.71
Private	2	20	0.20	80	3.54	31.34	17.83	8.74
Private	2	21	0.20	180	1.41	10.25	6.17	3.02
Private	2	22	0.20	105	1.97	13.80	6.63	3.25
Private	2	23	0.15	420	2.24	4.17	2.42	1.18
Private	2	24	0.40	30	0.93	6.39	3.69	1.81

Tenure	Stratum no.	Plot no.	Plot area	N	G	V	Biomass (t/Ha)	Carbon (t/Ha)
Private	2	25	0.30	177	2.83	20.85	11.03	5.40
Private	2	26	0.50	56	5.66	45.27	14.50	7.10
Mean (stratum 2)			**0.31**	**149**	**2.57**	**18.06**	**8.73**	**4.28**
Private	3	13	0.20	80	5.58	49.67	20.78	10.18
Private	3	14	0.20	220	9.44	113.70	50.32	24.66
Private	3	15	0.20	165	2.95	22.33	12.29	6.02
Private	3	16	0.06	250	7.49	63.38	31.53	15.45
Private	3	17	0.05	500	4.23	21.76	12.29	6.02
Private	3	18	0.08	288	3.16	19.73	10.54	5.16
Private	3	27	0.15	227	5.18	34.42	20.55	10.07
Private	3	28	0.11	227	1.52	8.02	4.41	2.16
Private	3	29	0.14	436	3.15	20.05	9.80	4.80
Private	3	30	0.22	123	1.40	8.89	5.10	2.50
Private	3	31	0.20	45	1.45	12.25	5.77	2.83
Private	3	32	0.20	45	1.85	18.99	11.55	5.66
Private	3	33	0.20	175	7.52	76.56	37.30	18.28
Private	3	34	0.20	185	4.49	48.60	24.99	12.25
Private	3	35	0.20	275	7.36	54.81	27.05	13.25
Private	3	36	0.20	140	2.83	20.85	11.03	5.40

Tenure	Stratum no.	Plot no.	Plot area	N	G	V	Biomass (t/Ha)	Carbon (t/Ha)
Private	3	37	0.20	205	3.80	29.73	16.64	8.15
Mean Values(stratum 3)			**0.17**	**211**	**4.56**	**39.72**	**20.53**	**10.06**
Private	4	38	0.10	960	6.89	35.40	17.68	8.66
Private	4	39	0.10	440	5.16	35.92	20.14	9.87
Private	4	40	0.50	234	3.25	28.62	16.14	7.91
Private	4	41	0.20	600	6.04	33.70	19.26	9.44
Private	4	42	0.42	252	7.59	62.83	31.88	15.62
Mean Values(stratum 4)			**0.26**	**497**	**5.79**	**39.29**	**21.02**	**10.30**
Mean (private tenure)			**0.20**	**229**	**4.19**	**32.95**	**16.64**	**8.15**
Communal	5	12	0.40	220	14.07	144.89	72.49	35.52
Communal	5	43	0.10	370	19.37	207.43	92.20	45.18
Mean Values(state tenure)			**0.25**	**295**	**16.72**	**176.16**	**82.35**	**40.35**
Mean Values per plot(Overall)			**0.20**	**232**	**4.77**	**39.61**	**19.70**	**9.65**

Appendix 5: Detailed summary on N, G, V/ha, Basal area/ha and tC/ha

Stratum			1	2	3	4	5	Grand total	Mean per plot (general)	Mean per plot private tenure	Mean per plot Communal tenure
Total Stocking values per hectare	Diameter classes										
	5 cm to 2o cm	**N**	1658	1062	3028	2370	313	**8431**	**196**	**198**	**156**
		G	16.53	9.87	29.91	21.44	3.83	**81.57**	**1.90**	**1.90**	**1.91**
		V	100.75	55.80	172.63	122.69	22.64	**474.52**	**11.04**	**11.02**	**11.32**
		Biomass/Ha	53.26	32.26	95.64	66.03	12.12	**259.31**	**6.03**	**6.03**	**6.06**
		tC/Ha	26.10	15.81	46.86	32.35	5.94	**127.06**	**2.95**	**2.95**	**2.97**
	21 cm to 40 cm	**N**	443	126	475	109	220	**1374**	**31.9484**	**17**	**110**
		G	26.81	7.63	32.79	6.46	16.94	**90.64**	**2.11**	**1.80**	**8.47**
		V	224.07	57.11	334.54	63.06	160.94	**839.71**	**20.00**	**17.00**	**80.00**
		Biomass/Ha	100.81	28.24	175.81	33.40	81.17	**419.44**	**9.75**	**8.25**	**40.59**
		tC/Ha	49.40	13.84	86.15	16.36	39.78	**205.52**	**4.78**	**4.04**	**19.89**
	22 cm to 6o cm	**N**	10	0	77	7	53	**146**	**3**	**2**	**26**
		G	1.39	0.00	13.10	1.04	9.24	**24.77**	**0.58**	**0.38**	**4.62**
		V	9.70	0.00	135.38	10.71	127.14	**282.94**	**6.58**	**3.80**	**63.57**
		Biomass/Ha	4.40	0.00	66.86	5.67	56.70	**133.64**	**3.11**	**1.88**	**28.35**
		tC/Ha	2.16	0.00	32.76	2.78	27.78	**65.48**	**1.52**	**0.92**	**13.89**

Stratum			1	2	3	4	5	Grand total	Mean per plot (general)	Mean per plot private tenure	Mean per plot Communal tenure
Total Stocking values per hectare	> 60 cm	N	0	4	5	0	5	**14**	**0**	**0**	**3**
		G	0	3.08	1.71	0.00	3.43	**8.22**	**0.19**	**0.12**	**1.71**
		V	0	31.59	32.73	0.00	41.60	**105.92**	**2.46**	**1.57**	**20.80**
		Biomass/Ha	0	9.33	10.64	0.00	14.70	**34.66**	**0.81**	**0.49**	**7.35**
		tC/Ha	0	4.57	5.21	0.00	7.20	**16.99**	**0.40**	**0.24**	**3.60**
GRAND TOTAL		N	**2112**	**1192**	**3585**	**2486**	**590**	**9965**	**232**	**229**	**295**
		G	**44.73**	**20.58**	**77.52**	**28.93**	**33.44**	**205.19**	**4.77**	**4.19**	**16.72**
		V	**334.53**	**144.50**	**675.27**	**196.47**	**352.32**	**1703.08**	**39.61**	**32.95**	**176.16**
		Biomass/Ha	**158.47**	**69.83**	**348.95**	**105.10**	**164.69**	**847.05**	**19.70**	**16.64**	**82.35**
		tC/Ha	**77.65**	**34.22**	**170.99**	**51.50**	**80.70**	**415.05**	**9.65**	**8.15**	**40.35**
Mean		N	**192**	**149**	**211**	**497**	**295**				
		G	**4.07**	**2.57**	**4.56**	**5.79**	**16.72**				
		V	**30.41**	**18.06**	**39.72**	**39.29**	**176.16**				
		Biomass/Ha	**14.41**	**8.73**	**20.53**	**21.02**	**82.35**				
		tC/Ha	**7.06**	**4.28**	**10.06**	**10.30**	**40.35**				

Appendix 6: Species stock distributions in the four diameter classes (general)

	DBH CLASSES														
	5cm-20cm					21cm-40cm					41cm-60cm				
SPP CODE	N	G	V	Biomass	tC	N	G	V	Biomass	tC/ha	N	G	V	Biomass/ha	tC/ha
1	14	0.11	0.76	0.46	0.22	14	1.29	14.20	8.56	4.19	2	0.28	2.77	1.67	0.82
2	13	0.15	1.10	0.75	0.37	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
3	13	0.06	0.29	0.12	0.06	20	2.51	36.46	15.68	7.68	40	6.87	107.37	46.17	22.62
4	15	0.09	0.43	0.23	0.11	20	1.29	13.10	7.14	3.50	0	0.00	0.00	0.00	0.00
5	2	0.05	0.36	0.19	0.09	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
6	15	0.19	1.05	0.63	0.31	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
7	2	0.01	0.05	0.02	0.01	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
8	10	0.08	0.24	0.12	0.06	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
9	8	0.16	0.74	0.43	0.21	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
10	13	0.17	0.56	0.25	0.12	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
11	15	0.19	1.25	0.64	0.31	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
12	5	0.04	0.12	0.01	0.00	10	0.80	3.62	0.23	0.11	0	0.00	0.00	0.00	0.00
13	5	0.04	0.20	0.13	0.07	10	0.38	3.07	2.07	1.01	0	0.00	0.00	0.00	0.00
14	10	0.25	2.80	1.26	0.62	5	0.60	7.39	3.32	1.63	0	0.00	0.00	0.00	0.00
15	0	0.00	0.00	0.00	0.00	5	0.19	1.54	0.94	0.46	0	0.00	0.00	0.00	0.00
16	5	0.03	0.05	0.03	0.02	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
17	5	0.01	0.03	0.02	0.01	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
18	10	0.08	0.26	0.17	0.08	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00

	DBH CLASSESSES														
SPP	**5cm-20cm**					**21cm-40cm**					**41cm-60cm**				
CODE	**N**	**G**	**V**	**Biomass**	**tC**	**N**	**G**	**V**	**Biomass**	**tC**	**N**	**G**	**V**	**Biomass**	**tC**
19	400	1.93	1.67	0.89	0.44	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
20	104	1.35	7.30	1.60	0.78	85	4.76	23.16	5.07	2.49	5	0.76	10.34	2.27	1.11
21	17	0.22	1.24	0.68	0.33	7	0.52	4.49	2.45	1.20	5	0.87	8.68	4.73	2.32
22	40	0.24	1.83	1.32	0.65	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
23	0	0.00	0.00	0.00	0.00	10	0.71	4.95	1.99	0.98	0	0.00	0.00	0.00	0.00
24	799	6.27	34.77	16.17	7.92	86	5.78	58.49	27.20	13.33	0	0.00	0.00	0.00	0.00
25	39	0.94	2.27	0.58	0.28	27	2.11	8.28	2.10	1.03	2	0.40	3.96	1.00	0.49
26	3	0.02	0.09	0.07	0.03	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
27	0	0.00	0.00	0.00	0.00	3	0.35	1.91	0.95	0.46	0	0.00	0.00	0.00	0.00
28	10	0.18	1.20	0.83	0.41	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
29	156	1.88	12.84	6.29	3.08	75	4.33	46.18	22.26	10.91	5	0.69	10.05	4.92	2.41
30	2	0.06	0.52	0.31	0.15	10	0.45	4.69	2.85	1.40	0	0.00	0.00	0.00	0.00
31	0	0.00	0.00	0.00	0.00	10	0.99	11.39	5.35	2.62	0	0.00	0.00	0.00	0.00
32	3	0.08	0.59	0.19	0.09	30	2.70	23.85	7.75	3.80	15	2.53	22.20	7.21	3.53
33	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
34	3183	34.61	216.27	131.71	64.54	335	21.35	217.00	132.15	64.76	10	1.66	11.64	7.09	3.47
35	34	0.45	2.69	0.89	0.44	50	2.26	13.24	4.37	2.14	0	0.00	0.00	0.00	0.00
36	10	0.13	0.71	0.35	0.17	10	0.45	3.88	1.90	0.93	0	0.00	0.00	0.00	0.00
37	0	0.00	0.00	0.00	0.00	5	0.23	2.04	0.98	0.48	0	0.00	0.00	0.00	0.00
38	20	0.43	2.18	1.06	0.52	15	0.84	5.87	2.85	1.40	0	0.00	0.00	0.00	0.00
39	20	0.20	0.96	0.44	0.21	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00

	DBH CLASSES														
SPP	5cm-20cm					21cm-40cm					41cm-60cm				
CODE	N	G	V	Biomass	tC	N	G	V	Biomass	tC	N	G	V	Biomass	Tc
40	340	3.61	20.51	8.45	4.14	31	1.24	10.48	4.34	2.13	0	0.00	0.00	0.00	0.00
41	0	0.00	0.00	0.00	0.00	10	0.80	6.03	2.67	1.31	0	0.00	0.00	0.00	0.00
42	200	1.28	6.96	3.45	1.69	25	0.95	4.77	2.36	1.16	0	0.00	0.00	0.00	0.00
43	208	1.56	10.58	7.95	3.89	37	2.18	21.74	16.37	8.02	17	3.28	36.31	27.34	13.40
44	5	0.01	0.04	0.03	0.01	5	0.51	5.90	4.07	1.99	0	0.00	0.00	0.00	0.00
45	339	2.87	15.43	7.01	3.43	168	13.66	131.64	59.99	29.40	15	2.25	22.16	10.06	4.93
46	1891	16.39	93.74	49.59	24.30	124	7.16	69.03	36.52	17.89	5	0.76	10.34	5.47	2.68
47	40	0.46	2.29	1.23	0.60	10	0.59	3.15	1.69	0.83	0	0.00	0.00	0.00	0.00
48	20	0.19	1.06	0.70	0.35	30	1.14	4.75	3.16	1.55	0	0.00	0.00	0.00	0.00
49	20	0.16	0.83	0.39	0.19	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
50	295	3.37	19.82	8.38	4.11	57	4.98	49.35	20.87	10.23	24	4.42	37.12	15.70	7.69
51	5	0.13	0.90	0.39	0.19	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
52	0	0.00	0.00	0.00	0.00	20	1.32	13.03	5.63	2.76	0	0.00	0.00	0.00	0.00
53	2	0.00	0.01	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
54	0	0.00	0.00	0.00	0.00	5	0.31	2.00	0.85	0.42	0	0.00	0.00	0.00	0.00
55	10	0.20	1.11	0.25	0.12	8	0.74	7.61	1.75	0.86	0	0.00	0.00	0.00	0.00
56	14	0.16	1.33	0.94	0.46	2	0.17	1.43	1.01	0.49	0	0.00	0.00	0.00	0.00
57	5	0.04	0.14	0.08	0.04	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
58	30	0.18	0.61	0.39	0.19	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
59	10	0.25	1.78	1.24	0.61	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00

	843 1	**81.5 7**	**474.5 2**	**259.31**	**127.0 6**	**137 4**	**90.6 4**	**839.7 1**	**419.44**	**205.5 2**	**14 6**	**24.7 7**	**282.9 4**	**133.64**	**65.4 8**

Dbh CLASS										
	>60 cm					TOTAL				
SPP CODE	N	G	V/ha	BIOMASS/ha	Tc	N	G	V/ha	BIOMASS/ha	tC/ha
1	0	0.00	0.00	0.00	0.00	30	1.68	17.73	10.69	5.24
2	0	0.00	0.00	0.00	0.00	13	0.15	1.10	0.75	0.37
3	0	0.00	0.00	0.00	0.00	73	9.45	144.11	61.97	30.36
4	0	0.00	0.00	0.00	0.00	35	1.38	13.52	7.37	3.61
5	0	0.00	0.00	0.00	0.00	2	0.05	0.36	0.19	0.09
6	0	0.00	0.00	0.00	0.00	15	0.19	1.05	0.63	0.31
7	0	0.00	0.00	0.00	0.00	2	0.01	0.05	0.02	0.01
8	0	0.00	0.00	0.00	0.00	10	0.08	0.24	0.12	0.06
9	0	0.00	0.00	0.00	0.00	8	0.16	0.74	0.43	0.21
10	0	0.00	0.00	0.00	0.00	13	0.17	0.56	0.25	0.12
11	0	0.00	0.00	0.00	0.00	15	0.19	1.25	0.64	0.31
12	0	0.00	0.00	0.00	0.00	15	0.84	3.74	0.24	0.12
13	0	0.00	0.00	0.00	0.00	15	0.42	3.27	2.20	1.08
14	0	0.00	0.00	0.00	0.00	15	0.85	10.19	4.57	2.24
15	0	0.00	0.00	0.00	0.00	5	0.19	1.54	0.94	0.46
16	0	0.00	0.00	0.00	0.00	5	0.03	0.05	0.03	0.02
17	0	0.00	0.00	0.00	0.00	5	0.01	0.03	0.02	0.01
18	0	0.00	0.00	0.00	0.00	10	0.08	0.26	0.17	0.08

SPP CODE	DBH CLASS >60 cm N	G	V	Biomass	Tc	TOTAL N	G	V	Biomass	tC
19	0	0.00	0.00	0.00	0.00	400	1.93	1.67	0.89	0.44
20	0	0.00	0.00	0.00	0.00	194	6.87	40.80	8.93	4.38
21	0	0.00	0.00	0.00	0.00	29	1.61	14.41	7.85	3.85
22	0	0.00	0.00	0.00	0.00	40	0.24	1.83	1.32	0.65
23	0	0.00	0.00	0.00	0.00	10	0.71	4.95	1.99	0.98
24	0	0.00	0.00	0.00	0.00	886	12.05	93.26	43.36	21.25
25	2	1.51	15.09	3.82	1.87	70	4.95	29.61	7.49	3.67
26	0	0.00	0.00	0.00	0.00	3	0.02	0.09	0.07	0.03
27	0	0.00	0.00	0.00	0.00	3	0.35	1.91	0.95	0.46
28	0	0.00	0.00	0.00	0.00	10	0.18	1.20	0.83	0.41
29	0	0.00	0.00	0.00	0.00	236	6.90	69.07	33.48	16.40
30	0	0.00	0.00	0.00	0.00	12	0.51	5.21	3.17	1.55
31	0	0.00	0.00	0.00	0.00	10	0.99	11.39	5.35	2.62
32	7.5	4.18	62.29	20.25	9.92	55	9.48	108.93	35.40	17.35
33	2	1.57	16.50	5.51	2.70	2	1.57	16.50	5.51	2.70
34	0	0.00	0.00	0.00	0.00	3528	57.62	444.91	270.95	132.76
35	0	0.00	0.00	0.00	0.00	84	2.70	15.93	5.26	2.58
36	0	0.00	0.00	0.00	0.00	20	0.59	4.59	2.24	1.10
37	0	0.00	0.00	0.00	0.00	5	0.23	2.04	0.98	0.48
38	0	0.00	0.00	0.00	0.00	35	1.27	8.06	3.92	1.92
39	0	0.00	0.00	0.00	0.00	20	0.20	0.96	0.44	0.21

	DBH CLASS					TOTAL				
SPP	>60 cm									
CODE	N	G	V	Biomass	tC	N	G	V	Biomass	tC
40	0	0.00	0.00	0.00	0.00	371	4.85	30.99	12.79	6.27
41	0	0.00	0.00	0.00	0.00	10	0.80	6.03	2.67	1.31
42	0	0.00	0.00	0.00	0.00	225	2.23	11.73	5.82	2.85
43	0	0.00	0.00	0.00	0.00	263	7.02	68.63	51.66	25.31
44	0	0.00	0.00	0.00	0.00	10	0.52	5.94	4.09	2.00
45	0	0.00	0.00	0.00	0.00	522	18.78	169.24	77.06	37.76
46	0	0.00	0.00	0.00	0.00	2019	24.31	173.11	91.57	44.87
47	0	0.00	0.00	0.00	0.00	50	1.05	5.44	2.92	1.43
48	0	0.00	0.00	0.00	0.00	50	1.34	5.81	3.87	1.89
49	0	0.00	0.00	0.00	0.00	20	0.16	0.83	0.39	0.19
50	2.5	0.96	12.03	5.09	2.49	379	13.73	118.31	50.05	24.52
51	0	0.00	0.00	0.00	0.00	5	0.13	0.90	0.39	0.19
52	0	0.00	0.00	0.00	0.00	20	1.32	13.03	5.63	2.76
53	0	0.00	0.00	0.00	0.00	2	0.00	0.01	0.00	0.00
54	0	0.00	0.00	0.00	0.00	5	0.31	2.00	0.85	0.42
55	0	0.00	0.00	0.00	0.00	18	0.94	8.72	2.00	0.98
56	0	0.00	0.00	0.00	0.00	16	0.33	2.76	1.95	0.95
57	0	0.00	0.00	0.00	0.00	5	0.04	0.14	0.08	0.04
58	0	0.00	0.00	0.00	0.00	30	0.18	0.61	0.39	0.19
59	0	0.00	0.00	0.00	0.00	10	0.25	1.78	1.24	0.61
	14	**8.22**	**105.92**	**34.66**	**16.99**	**9965**	**205.19**	**1703.08**	**847.05**	**415.05**

Appendix 7: Contribution of 17 species in communal tenure regime on stock values in different dbh classes

	DBH CLASSES														
	5cm-20cm					21cm-40cm					41cm-60cm				
SPP CODE	N	G	V	Biomass	tC	N	G	V	Biomass	Tc	N	G	V	Biomass	tC
2	3	0.06	0.45	0.31	0.15	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
3	0	0.00	0.00	0.00	0.00	20	2.51	36.46	15.68	7.68	40	6.87	107.37	46.17	22.62
9	3	0.08	0.35	0.21	0.10	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
10	3	0.02	0.06	0.03	0.01	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
14	0	0.00	0.00	0.00	0.00	5	0.60	7.39	3.32	1.63	0	0.00	0.00	0.00	0.00
20	18	0.19	0.90	0.20	0.10	25	1.97	7.88	1.72	0.85	0	0.00	0.00	0.00	0.00
24	60	0.24	1.07	0.50	0.24	3	0.10	0.77	0.36	0.17	0	0.00	0.00	0.00	0.00
32	3	0.08	0.59	0.19	0.09	20	1.84	14.24	4.63	2.27	0	0.00	0.00	0.00	0.00
34	113	1.75	11.59	7.06	3.46	73	5.29	55.17	33.60	16.46	10	1.66	11.64	7.09	3.47
35	0	0.00	0.00	0.00	0.00	10	0.62	2.77	0.91	0.45	0	0.00	0.00	0.00	0.00
38	10	0.20	1.21	0.59	0.29	10	0.53	3.72	1.81	0.89	0	0.00	0.00	0.00	0.00

40	13	0.16	0.96	0.40	0.19	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
43	8	0.12	0.78	0.59	0.29	25	1.55	15.62	11.76	5.76	0	0.00	0.00	0.00	0.00
45	18	0.23	1.16	0.52	0.26	18	1.16	8.80	4.00	1.96	0	0.00	0.00	0.00	0.00
46	3	0.06	0.45	0.24	0.12	5	0.33	4.17	2.21	1.08	0	0.00	0.00	0.00	0.00
50	63	0.63	3.08	1.30	0.64	5	0.21	1.44	0.61	0.30	3	0.71	8.13	3.44	1.69
55	0	0.00	0.00	0.00	0.00	3	0.23	2.52	0.58	0.28	0	0.00	0.00	0.00	0.00
Total	**313**	**3.83**	**22.64**	**12.12**	**5.94**	**220**	**16.94**	**160.94**	**81.17**	**39.78**	**53**	**9.24**	**127.14**	**56.70**	**27.78**

	DBH CLASS >60 cm					**TOTAL**				
SPP CODE	**N**	**G**	**V**	**BIOMASS**	**tC**	**N**	**G**	**V**	**BIOMASS**	**tC**
2	0	0.00	0.00	0.00	0.00	3	0.06	0.45	0.31	0.15
3	0	0.00	0.00	0.00	0.00	60	9.39	143.83	61.85	30.30
9	0	0.00	0.00	0.00	0.00	3	0.08	0.35	0.21	0.10
10	0	0.00	0.00	0.00	0.00	3	0.02	0.06	0.03	0.01
14	0	0.00	0.00	0.00	0.00	5	0.60	7.39	3.32	1.63

20	0	0.00	0.00	0.00	0.00	43	2.16	8.78	1.92	0.94
24	0	0.00	0.00	0.00	0.00	63	0.34	1.84	0.85	0.42
32	3	2.46	29.57	9.61	4.71	25	4.38	44.40	14.43	7.07
34	0	0.00	0.00	0.00	0.00	195	8.70	78.40	47.75	23.40
35	0	0.00	0.00	0.00	0.00	10	0.62	2.77	0.91	0.45
38	0	0.00	0.00	0.00	0.00	20	0.73	4.92	2.39	1.17
40	0	0.00	0.00	0.00	0.00	13	0.16	0.96	0.40	0.19
43	0	0.00	0.00	0.00	0.00	33	1.68	16.40	12.35	6.05
45	0	0.00	0.00	0.00	0.00	35	1.39	9.96	4.52	2.21
46	0	0.00	0.00	0.00	0.00	8	0.39	4.61	2.44	1.20
50	3	0.96	12.03	5.09	2.49	73	2.51	24.68	10.44	5.12
55	0	0.00	0.00	0.00	0.00	3	0.23	2.52	0.58	0.28
Total	**5**	**3.43**	**41.60**	**14.70**	**7.20**	**590**	**33.44**	**352.32**	**164.69**	**80.70**

Appendix 8: Stock value contribution of 59 species in private tenure regime on dbh classes

							DBH CLASSES								
	5cm-20cm					**21cm-40cm**					**41cm-60cm**				
SPP CODE	**N**	**G**	**V**	**Biomass**	**tC**	**N**	**G**	**V**	**Biomass**	**tC**	**N**	**G**	**V**	**Biomass**	**tC**
1	14	0.11	0.76	0.46	0.22	14	1.29	14.20	8.56	4.20	2	0.28	2.77	1.67	0.82
2	10	0.09	0.65	0.45	0.22	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00

3	12.5	0.06	0.29	0.12	0.06	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
4	15	0.09	0.43	0.23	0.11	20	1.29	13.10	7.14	3.50	0	0.00	0.00	0.00	0.00
5	2	0.05	0.36	0.19	0.09	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
6	15	0.19	1.05	0.63	0.31	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
7	2	0.01	0.05	0.02	0.01	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
8	10	0.08	0.24	0.12	0.06	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
9	5	0.08	0.39	0.23	0.11	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
10	10	0.15	0.50	0.23	0.11	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
11	15	0.19	1.25	0.64	0.31	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
12	5	0.04	0.12	0.01	0.00	10	0.81	3.62	0.23	0.11	0	0.00	0.00	0.00	0.00
13	5	0.04	0.20	0.13	0.07	10	0.38	3.07	2.07	1.01	0	0.00	0.00	0.00	0.00
14	10	0.26	2.80	1.26	0.62	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
15	0	0.00	0.00	0.00	0.00	5	0.19	1.54	0.94	0.46	0	0.00	0.00	0.00	0.00
16	5	0.03	0.05	0.03	0.02	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
17	5	0.01	0.03	0.02	0.01	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
18	10	0.08	0.26	0.17	0.08	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00

	DBH CLASSES														
SPP	**5 cm-20 cm**					**21 cm-40 cm**					**41 cm-60 cm**				
CODE	**N**	**G**	**V**	**Biomass**	**tC**	**N**	**G**	**V**	**Biomass**	**tC**	**N**	**G**	**V**	**Biomass**	**tC**
19	400	1.93	1.67	0.89	0.44	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
20	87	1.16	6.39	1.40	0.69	60	2.79	15.28	3.35	1.64	5	0.76	10.30	2.27	1.11
21	17	0.22	1.24	0.68	0.33	7	0.52	4.49	2.45	1.20	5	0.87	8.68	4.73	2.32
22	40	0.24	1.83	1.32	0.65	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
23	0	0.00	0.00	0.00	0.00	10	0.71	4.95	1.99	0.98	0	0.00	0.00	0.00	0.00
24	739	6.03	33.70	15.67	7.68	84	5.69	57.72	26.80	13.15	0	0.00	0.00	0.00	0.00
25	39	0.94	2.28	0.58	0.28	27	2.11	8.28	2.10	1.03	2	0.40	3.96	1.00	0.49
26	3	0.02	0.09	0.07	0.04	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
27	0	0.00	0.00	0.00	0.00	3	0.35	1.91	0.95	0.46	0	0.00	0.00	0.00	0.00
28	10	0.18	1.20	0.83	0.41	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
29	156	1.88	12.84	6.29	3.08	75	4.33	46.18	22.30	10.91	5	0.69	10.00	4.92	2.41
30	2	0.06	0.52	0.31	0.15	10	0.45	4.69	2.85	1.40	0	0.00	0.00	0.00	0.00
31	0	0.00	0.00	0.00	0.00	10	0.99	11.39	5.35	2.62	0	0.00	0.00	0.00	0.00
32	0	0.00	0.00	0.00	0.00	10	0.86	9.61	3.12	1.53	15	2.53	22.20	7.21	3.53
33	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
34	3070	32.90	204.70	124.60	61.08	263	16.05	161.80	98.60	48.29	0	0.00	0.00	0.00	0.00
35	34	0.45	2.70	0.89	0.44	40	1.64	10.46	3.45	1.69	0	0.00	0.00	0.00	0.00
36	10	0.13	0.71	0.35	0.17	10	0.45	3.88	1.90	0.93	0	0.00	0.00	0.00	0.00
37	0	0.00	0.00	0.00	0.00	5	0.23	2.04	0.98	0.48	0	0.00	0.00	0.00	0.00

38	10	0.23	0.98	0.47	0.23	5	0.31	2.16	1.05	0.51	0	0.00	0.00	0.00	0.00
39	20	0.20	0.96	0.44	0.22	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00

	DBH CLASSES														
SPP	**5 cm-20 cm**					**21 cm-40 cm**					**41 cm-60 cm**				
CODE	**N**	**G**	**V**	**Biomass**	**tC**	**N**	**G**	**V**	**Biomass**	**Tc**	**N**	**G**	**V**	**Biomass**	**tC**
40	327	3.45	19.55	8.06	3.95	31	1.24	10.48	4.34	2.13	0	0.00	0.00	0.00	0.00
41	0	0.00	0.00	0.00	0.00	10	0.81	6.03	2.67	1.31	0	0.00	0.00	0.00	0.00
42	200	1.28	6.96	3.45	1.69	25	0.95	4.77	2.36	1.16	0	0.00	0.00	0.00	0.00
43	201	1.44	9.80	7.36	3.61	12	0.63	6.12	4.61	2.26	17	3.28	36.30	27.30	13.40
44	5	0.01	0.04	0.03	0.01	5	0.51	5.90	4.07	1.99	0	0.00	0.00	0.00	0.00
45	321	2.63	14.28	6.48	3.18	151	12.50	122.80	56.00	27.44	15	2.25	22.20	10.10	4.93
46	1888	16.30	93.29	49.35	24.18	119	6.83	64.86	34.30	16.81	5	0.76	10.30	5.47	2.68
47	40	0.46	2.29	1.23	0.60	10	0.59	3.15	1.69	0.83	0	0.00	0.00	0.00	0.00
48	20	0.19	1.06	0.70	0.35	30	1.14	4.75	3.16	1.55	0	0.00	0.00	0.00	0.00
49	20	0.16	0.83	0.39	0.19	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
50	232	2.74	16.74	7.08	3.47	52	4.77	47.91	20.30	9.93	22	3.71	29.00	12.30	6.01
51	5	0.13	0.90	0.39	0.19	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
52	0	0.00	0.00	0.00	0.00	20	1.32	13.03	5.63	2.76	0	0.00	0.00	0.00	0.00
53	2	0.00	0.02	0.01	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
54	0	0.00	0.00	0.00	0.00	5	0.31	2.00	0.85	0.42	0	0.00	0.00	0.00	0.00
55	10	0.20	1.11	0.25	0.13	5	0.51	5.09	1.17	0.57	0	0.00	0.00	0.00	0.00
56	14	0.16	1.33	0.94	0.46	2	0.17	1.43	1.01	0.49	0	0.00	0.00	0.00	0.00
57	5	0.04	0.14	0.08	0.04	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
58	30	0.18	0.61	0.39	0.19	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
59	10	0.25	1.78	1.24	0.61	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00

Total	**8118**	**77.70**	**451.90**	**247.20**	**121.10**	**1154**	**73.70**	**678.80**	**338.00**	**165.70**	**93**	**15.53**	**156.00**	**76.90**	**37.70**

SPP CODE	DBH CLASS >60 cm N	G	V	Biomass	tC	Total N	G	V	Biomass	tC
1	0	0	0	0	0	30	1.68	17.70	10.69	5.24
2	0	0	0	0	0	10	0.09	0.65	0.45	0.22
3	0	0	0	0	0	13	0.06	0.29	0.12	0.06
4	0	0	0	0	0	35	1.38	13.50	7.37	3.61
5	0	0	0	0	0	2	0.05	0.36	0.19	0.09
6	0	0	0	0	0	15	0.19	1.05	0.63	0.31
7	0	0	0	0	0	2	0.01	0.05	0.02	0.01
8	0	0	0	0	0	10	0.08	0.24	0.12	0.06
9	0	0	0	0	0	5	0.08	0.39	0.23	0.11
10	0	0	0	0	0	10	0.15	0.50	0.23	0.11
11	0	0	0	0	0	15	0.19	1.25	0.64	0.31
12	0	0	0	0	0	15	0.84	3.74	0.24	0.12
13	0	0	0	0	0	15	0.42	3.27	2.20	1.08
14	0	0	0	0	0	10	0.26	2.80	1.26	0.62
15	0	0	0	0	0	5	0.19	1.54	0.94	0.46
16	0	0	0	0	0	5	0.03	0.05	0.03	0.02
17	0	0	0	0	0	5	0.01	0.03	0.02	0.01
18	0	0	0	0	0	10	0.08	0.26	0.17	0.08

SPP CODE	DBH CLASS >60 cm N	G	V	Biomass	tC	Total N	G	V	Biomass	tC
19	0	0	0	0	0	400	1.93	1.67	0.89	0.44
20	0	0	0	0	0	152	4.71	32.00	7.01	3.44
21	0	0	0	0	0	29	1.61	14.40	7.85	3.85
22	0	0	0	0	0	40	0.24	1.83	1.32	0.65
23	0	0	0	0	0	10	0.71	4.95	1.99	0.98
24	0	0	0	0	0	823	11.72	91.40	42.51	20.83
25	2	1.51	15.09	3.82	1.87	70	4.95	29.60	7.49	3.67
26	0	0	0	0	0	3	0.02	0.09	0.07	0.03
27	0	0	0	0	0	3	0.35	1.91	0.95	0.46
28	0	0	0	0	0	10	0.18	1.20	0.83	0.41
29	0	0	0	0	0	236	6.90	69.10	33.48	16.41
30	0	0	0	0	0	12	0.51	5.21	3.17	1.55
31	0	0	0	0	0	10	0.99	11.40	5.35	2.62
32	5	1.71	32.73	10.64	5.21	30	5.10	64.50	20.97	10.28
33	2	1.57	16.5	5.51	2.7	2	1.57	16.50	5.51	2.70
34	0	0	0	0	0	3333	48.92	367.00	223.20	109.37
35	0	0	0	0	0	74	2.09	13.20	4.34	2.13
36	0	0	0	0	0	20	0.59	4.59	2.24	1.10
37	0	0	0	0	0	5	0.23	2.04	0.98	0.48
38	0	0	0	0	0	15	0.54	3.13	1.52	0.75
39	0	0	0	0	0	20	0.20	0.96	0.44	0.21

	DBH CLASS									
SPP			>60 cm			Total				
CODE	N	G	V	Biomass	tC	N	G	V	Biomass	tC
40	0	0	0	0	0	358	4.70	30.00	12.39	6.07
41	0	0	0	0	0	10	0.81	6.03	2.67	1.31
42	0	0	0		0	225	2.23	11.70	5.82	2.85
43	0	0	0	0	0	230	5.34	52.20	39.31	19.26
44	0	0	0	0	0	10	0.52	5.94	4.09	2.00
45	0	0	0	0	0	487	17.39	159.00	72.54	35.55
46	0	0	0	0	0	2012	23.91	168.00	89.13	43.68
47	0	0	0	0	0	50	1.05	5.44	2.92	1.43
48	0	0	0	0	0	50	1.34	5.81	3.87	1.89
49	0	0	0	0	0	20	0.16	0.83	0.39	0.19
50	0	0	0	0	0	306	11.22	93.60	39.61	19.41
51	0	0	0	0	0	5	0.13	0.90	0.39	0.19
52	0	0	0	0	0	20	1.32	13.00	5.63	2.76
53	0	0	0	0	0	2	0.00	0.01	0.01	0.00
54	0	0	0	0	0	5	0.31	2.00	0.86	0.42
55	0	0	0	0	0	15	0.71	6.20	1.43	0.70
56	0	0	0	0	0	16.4	0.33	2.76	1.95	0.95
57	0	0	0	0	0	5	0.04	0.14	0.08	0.04
58	0	0	0	0	0	30	0.18	0.61	0.39	0.19
59	0	0	0	0	0	10	0.26	1.78	1.24	0.61
Total	**9**	**4.79**	**64.32**	**19.96**	**9.78**	**9375**	**171.80**	**1351.00**	**682.40**	**334.35**

Appendix 9: Land expectation value calculation for private tenure regime

S/N	PRICE/COST	UNIT		AMOUNT(TSHS)
1	Site preparation cost	67754 tshs/ha	67754* 47.4560	3215333.824
2	Purchase of seedlings cost	100 tshs/seedling	100 *47.4560*1600	7592960
3	Planting cost	67754 tshs/ha	67754*47.4560	3215333.824
4	Thinning cost	101631 tshs/ha	101631*47.4560	4823000.736
5	Weeding(twice a year) cost	112924 tshs/ha	112924*47.4560	5358921.344
6	Pruning cost	62108 tshs/ha	62108*47.4560	2947397.248
7	clear felling cost	2240 tshs/m3	2240*1552.3	3477152
8	Costs for releasing 64.4403 tC in the atmosphere through burning of sawdust and firewood	10*1750*64.4403	934384.35	10*1750*64.4403
9	Transport costs	92926*1133.17	105300955.4	92926*1133.17
10	Costs for releasing 21.576 tC in the atmosphere through decomposition of waste/logging residues(branches and tops)	10*1750*21.5766	312860.7	10*1750*21.5766
11	Sawing cost	22982 tshs/m3	22982*1133.179	26042719.78
	Total costs			**163221019.2**
12	Overhead	30% of total		48966305.77
	Total costs including overhead			**212187325**
13	Pole revenue	600/m=28,800 TSHS/M3	28800*97.0188	2794141.44
14	Firewood revenue	15000/m3	15000*147.4685	2212027.5

S/N	PRICE/COST	UNIT		AMOUNT(TSHS)
15	Lumber revenue	205297 tshs/m3	205297*0.4*1133.179	93055299.67
16	Sawdust revenue	2000 tshs/m3	2000*226.6358	453271.6
17	slabs revenue	15000/m3	15000*453.2716	6799074
18	Sale of carbon(from standing trees 1089.21 tC)	10 US$/tC	934384.35	15793545
19	Revenue for storing completely 297.557 tC	10 US$/tC	10*1750*297.557	4314576.5
	Total revenue			**125421935.7**
	Estimated net revenue =Total revenue - Total costs			**-82605088.29**
	LEV= --826 050 882.9 Tshs (-4573925.154 Tshs/ha) equivalent to -472029.1 US$ (-25326.27 US$/ha)			

Appendix 10: Land expectation value calculation for communal tenure regime

S/N	PRICE/COST	UNIT		AMOUNT(TSHS)
1	Site preparation cost	67754 tshs/ha	67754* 0.0899	6091.0846
2	Purchase of seedlings cost	100 tshs/seedling	100 * 0.0899*1600	14384
3	Planting cost	67754 tshs/ha	67754* 0.0899	6091.0846
4	Thinning cost	101631 tshs/ha	101631* 0.0899	9136.6269
5	Weeding(twice a year) cost	112924 tshs/ha	112924* 0.0899	10151.8676
6	Pruning cost	62108 tshs/ha	62108* 0.0899	5583.5092
7	clearfelling cost	2240 tshs/m3	2240*11.1738	25029.312
8	Costs for releasing 0.4821 tC in the atmosphere through burning of sawdust and firewood	10 US$/Tc	10*1750*0.4821	8436.75
9	Transport costs	92926 tshs/m3	92926*8.1569	757988.0894
10	Costs for releasing 0.1614 tC in the atmosphere through decomposition of waste/logging residues(branches and tops)	10US$/tC	10*1750*0.1614	2824.5
11	Sawing cost	22982 tshs/m3	22982*8.1569	187461.8758
	Total costs			1033178.7
12	Overhead	30% of total		309953.61
	Total costs including overhead			1343132.31
13	Pole revenue	600/m=(600*4m*12pcs*97.01875)=28,800 TSHS/M3	28800*8.1569	234918.72
14	Firewood revenue	15000/m3	15000*1.0615	15922.5

S/N	PRICE/COST	UNIT		AMOUNT(TSHS)
15	Lumber revenue	205297 tshs/m3	205297*0.4*8.1569	669834.8397
16	Sawdust revenue	2000 tshs/m3	2000*1.6314	3262.8
17	slabs revenue	15000/m3	15000*3.2628	48942
18	Sale of carbon(from standing trees	10 US$/tC	10*1750*49.5854	867744.5
19	Revenue for storing completely 2.2.2259 tC	10 US$/tC	10*1750*2.2259	39532.5
	Total revenue			**1880157.86**

Estimated net revenue = Total revenue-Total cost **537025.5496**

LEV= Tshs. 5 370 255.496 (Tshs/ha),
equivalent to 4130965.76 US$(2360.551866 US$/ha)

Appendix 11: Carbon equivalency values of the tree produce from private and communal tenure regimes

		Tenure regime			
		Private		Communal	
S/N	**Tree Produce**	**Volume m^3**	**Carbon(tC) (vol*0.2471)**	**Volume m^3**	**Carbon(tC) (vol*0.2291)**
1	Poles	97.0188	23.9733	0.6984	0.1793
2	Waste(50%)	87.3169	21.576	0.6285	0.1614
3	Slabs	453.2716	112.0034	3.2628	0.8379
4	50%sawdust volume	113.3179	28.0009	0.8157	0.2095
5	Lumber	453.2716	112.0034	3.2628	0.8379
6	Total carbon to be stored completely (1+2+3+4+5)		297.557		2.226
7	Firewood	147.4685	36.4395	1.0615	0.2726
8	50%sawdust volume	113.3179	28.0008	0.8157	0.2095
9	50%waste	87.3169	21.576	0.6285	0.1614
10	Total carbon to be released to the atmosphere(7+8+9)		86.0163		0.6435
11	Total carbon in tenure regime(mean carbon/ha*area of TOF under tenure regime) 180.6ha*8.1549stems/ha		1472.783	1.3ha*40.3499	52.4548
12	Total carbon to be removed from through harvesting(6+10)		383.5733		2.8694
13	Total carbon remaining stored in standing trees(11-12)		1089.21		49.5854