CARBON STOCK AND EMISSION DIFFERENCE BY WOODLAND DEGRADATION AROUND A REDD+ PILOT SITE IN KILOSA, MOROGORO TANZANIA

ALBERT LEONARD MANGOWI

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN ECOSYSTEM SCIENCE AND MANAGEMENT OF SOKOINE UNIVERSITY OF AGRICULTURE, MOROGORO, TANZANIA

2015

ABSTRACT

Among the major issues in the implementation of REDD+ activities is leakage or displacement' resulting from activity shifting associated with the process. This study aimed at assessing potential leakage in terms of carbon stock and emission difference by degradation in REDD+ pilot site and areas around REDD+ pilot project in Kilosa. Data were collected from 84 rectangular plots measuring 20×10m established within the REDD+ pilot site and around REDD+ pilot sites. The numbers of stumps, stump diameter, diameter at breast height (DBH) for trees ≥5cm diameter and species local and botanical names were recorded. The above ground carbon stocks were estimated to be 31.5 $tCha^{-1}$ in the REDD+ pilot site and 3 $tCha^{-1}$ around REDD+ pilot sites. The genera *Brachystegia* contributed the highest amount in both sites with 70% of total above ground carbon in REDD+ pilot site and 55% around REDD+ pilot site. Areas around the REDD+ pilot site had higher stump density of 70 stumps ha^{-1} than those in the REDD+ pilot site with 12 stumps ha^{-1} of which majority were *Brachystegia microphylla* and *Brachystegia boehmii*. The estimated carbon loss was 1.17 $tCha^{-1}$ (4.29 $tCO_2e\ ha^{-1}$) in REDD+ pilot site and 1.92 $tCha^{-1}$ (7.05 $tCO_2e\ ha^{-1}$) around the REDD+ pilot sites. This is an indication of shifts in utilization resulting from the implementation of REDD+ activity in Kilosa. Such anomalies should be addressed before one can judge the success of the REDD+ project in the area.

Key words: *Carbon emission, degradation, leakage, REDD+ pilot site*

DECLARATION

I, Albert Leonard Mangowi; do declare to the senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in other institution.

Albert Leonard Mangowi Date

(Msc Ecosystem Science and Management)

The above declaration is confirmed by,

Professor P. K. T. Munishi Date

(Supervisor)

COPYRIGHT

ACKNOWLEDGEMENT

I acknowledge the Leakage Project through Climate Change Impacts, Adaptation and Modelling for sponsoring my research. The leakage project was funded by Climate Change Impacts, Adaptation and Modelling programme implemented by Norway and Tanzania governments. Thanks to Mr Anton from Nyali village for his taxonomic expertise and assistance with plant identification in the field. I am also thankful to Mr John Herbert for assisting me with data collection.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

$\approx$	Approximately to
bd	Stump diameter
CCIAM	Climate Change Impacts, Adaptation and Modelling
CIFOR	Centre for International Forestry Research
dbh	Diameter at breast height
FAO	Food and Agriculture Organization of United Nation
GHG	Greenhouse gas
MJUMITA	Mtandao wa Jamii wa Usimamizi wa Misitu Tanzania
m	Metre
mm	Millimetre
MNRT	Ministry of Natural Resources and Tourism
MRV	Measurement, Reporting and Verification
PEN	Poverty and Environmental Network
REDD	Reduce Emission from Deforestation and Forest Degradation
ha^{-1}	Per hectare
$tCha^{-1}$	Tonnes of carbon per hectare
tCO_2eha^{-1}	Tonnes of carbon dioxide emission per hectare
TFCG	Tanzania Forest Conservation Group
UNFCCC	United Nation Framework on Convention on Climate Change

CHAPTER ONE

1.1 Background Information

In the tropics dry woodland including miombo provides 40% of the forest cover (Abbot and Homewood, 1999). According to MNRT (1998), 66% (≈ 226 666 km^2) of the forest cover in Tanzania is woodland (Fyhrquist *et. al.,* 2002; Shirima *et al.,* 2011), whereas the miombo woodland makes 23% (≈ 1 228 km^2) of all the standing vegetation in the Eastern Arc Mountain (Shirima *et al.,* 2011).

Rough estimates a decade ago suggested that 40 million people inhabited areas covered, or formerly covered, by miombo woodland, with an additional 15 million urban dwellers relying on miombo wood or charcoal as a source of energy (Campbell, 1996; Campbell *et al*., 2007). The miombo is characterized by the genera Julbernadia, Brachystegia, and Isoberlinia (Byers *et. al.,* 2001), a mature single storey comprising 10-20 m high, partly closed canopy of pinnate single-leafed trees; a discontinuous understorey of broad leafed shrubs; and often sparse and continuous herbaceous layer of forbs small sedges, and caespitose, heliophytic C_4 grasses (Campbell, 1996; Shirima *et al.,* 2011). Elephants, lions, buffalos, antelopes and high bird diversity are the likely fauna present in the area (Byers *et. al.,* 2001).

The mean annual temperature and precipitation of the area is (18.0–23.1) ^{O}C and 710–1365 mm (Frost, 1996) making the area conducive for the mentioned vegetation. But again maintenance of the grasses is through early season burning in most part of the ecosystem, whereas some places receives very little rain to an extent that supports only woody savannah (Shirima *et al.,* 2011).

Miombo woodlands are the primary source of energy, in the form of firewood and charcoal, and a crucial source of essential subsistence goods (Gauslaa, 1988; Dewees, 1994). Important products include poles and construction products, timber, materials for tool handles and household utensils, foods, medicines, leaf litter, grazing and browse. In addition woodlands have a service role in controlling soil erosion, providing shade, modifying hydrological cycles and maintaining soil fertility. Religious and cultural customs which relate to designated woodland areas and certain tree species are vital to the spiritual well-being and effective functioning of rural communities.

The majority of the residents of the miombo region are poor and about 75% of them live in rural areas. Typically they are small-scale farmers who use goods and services produced by miombo woodlands (Campbell *et al*., 2002; Bond *et al.,* 2010). The resources of miombo are the central of livelihood systems for millions of rural and urban dwellers (Campbell, 1996). There have been marked changes in land cover in miombo woodland in recent years, mostly involving the conversion of woodland and wooded grassland to cultivated land, reflecting the need for more land by a continually growing population (Campbell *et al*., 2002). The increasing human population adjacent to the miombo have directly led to the increasing rates of deforestation and forest degradation that exacerbates climate change, but again deforestation and forest degradation are estimated to account for about 20% of global anthropogenic CO_2 emissions through combustion of forest biomass and decomposition of remaining plant material and soil carbon (Van der Werf *et al*., 2009) of which REDD+ Policy is the only current exciting option available.

The reasoning behind REDD+ is that forests are converted to other uses, primarily agriculture, because it makes economic sense to the land managers and users, i.e. the returns from converted landscape exceed the returns from the natural forest or woodland The solution that is encompassed in REDD+ is that individuals, communities, and local and national governments must be rewarded for conserving forests (Angelsen and Atmadja, 2008; Bond *et al*., 2010).

REDD+, as an idea, is a success story. It has generated excitement about possibilities for getting underway on climate change mitigation quickly and cheaply. REDD+ has also been broad enough to serve as a canopy under which a wide range of actors can grow their own trees. It has been through an intensive process of conceptualization, design and implementation even if it is still far from realizing its fundamental goal, namely large scale emission reductions. No idea for saving the world's tropical forests has generated anywhere near the same excitement and commitment of funds as has REDD+ (Angelsen *et al*., 2009).

However, to scientists and professionals with experience in tropical woodlands, it is not surprising that REDD+ has turned out to be much harder to implement than expected. Deforestation and forest degradation have a long history and powerful interests are much at stake in their continuation (Angelsen *et al*., 2009). Policy arenas in many countries are battlefields between interests of 'business as usual' and interests of transformational change. But this is also a good sign: those who benefit from business as usual take REDD+ seriously enough to react: this indicates that REDD+, if implemented, can have an impact (Angelsen *et al*., 2009).

REDD+ interventions can cause local/cross-province/cross-national leakage, which occurs when an emission reduction activity limits the supply of goods and services that people depend upon and in order to meet the continued demand the activities shift elsewhere. Typical examples are forest conservation activities that reduce deforestation from subsistence production, e.g., shifting cultivation or fuel wood gathering. In order to produce the agricultural crops or obtain the fuel wood needed, local deforestation agents are likely to move to surrounding areas to continue activities (Schwarze *et al.,* 2002).

Different ways exist to detect and measure leakage effects, from activity shifting can best be detected with the help of direct measurements, often in an area around a project where activities are likely to be displaced to in case leakage occurs. Measurement tools to quantify leakage effects in the area around the project site include for example ground measurements of forest area, biomass and carbon stocks where by any carbon stock and emission difference through degradation can unveil the presence or absence of leakage in areas around the project (Henders and Ostwald, 2012). Therefore for successful implementation of REDD+ strategy, assessment of carbon stock and emission difference through degradation in and around REDD+ pilot site is important.

1.2 Problem Statement and Justification

Woodlands provide a variety of goods and services including building materials, fuelwood and food (Campbell *et al.,* 2002). Before the initiation of REDD+ project local communities used to directly derive goods and services from the miombo woodlands of the Kilosa. With much of their income used to be derived from forest resources, we do not know yet if REDD+ interventions have changed this dependency on the forests for income, goods and services.

At Kilosa REDD+ pilot site much effort has been on initial phases of REDD+ implementation were the challenge is largely technical to measure greenhouse gas (GHG) emissions and removals through degradation. But the more immediate challenge, which has received little or no attention so far, is to assess whether communities have shifted their dependency to other nearby forest resources around REDD+ pilot site, resulting into leakage.

1.3 Objectives

1.3.1 Overall objective

This study aimed at assessing potential leakage in terms of carbon stock and emission difference by degradation in REDD+ pilot site and areas around REDD+ pilot project in Kilosa.

1.3.2 Specific objectives

The specific objectives were to:

- Determine carbon stock difference between the REDD+ pilot site and around REDD+ pilot site
- Determine degradation difference between REDD+ pilot site and around REDD+ pilot site
- Assess emission differences by degradation between the REDD+ pilot and around REDD+ pilot site

CHAPTER TWO

2.1 LITERATURE REVIEW

2.1.1 The evolution of REDD+

Man as the main agent of global warming was concern about the current acceleration of global carbon dioxide emission, followed by proposition of one of the mechanism for reducing emission from deforestation and forest degradation (REDD) in developing country as a mitigation measure (Burgess *et al*., 2010). Later after a second thought about addition of sustainable management of forests and enhancement of carbon stock the concept was then transformed into REDD+, an international move that lights up carbon loss due to change of carbon rich ecosystem such a forests.

Some decision during initiation phases was that for this mechanism to be successful i.e. with minimum displacement greenhouse gases between countries i.e. International leakage, it was suggested that the countries having large proportion of world forests should be ready to participate shortly after the launch. To test effectiveness the countries were supposed to get prepared for REDD+ by building capacity, design and planning REDD+ programs and pilot activities (Burgess *et al.,* 2010). In Tanzania several pilot sites were initiated, Kilosa REDD+ pilot site being among them.

2.1.2 The ecology of miombo woodland

The ecology of miombo is determined by the old geological soil crust in the semiarid zone of seasonal rainfall that has given rise to flat topography of poor drainage. The aged ancient erosion surfaces (pediplains) have resulted into river valleys of many of the major southern African rivers, with remnant plateaus of varying elevation, this creates a landscape heterogeneity of large scale across the region (Byers *et. al.,* 2001).

The emergent feature of this geology (old, flat) with a climate of single long dry season (semiarid) brought up surface and subsurface hydrological processes (i.e. dambos and seasonally flooded grasslands) that are unique in Africa. The geomorphology and the hydrology have led to leaching of nutrients from the plateau to the valleys forming a gradient of both soil nutrients and moisture resulted from erosion and other processes. These repeated patterns of soil nutrients and moisture are a characteristic feature in miombo landscape (Byers *et. al.,* 2001).

Despite of having a relative geological stability, climate change and other anthropogenic activities has led to fragmentation of miombo ecosystem and habitat reconnection that has led to speciation and adaptive radiation that has made a miombo being a centre of endemism and diversity of some taxonomic groups, e.g. a group of plant family Caesalpinioideae (Byers *et. al.,* 2001). Soils of miombo woodland are typically nutrient-poor (Campbell, 1996), with slow nutrient circling due to lack of soil moisture for a long dry season leads to low level of herbivory, but favours bulk feeding mega herbivores such as Elephants and Buffalos, such big mammals have low population increase rate adapting to low population densities. These factors, in turn, make the Caesalpinoid woodlands a “high-carbon” landscape, with an abundance of woody biomass (Byers *et. al.,* 2001).

With few herbivores and limited decomposition, fire becomes a major component of nutrients redistributor and consumer of carbon. But it is climate and human activities leads to frequent fires in the miombo woodlands (Byers *et. al.,* 2001).

2.1.3 Deforestation and forest degradation

Deforestation in UNFCCC terms involves a permanent change to another land use (Burgess *et al*., 2010), and the reasons for declining forest area in Tanzania are due to expansion of agriculture fields, uncontrolled wildfire, intense livestock grazing and charcoal making. The deforestation rate for miombo woodland is 13% over 10 years, for coastal forests is 7% and that of the closed canopy of the Eastern Arc Mountains is 1% over the same period of time (Burgess *et al*., 2010).

Degradation according to UNFCCC is a long term loss of a certain per cent of forest carbon stock and forest values since a certain time and not qualified as deforestation induced by human (Burgess *et al*., 2010). Forest degradation is due to pole cutting, logging, fire wood collection, overgrazing and wildfires. An area is still qualified as a degraded forest even if it is devoid of tress, but they are likely to grow back.

2.1.4 Agents of deforestation and woodland degradation

The population of southern Africa has been growing at a rapid rate, one of the causes of such rapid population growth rates is the high fertility levels and the reduced mortality rates experienced throughout the region. Coupled with high intrinsic growth rates is the movement of refugees (MNRT, 1994). In Tanzania, the rate of population increase per year is 2.7% with the majority of people living in rural areas where forests are located. The annual loss of forest cover in the country has increased by 37% from the period of 1990-1995 (322 000 ha/year) to 2000-2010 (403 000 ha/year). The loss is mainly due to agriculture clearings, charcoaling, firewood, and timber harvesting (FAO, 2010; Newmark, 2002).

However, one of the most striking changes in the miombo region is the rapidly-increasing urban population, a result of the very high rate of urban growth. With increased urban population comes increased woodfuel demand, usually in the form of charcoal, and increased deforestation and forest degradation in the vicinity of the urban areas (Misana *et al*., 1996).

Elephants are notably for changing woody vegetation by breaking, pushing over and uprooting trees and shrubs (Frost, 1996); it is suggested to be a display of social behaviour by male elephants. Therefore whatever it causes, damage to trees has resulted into dramatic change of woodland cover. According to Thomson (1975) in one year in Chizarira National Park, Zimbabwe, elephants killed 18% of the dominant tree species of *Brachystegia boehmii*. The overall effect in these cases has been to transform relatively dense woodlands into more open wooded grasslands with scattered tall trees, resprouting tree stumps, and a dense layer of low growing shrubs (Frost, 1996).

In the predominantly miombo woodland areas of central and western Tanzania, where more than 60% of the country's tobacco is produced, areas for cultivation have shown a staggering increase, rising from 228 000 ha in 1985-86 to 1 374 000 ha in 1991-92. Increased tobacco production has had far reaching consequences on miombo woodlands. It has led to large losses of woodlands, for land and wood fuel. While tobacco production has nearly doubled in the last ten years, wood consumption for curing and storing has increased by only 29% (Misana *et al*., 1996).

The miombo region supports considerable livestock populations. High livestock numbers are reported in Tanzania, where large tracts of land are said to be overstocked and overgrazed (Moyo *et al.,* 1993). The livestock population in Tanzania far exceeds the local carrying capacity

2.1.5 Drivers of deforestation and degradation in miombo woodlands

The drivers of land-use change vary markedly between the countries in the region depending largely on location, physical access, topography rates of economic growth, and land tenure.

There are three core or common reasons for land-use change (Campbell *et al*., 2007), which are: the conversion of woodland for agriculture and settlement; the extraction of fuel wood to meet household (Kacholi, 2013), urban and sometimes industrial purposes; hardwood timber extraction (Bond *et al.,* 2010). These processes can often reinforce each other and are often aided by the development of mines, urban settlements or the upgrading or the development of new roads. New settlements, such as mines or government-designated growth points that attract significant numbers of people become centres of demand for firewood and charcoal (Bond *et al*., 2010).

The problem is further exacerbated by the way in which people use the woodlands. Significant modification or deforestation of the standing vegetation normally occurs for settlement and cultivation (FAO, 2010). At low rates of extraction, the collection and harvest of timber, fuel wood and building materials can be sustainable, albeit leading to the loss of stem carbon, i.e. degradation. However, continuous extraction of timber can easily lead from degradation into a state of deforestation (Bond *et al*., 2010).

2.1.6 Leakage and its potential impacts on REDD+ initiatives

Leakage which is referred to as displacement of greenhouse gas (GHG) emissions from one place to another due to emission reduction activities which is caused by a direct or indirect shift of activities that create those emissions from within an emissions accounting system to out of that system (Henders and Ostwald, 2012). Leakage undermine the overall efficiency of emission reduction activities; thus increasing the cost of REDD+ implementation, since it leads to more emissions (Fisher *et al.,* 2011).

CHAPTER THREE

3.1 MATERIALS AND METHODS

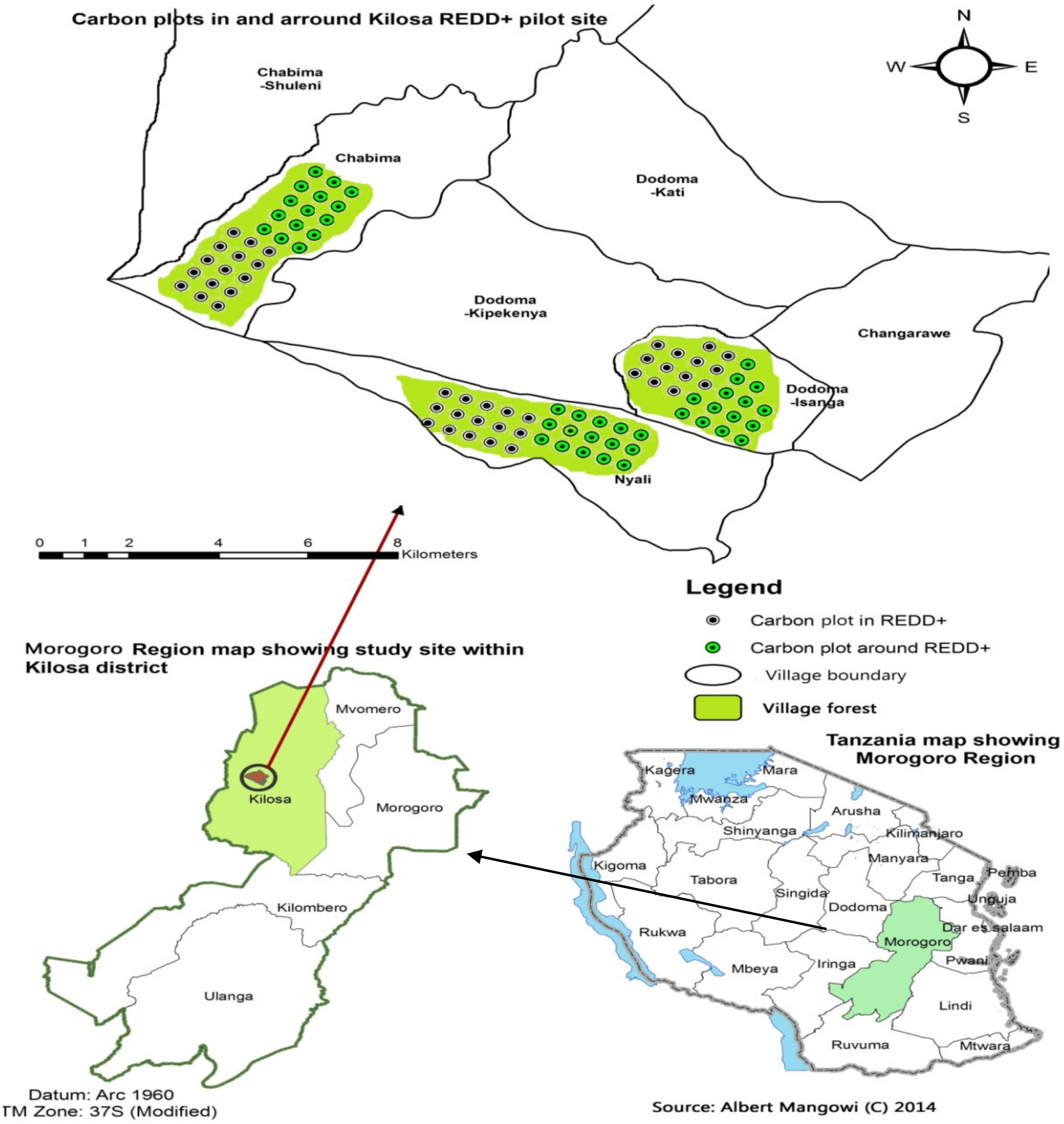
3.1.1 Study site

The study forest in Kilosa district of Morogoro region is part of the Eastern Arc Mountains forests, an important biodiversity hotspot on the East Africa belt as well as the miombo woodland in the lowland areas, having 22 villages participating in the REDD+ pilot project (TFCG, 2011). The study focused on 3 villages namely Chabima, Dodoma Isanga and Nyali. The 3 villages in Kilosa site have been selected for this study primarily because the pilot projects being implemented include community managed forest which initially provided goods and services before establishment of the REDD+ pilot projects (TFCG, 2011).

Tanzania Forest Conservation Group (TFCG) and MJUMITA are implementing a five year REDD+ pilot project in making REDD+ work for communities and forest conservation in Tanzania.

3.1.2 Geographic location

The study was conducted in and around REDD+ pilot site, Kilosa District of Morogoro Region in Tanzania. The study areas were three bordering villages i.e. Chabima (20^{o}I45’S, 30^{o}I46’E), Dodoma Isanga (20^{o} 15’S, 30^{o} 30’E) and Nyali (20^{o} 15’S, 30^{o} 30’E) (Figure 1). All the villages portioned part of their forest reserves for piloting REDD+ project.



Source: Albert Mangowi (C) 2014

Figure 1: Location of study area showing the carbon plots in and around REDD+ pilot site in Kilosa, Morogoro Tanzania.

3.2 Data Collection

3.2.1 Sampling design

Systematic sampling was used to delineate sample plots for assessing carbon stock and emission difference by degradation in and around the REDD+ pilot site.

A total of 84 plots measuring 20m x 10m were established (Figure 1), in such a way that half of the plots were inside the REDD+ pilot site and the other half around the REDD+ pilot site in the three villages.

The use of rectangular plots in forest inventory aimed at increasing the accuracy of the measurement and sampling intensity of large trees, and simultaneously saving time. Also the rectangular plot design ensures that small trees and large trees (which constitute most of the biomass per unit area) were measured in plots (Lackmann, 2011). Whereas with circular plots it is easier to leave some trees outside the plot or measuring trees that are outside of the plot.

3.2.2 Data collection

In each plot the following information was assessed: diameter for all trees ≥5 cm DBH, degradation by counting the number of stumps (an indicator of cut trees) and use the cut trees to get stump diameter. Other data collected included species name for all trees measured using both the scientific and local names. Botanical identification was made by matching local names with botanical names available in literature (Sawe *et al*., 2014).

3.2.3 Estimation of carbon storage and emission through degradation

Tree biomass was computed by use of the formula, $B = 0.0625 \times D^{2.553}$ (Chamshama *et al*., 2004) where, B=biomass (t), D=dbh ≥5cm. The conversion of biomass to carbon stock was by the factor of 0.49 (Munishi and Shear, 2004; Munishi *et. al.,* 2010).

3.2.4 Emissions from degradation

Degradation was assessed by the number of stumps enumerated in each plot and the density of the stumps computed as the number of stumps counted divided by the plot size.

Diameter at breast height (dbh) for removed trees was obtained by regressing dbh and stump diameter (bd) of sample trees, from the equation, dbh = -1.77+0.924(bd), R^2 = 0.9628, $p<0.0001$(Sawe *et al*., 2014), and biomass computed based on allometric model by Chamshama *et al*. (2004). A factor of 3.67 tCO_2 per unit of C was used to convert carbon to emissions i.e. carbon dioxide equivalent (Zahabu, 2008; Munishi *et. al.,* 2010; Sawe *et al*., 2014).

CHAPTER FOUR

4.1 RESULTS

4.1.1 Carbon Storage and Emission Through Degradation

The above ground carbon was estimated to be 31.5 $tCha^{-1}$ in the REDD+ pilot site, and 3 $tCha^{-1}$ around the REDD+ pilot site. The genera *Brachystegia* contributed the highest amount in both sites with 70% of total above ground carbon in REDD+ pilot site and 55.1% around the REDD+ pilot site (Table 1). High degradation was found around the REDD+ pilot site with 70 stumps ha^{-1}, while inside the REDD+ pilot site the stump density was 12 stumps ha^{-1} (Figure 4).

Table 1: **Carbon contribution by major tree species in and around REDD+ pilot site in Kilosa, Morogoro**

Botanical name	REDD+ pilot site (t/ha)	Percentage (%)	Around REDD+ pilot site (t/ha)	Percentage (%)
Brachystegia spiciformis	3.8	10.44	1.06	23.64
Brachystegia microphylla	7.73	21.21	0.2	4.34
Brachystegia boehmii	6.36	17.45	0.67	14.83
Brachystegia bussei	3.6	9.88	0.56	12.48
Brachystegia longifolia	4.02	11.03	0	0
Pseudolachnostylis glauca	2.8	7.68	0.11	2.45
Hymenodictyon floribundum	0.98	2.69	0	0
Combretum collinum	0.54	1.49	0.11	2.5
Acacia polyacantha	0.89	2.44	0	0
Diplorhinchus condylocarpon	0.811	2.23	0.15	3.33
Pseudolachnostylis maprouneifolia	0	0	0.17	3.85
Total	31.531		3.03	

Only species contributed more than 2% carbon are shown from either in or around REDD+ pilot site in Kilosa, Morogoro

It is estimated that the carbon loss in the REDD+ pilot site was 1.17 $tCha^{-1}$ (4.29 $tCO_2e\ ha^{-1}$), while the loss around the REDD+ pilot site was 1.92 $tCha^{-1}$ (7.05 $tCO_2e\ ha^{-1}$). The tree species that accounts for high carbon loss were *Brachystegia microphylla* and *Brachystegia boehmii*. The activities contributing to wood removal were charcoal making, timber harvesting, and poles extraction (Tables 2 and 3).

4.1.2 Carbon stock difference

The computed carbon stock shows that between the two sites, plots around the REDD+ pilot site have less carbon stock compared to those inside REDD+ pilot site (Figure 1). Shifting cultivation, timber harvest and fuel wood collection in village forests are the major cause of the degradation (Newmark, 2002).

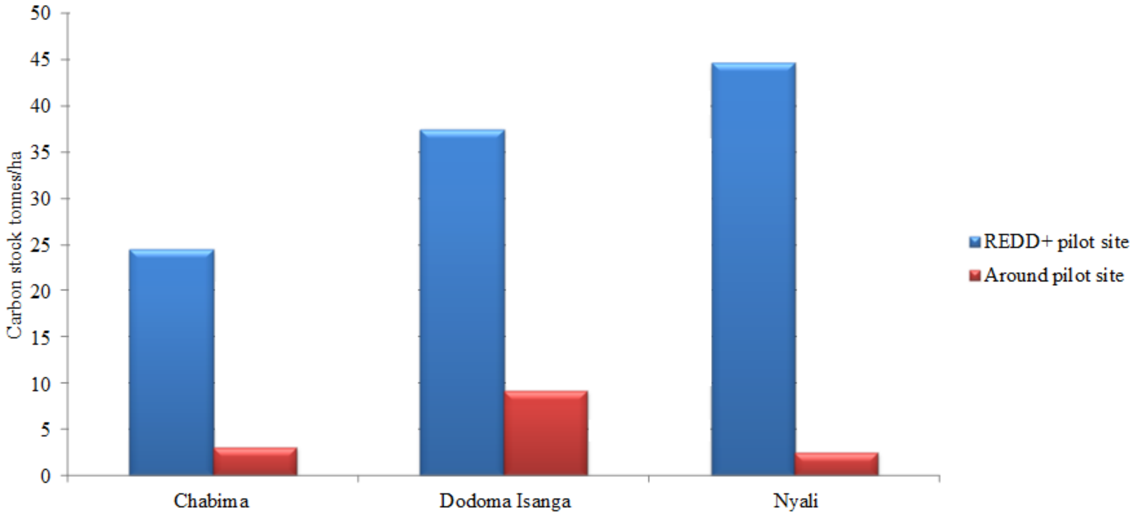


Figure 2: Carbon stock difference between REDD+ pilot site and around REDD+ pilot site in Kilosa, Morogoro

4.1.3 Degradation difference

The number of cut trees around the REDD+ pilot site was higher compared to those in the REDD+ pilot site (Figure 2). Due to high presence of charcoal spots around the REDD+ pilot site, with its production involving tree felling and leaving behind stumps (Misana *et al.,* 1996), most of them from *Brachystegia microphylla* (Table 2). This justifies the preference of this species due to its high calorific value.

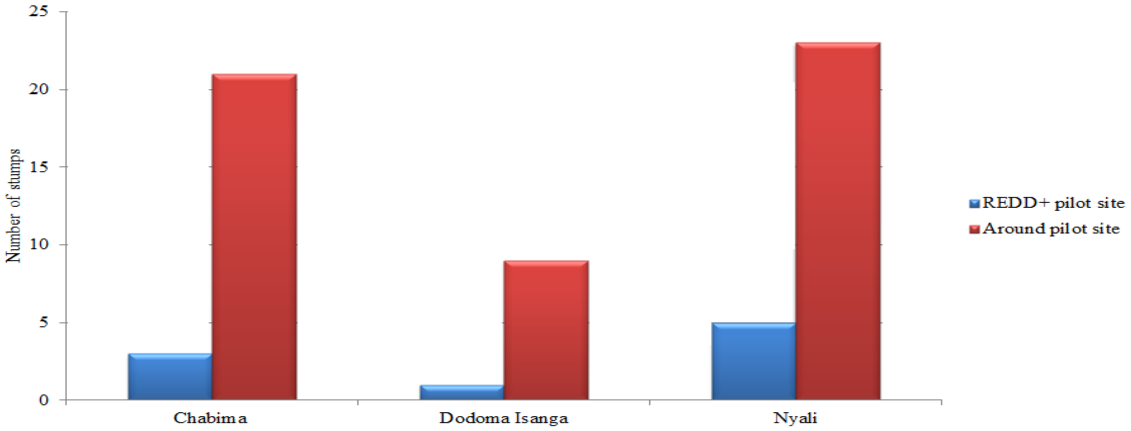


Figure 3: Degradation difference between REDD+ pilot site and around REDD+ pilot site in Kilosa, Morogoro

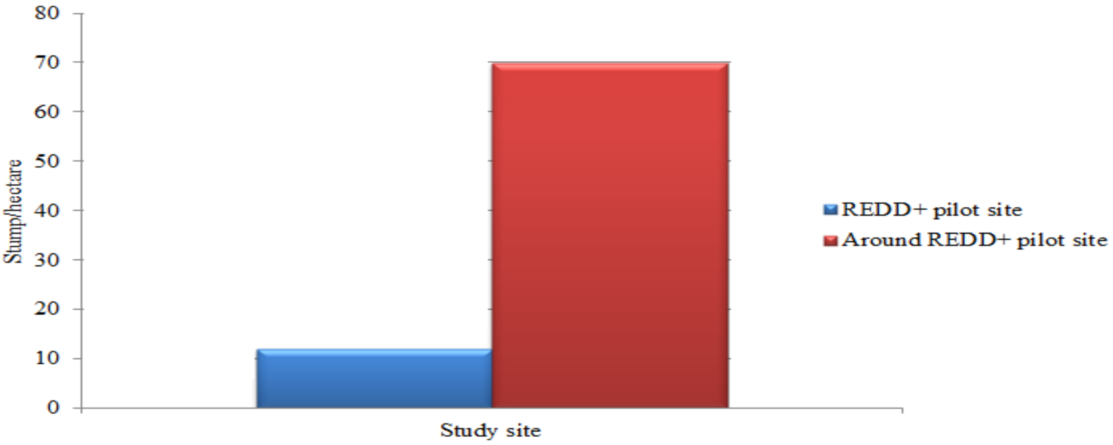


Figure 4: Difference in stump density between REDD+ pilot site and around REDD+ pilot site in Kilosa, Morogoro

Table 2: **Tree species degradation frequency in and around REDD+ pilot site in Kilosa, Morogoro**

Botanical name	Scientific name	Number of plants	Percentage (%)
Msani	*Brachystegia microphylla*	19	38
Myombo	*Brachystegia boehmii*	13	26
Mlama mwekundu	*Combretum collinum*	4	8
Msolo	*Pseudolachnostylis glauca*	4	8
Mlama mweusi	*Combretum molle*	2	4
Mtogo	*Diplorhinchus condylocarpon*	2	4
Ngurukanziwa	*Julbernardia globiflora*	2	4
Muhugwe	*Brachylaena huillensis*	2	4
Mng'ongo	*Sclerocarya birrea*	2	4

Only species with more than 1 degradation frequency are shown from both sites

4.1.4 Emission difference

Carbon emission in around REDD+ pilot sites was higher compared to emissions from REDD+ pilot sites (Figure 3). Degradation resulted into carbon loss of 1.17 tCha^{-1} (4.29 tCO$_2$e ha^{-1}) inside the REDD+ pilot site and 1.92 tCha^{-1} (7.05 tCO$_2$e ha^{-1}) around the REDD+ pilot site.

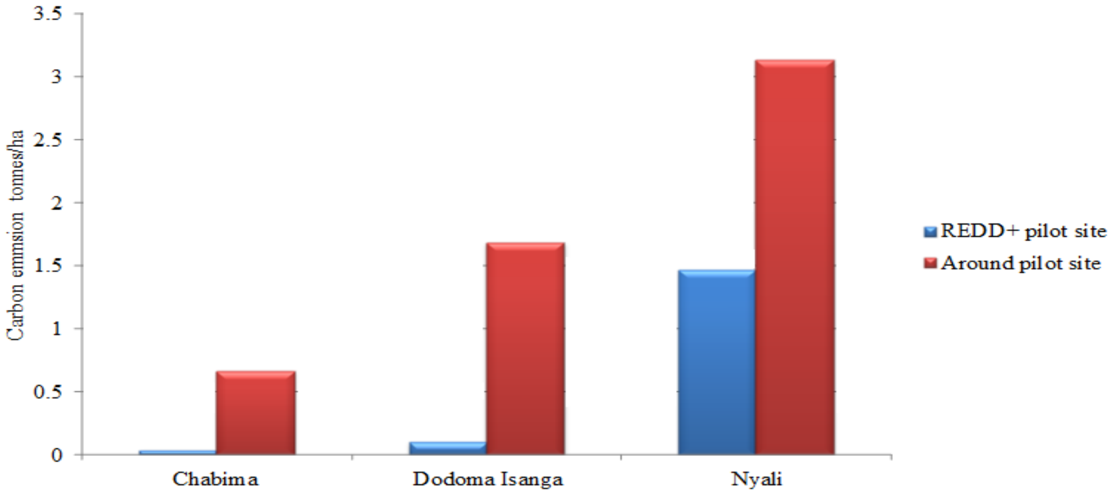


Figure 5: Emission difference between REDD+ pilot and around REDD+ site in Kilosa, Morogoro

Table 3: **Species contribution to carbon loss in and around REDD+ pilot site in Kilosa, Morogoro**

Botanical name	REDD+ pilot site (t/ha)	Percentage (%)	Around REDD+ pilot site (t/ha)	Percentage (%)
Brachystegia boehmii	0.61	34.06	1	50.6
Pterocarpus angolensis	0	0	0.31	15.76
Brachystegia bussei	0	0	0.31	15.76
Brachystegia longifolia	0.41	23.17	0	0
Brachystegia spiciformis	0.14	8.02	0	0
Brachystegia microphylla	0	0	0.13	6.24
Combretum collinum	0.01	0.33	0.07	3.41
Lonchocarpus bussei	0	0	0.03	1.57
Crossopteryx febrifuga	0	0	0.05	2.78
Diplorhinchus condylocarpon	0	0	0.02	1.21
Total	1.17		1.92	

Only species contributed more than 1% carbon loss are shown from either in or around REDD+ pilot site

4.2 Discussion

The study estimated average carbon density of 31.5 tCha^{-1} inside the REDD+ pilot site (Table 1) which is relatively higher than carbon reported in similar studies by Munishi *et al*. (2010) and Zahabu (2008) who reported carbon density of 19.12 tCha^{-1} for un degraded miombo of southern Tanzania, 21.1 and 19.89 tCha^{-1} for miombo of Kitulangalo and Kimunyu Reserves in Eastern Tanzania, respectively. The carbon density around the REDD+ pilot site of 3.03 tCha^{-1} was lower than any other reported figures for such ecosystem. These differences in carbon densities might mainly be due to varying degrees of exposure to human induced degradation, stage of regeneration but also the type of species as well as tree sizes (Burgess *et al.,* 2010; Munishi *et al.,* 2010; Shirima *et al*., 2011; Sawe *et al*., 2014).

The carbon loss of 1.17 tCha^{-1} (4.29 tCO$_2$e ha^{-1}) inside the REDD+ pilot site and 1.92 tCha^{-1} (7.05 tCO$_2$e ha^{-1}) around the REDD+ pilot site, whereas values of inside the

REDD+ pilot site are higher compared to finding from Zahabu (2008) who observed a carbon loss of 0.5 $tCha^{-1}$ and 1.75 $tCha^{-1}$ for Kitulangalo woodland forests and the lowland montane forests of Handeni. But all are lower than those of Sawe *et al.* (2014) reported a loss of 4.1 ± 0.9 t Cha^{-1} in Manga reserve, Chunya District Mbeya, Tanzania. The comparisons between different studies may be an inadequate strategy since different methodologies may have been used in different cases. For example, the sizes of the plots vary greatly among studies and this has a strong effect on the results obtained (Kacholi, 2014). The macro indicators of poverty such as per capita income show high levels of poverty in communities within the miombo woodlands (Campbell *et al.*, 2007) adding on the fact that woodland degradation in search for livelihoods is likely high. Miombo woodlands, like many other ecosystems, are converted to other uses such as agriculture because they provide higher short-term benefits than conservation (Bond *et al.*, 2010).

Wood fuel is the most important source of energy in the region, with over 80% of the population depending on woodfuel for cooking, heating and lighting requirements (Shaba, 1993). The demand for wood fuel has steadily increased over the years and the situation is not likely to change in the near future, given the poverty situation and the low levels of income that prevail in most rural and urban areas (Misana *et al.*, 1996). Fuelwood is an important woodland resource in developing countries, and has been suggested that through its collection it has led to rapid woodland disappearance (Abbott and Homewood 1999), and Campbell (1996) mentioned that 15 million urban dwellers rely on miombo wood or charcoal as energy source. Anglesen *et al.* (2012) also observed that with absence of alternative supplies of woodland resources, villagers will continue to exploit the surrounding woodland. Based on these findings it would be possible to tie the degradation with human induced activities on the woodlands thus justifying the observed degradation and resultant emissions.

The observation that emissions are high in around REDD+ pilot sites is an indication that REDD+ activities may cause a shifting pressure from the REDD+ pilot sites to around REDD+ pilot site making it important to consider leakage at both local and national scale when planning for REDD+ activities (Anglesen *et al*., 2012).

Because of increasing population in the communal areas in Kilosa village forests, land clearance for cultivation and wood extraction has increased over time, resulting in widespread deforestation and forest degradation (FAO, 2010). Woodlands in the government reserves and commercial areas such as REDD+ pilot site, at least in the case of Kilosa, however, have remained almost intact (Misana *et al*., 1996). Thus the majority of people have been left to rely on woodland resources on land that is currently not under piloting REDD+ or strict protection. This has imposed enormous pressure on resource use in the communal lands (Vermeulen, 1993).

The rapid growth in urban demand for charcoal has enabled very large numbers of people to engage in its trade (Arnold *et al.,* 2006; Campbell *et al*., 2007). This has resulted in high rates of deforestation and forest degradation around major cities and towns. Therefore as with many other ecosystems, miombo woodlands are settled and converted to other uses because these uses provide the land manager with a higher rate of return than is earned from the maintenance of the indigenous vegetation (Bond *et al.,* 2009). In the miombo region, land is generally cleared for settlement; agriculture and fuel wood (Campbell *et al.,* 2007). The construction or improvement of roads, and the development of settlements and agricultural policies, are all indirect drivers of deforestation. Any new initiative such as REDD+ that is dependent on the forest will compete with these uses. For areas that are likely to be converted to non-forest uses, the benefits from REDD+ need to be equal or exceed those from these alternative uses i.e. the opportunity costs (Bond *et al*., 2010).

CHAPTER FIVE

5.1 Conclusion

The carbon emissions and the contribution to climate change mitigation will only be real if the changes are additional, permanent and there is no leakage. The REDD+ pilot program seem to have good potential towards reducing emissions though leakage may undermine this potential. Measures to contain leakage are important before REDD+ activities and programs can fully realize their potential to reduce emissions.

5.2 Recommendation

Leakages should thoroughly be analysed and addressed when planning for REDD+ activities in order to enhance the potential of REDD+ contribution to emission reduction. Accounting for leakages especially at local scale, for example by providing alternatives to the residents of Kilosa to ensure that they don’t rely on wood products, will likely improve the performance of REDD+ activities by reducing emission and the cost of implementing REDD+.

REFERENCES

Abbot, J. I. O. and Homewood, K. (1999). A history of change: causes of miombo woodland decline in protected area Malawi. The journal of applied ecology, vol. 36 No.3, 422-433

Angelsen, A. and Atmadja, S. (2008). ‘What is this book about?’ in Angelsen. (ed) Moving Ahead with REDD: Issues, options and implications. Center for International Forestry Research (CIFOR), Bogor.

Angelsen, A., with Brockhaus, M., Kanninen, M., Sills, E., Sunderlin, W.D. and Wertz-Kanounnikoff, S. (Eds). (2009). Realising REDD+: national strategy and policy options. CIFOR, Bogor, Indonesia. 361p.

Arnold, J.E.M., Köhlin, G. and Persson, R. (2006). Woodfuels, livelihoods, and policy interventions: changing perspectives. World Development 34(3):596–611.

Bond, I., Grieg-Gran, M., Wertz-Kanounnikoff, S., Hazlewood, P., Wunder, S. and Angelsen, A. (2009). Incentives to sustain forest ecosystem services: A review and lessons for REDD. Natural Resouce Issues No. 16. International Institute for Environment and Development, London, UK, with CIFOR, Bogor, Indonesia, and World Resources Institute. Washington, D.C., USA.

Bond, I., Chambwera, M., Jones, B., Chundama, M. and Nhantumbo, I. (2010). REDD+ in dryland forests: Issues and prospects for pro-poor REDD in the miombo wooldands of southern Africa, Natural Resource Issues No. 21. IIED, London.

Burgess, N. D., Bahane, B., Clairs, T., Danielsen, F., Dalsgaard, S., Funder, M., Hagelberg N., Harrison, P., Haule, C., Kabalimu, K., Kilahama, F., Kilawe, E., Lewis, S. L ., Lovett, J. C ., Lyatuu, G., Marshall, A. R., Meshack, C., Miles, L., Milledge, S. A. H., Munishi, P. K. T., Nashanda, E., Shirima, D., Swetnam, R. D., Willcock, S., Williams, A. and Zahabu, E. (2010). Getting ready for REDD+ in Tanzania: a case study of progress and challenges. Fauna & Flora International, Oryx, 44(3), 339–351

Byers, B.A., Cunliffe, R.N. and Hudak, A.T. (2001). Linking the Conservation of Culture and Nature: A Case Study of Sacred Forests in Zimbabwe. Human Ecology, Vol. 29, No.2.

Campbell, B. M. (1996). The miombo in Transition: woodlands and welfare in Africa. Center for International Forestry Research (CIFOR), Bogor, Indonesia

Campbell, B. M., Jeffrey, S., Kozanayi, W., Luckert, M., Mutamba, M. and Zindi, C. (2002). Household Livelihoods in Semi-Arid Regions: Options and Constraints. Jl. CIFOR, Situ Gede, Sindang Barang, Bogor Barat 16680, Indonesia

Campbell, B.M., Angelsen, A., Cunningham, A., Katerere, Y., Sitoe, A. and Wunder, S. (2007). Miombo woodlands – opportunities and barriers to sustainable forest management

Chamshama, S.A.O., Mugasha, A.G. and Zahabu, E. (2004) Stand biomass and volume estimation for miombo woodlands at Kitulangalo, Morogoro, Tanzania. J. S. Afr. For. 200, 59–64.

Dewees, P.A. (1994). Social and economic aspects of miombo woodland management in Southern Africa. Options and opportunities for research. CIFOR Occasional Paper 2, Bogor, Indonesia.

Fisher, B., Lewis, S.L., Burgess, N.D., Malimbiwi, R.E., Munishi, P.K., Swetnam, R.D., Turner, R.K., Willcock, S. and Balmford, A. (2011). Implementation and opportunity costs of reducing deforestation and forest degradation in Tanzania. Nat. Clim. Change, 1, 161–164.

Frost, P. (1996). The ecology of miombo woodlands. In: The Miombo in Transition: woodlands and welfare in Africa (Ed. Campbell, B.). CFIOR, Bogor.

Fyhrquist, P., Mwasumbi, L., Haeggstro¨m, C.A., Vuorela, H., Hiltunen, R. and Vuorela, P. (2002). Ethnobotanical and antimicrobial investigation on some species of Terminalia and Combretum (Combretaceae) growing in Tanzania. J. Ethn. 79(2), 169–177.

Gauslaa, Y. (1988). Management and regeneration of Tropical Woodlands with Species reference to Tanzanian conditions. A Literature Review. NORAGRIC Report, June 1988, Oslo.

Global forest resources assessment. (2010). Main Report. FAO Paper 163, Food and Agriculture Organization of the United Nation (FAO), Rome, Italy, 2010.

Henders, S. and Ostwald, M. (2012). Forest Carbon Leakage Quantification Methods and their Suitability for Assessing Leakage in REDD. Center for Climate Science and Policy Research, Department of Water and Environmental Studies, Linköping University, Norrköping 601 74, Sweden.

Kacholi, D. S. (2013). Effects of habitat fragmentation on biodiversity of Uluguru Mountains forests in Morogoro region, Tanzania [Ph.D. thesis submitted at Georg-August University Goettingen], Cuvillier Verlag, Georttingen, German

Kacholi, D. S. (2014). Analysis of structure and Diversity of the Kilengwe Forest in the Morogoro Region, Tanzania. Hindawi Publishing Corporation, International Journal of Biodiversity Vol. 2014, Article ID 516840, 8 pages

Lackmann, S. (2011). Regional Workshop: “Capacity Development for Sustainable National Greenhouse Gas Inventories – AFOLU sector (CD-REDD II) Program. Lesson 8 Good practice in designing forest inventory. Coalition for Rainforest Nations. Quito, Ecuador

Ministry of Natural Resources and Tourism-MNRT. (1994). Tanzania Forestry Action Plan 1989/90 - 2007/08 Update. Third Draft, Dar es Salaam.

Ministry of Natural Resources and Tourism-MNRT. (1998). National Forest Policy. Forestry and Beekeeping Division of the Ministry of Natural Resources and Tourism, Dar es Salaam, Tanzania.

Misana, S., Mung’ong’o, C. and Mukamuri, B. (1996). miombo Miombo woodlands in the wider context: macro-economic and inter-sectoral influences. In: Campbell, B (ed.). The Miombo in Transition: Woodlands and Welfare in Africa. CIFOR, Bogor, Indonesia. Pp 73-98.

Moyo, S., O’Keefe, P. and Sill, M. (1993). The Southern African environment: profiles of the SADC Countries. Earthscan, London.TFCG, 2011.

Munishi, P.K.T. and Shear, T.H. (2004). Carbon storage in afro-montane rain forests of the eastern arc mountains of Tanzania: their net contribution to atmospheric carbon. J. Trop. For. Sci.16, 78–98.

Munishi, P.K.T., Mringi, S., Shirima, D.D. and Linda, S.K. (2010). The role of the Miombo Woodlands of the Southern Highlands of Tanzania as carbon sinks. J. Ecol. Nat. Environ. 2(12):261-269.

Newmark, W. D. (2002). Conserving Biodiversity in East African Forests. A study of the Eastern Arc Mountains, Springer, New York, NY, USA.

Sawe, T. C., Munishi, P.K.T. and Maliondo, S. M. (2014). Woodlands degradation in the Southern Highlands, Miombo of Tanzania: Implications on conservation and carbon stocks. International Journal of Biodiversity and Conservation. Vol. 6(3), pp. 230-237.

Schwarze, R., Niles, J. and Olander, J. (2002). Understanding and managing leakage inforest-basedgreenhouse-gas-mitigation projects. Philos. Trans. A, 360, 1685–1703.

Shaba, M.W.M. (1993). A perspective of indigenous forests management in the SADC Region. In: Piearce, G.D. and Gumbo, D.J. (eds). The ecology and management of indigenous forests in Southern Africa, 29-37. Proceedings of an international symposium, Victoria Falls, Zimbabwe, 27- 29 July 1992. Zimbabwe Forestry Commission and SAREC, Harare.

Shirima, D., Munishi, P.K.T., Lewis, S.L., Burgess, N.D., Marshall, A.R., Balmford, A., Swetnam, R.D. and Zahabu, E. M. (2011). Carbon storage, structure and composition of miombo woodlands in Tanzania's Eastern Arc Mountains Blackwell Publishing Ltd, Afr. J. Ecol., 49, 332–342.

Tanzania Forest Conservation Group-TFCG. (2011). Training Manual. Participatory Forest Management and Reducing Emissions from Deforestation and forest Degradation (REDD): Village Level Training Events in Tanzania. TFCG Technical Report 30.

Thomson, P.J. (1975). The role of elephants, fire and other agents in the decline of a *Brachystegia boehmii* woodland. Journal of the Southern African Wildlife Management Association 5, 11-18.

Van der Werf, G.R., Morton, D.C., DeFries, R.S., Olivier, J.G.J., Kasibhatla, P.S., Jackson, R.B., Collatz, G.J. and Randerson, J.T. (2009). CO_2 emissions from forest loss: Commentary. J. Nature geoscience | VOL 2 | NOVEMBER 2009 | www.nature.com/naturegeoscience.

Vermeulen, S. (1993). Consumption, harvesting and abundance of wood along the boundary between manufacturing Mafungautsi State Forest and Gokwe Communal Area, Zimbabwe. M.Sc thesis, University of Zimbabwe, Harare.

Zahabu, E. (2008). Sinks and Sources, a strategy to involve the forest communities in Tanzania in global climate policy. Dissertation to obtain the degree of doctor at the University of Twente, on the Authority of the Rector Magnifinicus, p. 249.