ASSESSMENT OF DEGRADATION IN FORESTED AREAS OF TANZANIA: A CASE STUDY OF TANGA, MOROGORO, PWANI AND DAR-ES-SALAAM REGIONS

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

2017

ABSTRACT

Study was conducted to assess the level of degradation in the forested areas in Tanzania particularly on eastern zone regions (Tanga, Pwani, Morogoro and Dar es salaam). Three vegetation types were taken into consideration where both volume and biomass removed was determined. The NAFORMA data was used where a total of 1413 plots with stumps were used. The study revealed that montane forest lost 48.47$\pm$8.2 m^3/ha, lowland forest 22.27$\pm$2.25 m^3/ha and woodland forest 13.77$\pm$1.39 m^3/ha. The weighted mean volume and biomass removed was 15.67 m^3/ha and 11.02 t/ha respectively. Average volume and biomass lost in woodland forests were 13.7 m^3/ha and 9.77 t/ha respectively. The most harvested species in woodland were found to be *Brachystegia sp*. 2.57 m^3/ha followed by *Commiphora sp*. 1.5 m^3/ha while other remaining species account for 9.63 m^3/ha. Average volume and biomass lost in lowland forests were 22.27 m^3/ha and 14.88 t/ha respectively. The most harvested species in the lowland forest were found to be *Brachystegia sp*. 5.5 m^3/ha followed by *Combretum sp*. 3.4 m^3/ha and other remaining species contributed about 13.37 m^3/ha. On the other hand average volume and biomass lost in montane forests were 48.46 m^3/ha and 33.69 t/ha respectively where as the most degraded species in montane forest were found to be *Ocotea usambarensis* 14 m^3/ha followed by *Olea usambarensis* 3 m^3/ha and other remaining species 31.4 m^3/ha. Volume removed in the woodland forest is contributed mostly by charcoal making 2.92 m^3/ha followed by timber extraction 2.09 m^3/ha, the remaining volume 8.76 m^3/ha include other drivers of degradation. For lowland and montane forests, timber extraction is the most driver of degradation where about 5.03 m^3/ha (22.5%) and 14.82 m^3/ha (30.57%) respectively were extracted.

DECLARATION

I, Nelson George Ayila do hereby declare to the Senate of the Sokoine University of Agriculture that this dissertation is my own original work, and has neither been submitted nor is concurrently being submitted for a higher degree award in any institution.

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Signature:_______________________ Date: ________________________

Prof. E. Zahabu (Supervisor)

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ACKNOWLEDGEMENT

Firstly, I would like to present my special thanks to Almighty God for his guidance and protection subjected to me from the beginning of my study to the moment. Secondly, I would like to express my special appreciation to the department of forest Resources assessment and Management of Sokoine University of Agriculture for the valuable knowledge I acquired.

I wish to express my sincere gratitude to my supervisor Prof. R. E. Malimbwi from University of Sokoine who had the capability of making corrections but respecting the work and talent of others. My understanding of the subject grew from my frequent discussions with him. I appreciate his guidance, strength, confidence and tireless efforts in giving challenge advice that have made possible the completion of this study.

I would also wish to acknowledge my co-supervisor Prof. E. Zahabu for the foundation of this study and valuable advice on writing my dissertation. Special thanks to Mr. Godfrey Erick Ayila who devoted his time to proofread the manuscript of this dissertation.

Last but not least, thanks should go to my family for love, encouragement, patience and moral support during my study.

DEDICATION

This work is dedicated to my beloved parents (Mr. George and Rose) who laid down the foundation of my education. Also the work is dedicated to my classmate Asiad Said Singano who encourages me when I was undertaking this study.

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LIST OF ABREVIATIONS

BD	Basal diameter
CoP	Conference of parties
Dbh	Diameter at breast height (1.3m from the ground)
FAO	Food and Agriculture Organization of United Nation
H	Height of tree
JFM	Joint Forest Management
LAFRs	Local authority forest reserves
MNRT	Ministry of Natural Resources and Tourism
MRV	Measurement, Reporting and Verification.
NAFORMA	National Forest Monitoring and Assessment
NFRs	National Forest Reserves
REDD	Reduced Emission from Deforestation and Degradation
REDD +	Reduced Emission from Deforestation and Forest Degradation and the role of conservation, sustainable forest management and enhancement of forests carbon stock in developing countries
REL	Reference Emission Level
SUA	Sokoine University of Agriculture
S.E	Standard Error
Sp	Species
UNFCCC	United Nations Framework for Convention on Climate Change
URT	United Republic of Tanzania
VLFRs	Village Land Forest Reserves

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

Tanzania has a total area of about 94.5 million hectares out of which 88.6 million hectares are covered by landmass and the rest is inland water. Forests and woodlands in Tanzania mainland has a total area of 48.1 million hectares which is 55% of the total land area of Tanzania mainland (MNRT, 2015). The Forestry and Beekeeping Division (FBD) of the Ministry of Natural Resources and Tourism (MNRT) is responsible for forest policy issues on mainland Tanzania. Its primary role is to support implementation of the Forest Policy (URT, 1998) and Forest Act (URT, 2002). Tanzania Forest Service (TFS) oversees the day to day forest management. It has the mandate to manage and supervise national forest reserves (NFRs); collect revenue on forest operations and harvesting; issue licenses and permits and, thereby, regulate harvesting of forest products nationally; promote forest development; provide training in forestry; and undertake forest research through the Tanzania Forest Research Institute (TAFORI).

Formal management of forests in the country was initiated towards the end of the nineteenth century (1890) by the German rulers when the importance of conserving water sources was recognised. Between 1890 and 1920, efforts were made as much as possible to catchment forests. This brought about reservation of a chain of mountain areas in the northern and southern parts of the country with a total of 0.5 million hectares (Hermansen *et al*., 1985). The British administration (1920-1961) followed up by protecting the catchment forests and reservation of more catchment and other forests, bringing the total reserved areas to 1.3 million hectares. After independence in 1961, management of forests in Tanzania has been the responsibility of the central government and local government agencies where by efforts were made to re-survey and demarcate old forest reserves while new ones were created. Current statistics show that the country has a total of 48.1 million hectares of forest and woodland (URT, 2015).

1.2 Problem statement and justification

FAO (2002) defines forest degradation as the reduction of the capacity of a forest to provide goods and services. Capacity includes the maintenance of ecosystem structure and functions (ITTO, 2005).Despite the significant contribution of forests to local livelihoods and the national economy, forest degradation and environmental degradation continue and, with it, negative impacts on marginal communities that depend on forests and forest products (Mariki, 2001). Commercial production of firewood and charcoal as an alternative source of income to meet urban energy demands contributes significantly to forest degradation.

Studies to date offer limited information on both wood volume and biomass removed from the forested areas despite the fact that good information on the extent of forest degradation is needed to elaborate policies and implement forest-management plans allowing the restoration of degraded forests and the rehabilitation of degraded forest lands. This kind of understanding is crucial for subsequent development of management techniques for ecological restoration (Marshall, 2008).

For that reason, a great effort is required to develop a strong understanding of the level of degradation in the forested areas of Tanzania. The information will be relevant for scientists and decision makers dealing with sustainable management of natural resources who will be able to estimate quantities and proportional of both wood volume and biomass removed from a particular forested area. Furthermore, as far as REDD+ is concerned, it is critical to clearly understand where the country stands today on the extent of Emission from forest degradation. Deforestation is easily detected from space, particularly when it occurs on a large scale. However, forest degradation, such as the removal of a few trees per hectare (selective logging) or undergrowth (by fire) or branches and small trees (for fuel wood) is much more difficult to observe remotely. Whereas degradation is often obvious from the ground, it is more difficult to detect from space and this result to the complexity of assessing degradation relative to deforestation. Measuring forest degradation (loss of biomass within a forest) remotely is much more challenging and up to date there is no figure of degradation despite the fact that they are required to estimate Reference Emission Level (REL) in the REDD+ projects.

1.3 Research objectives

1.3.1 General objective

To assess the level of degradation using tree stumps in order to obtain the current status of forested areas in Tanzania

1.3.2 Specific objectives

a) To estimate both volume and biomass removed as the result of degradation in the forested areas of Tanzania

b) To identify the most degraded species in the forested areas and their possible uses

c) To identify major drivers of degradation.

1.4 Research questions

a) What is the amount of both volume and biomass removed as the result of degradation in the forested areas?

b) What species are most removed their possible uses and their link to ecological importance in the forest?

c) What are the major drivers of forest degradation in the forested areas?

d) What alternative activities can be done by the marginal communities instead of illegal timber harvesting?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definition of terms

2.1.1 Woody biomass

Woody biomass is the accumulated mass, above and below ground, of the roots, wood, barks, and leaves of living and dead woody shrubs and trees. It can be used for heat, power, and electricity generation; biofuels production; and biochemical production (e.g., adhesives, solvents, plastics, inks, and lubricants). Wood; wood residue and byproducts; and bushes, shrubs, and fast growing trees, grown specifically for energy, are all considered as woody biomass.

2.1.2 Forest Degradation

The UNFCCC definition of forest degradation is direct human-induced long-term loss (persisting for X years or more) of at least Y per cent of forest carbon stocks (and forest values) since time (T), in a manner that does not qualify as deforestation (Penman *et al*. 2003).According to FAO (2006), Forest degradation is the changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and/or services. This takes different forms particularly in open forest formations deriving mainly from human activities such as overgrazing, overexploitation (for fuelwood or timber), repeated fires, or due to attacks by insects, diseases, plant parasites or other natural sources such as cyclones. Very often degradation does not show up so much in decrease of woody vegetation but rather as a gradual reduction in biomass, changes in species composition and soil degradation (Milledge and Kaale, 2003).Unsustainable logging practices can contribute to degradation if the extraction of mature trees is not accompanied with their regeneration.

2.2 General overview of Forest Degradation

Forest degradation can be quite confusing as most of the literature and experts do not give a clear-cut distinction between forest degradation and deforestation (Arildsen and Kaimowitz, 2001; Geist and Lambin, 2002).

A universal definition of forest degradation is absent (Schoene *et al.*, 2007). For practical reasons degradation is usually defined as a reduction of tree canopy cover and carbon stock, while other aspects of forest ecosystems, like reduction of biodiversity and ecological integrity, are usually omitted (Sasaki and Putz, 2009). (FAO, 2001) define Forest degradation as the changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and/or services. This change process is caused by disturbance (although not all disturbance causes degradation), which may vary in extent, severity, quality, origin and frequency. Disturbance may be natural (e.g. that caused by fire, storm or drought), human-induced (e.g. through harvesting, road construction, shifting cultivation, hunting or grazing) or a combination of the two. Human-induced disturbance may be intentional (direct), such as that caused by logging or grazing, or it may be unintentional (indirect), such as that caused by the spread of an invasive alien species (FAO, 2009).These activities affect the canopy cover only minimally but can affect the forest stock significantly (DeFries *et al.*, 2007). Selective logging usually involves removal of a few trees in such a way that it only results in the deterioration in the density or structure of vegetation cover or its species composition. That deterioration can be temporary or permanent. Such disturbances have been termed by Grainger (1993) as "degradation". In this study the definition adopted for forest degradation is in the context of climate change as defined by Zahabu (2008), which refers to the loss of carbon from within a forest due to thinning out of the biomass stock, without loss of forest area.

2.3 Drivers of Forest degradation

Dallu (2006) and Mbonde (2005) list the threats currently facing forest management in Tanzania as illegal harvesting and trade in timber and other forest products, forest encroachment due to small-scale shifting agriculture, and the impacts of refugees, livestock, mining and fire.

Charcoal production for the market require large volume of wood, is the main source of the income in the eastern Tanzania (Luoga *et al.*, 2000) and can result in severe local disturbance of woodland. Common degrading activities in the tropics include selective logging, large-scale and open forest fires, collection of fuel wood and non-timber forest products and production of charcoal, grazing, sub-canopy fires, shifting cultivation (GOFC-GOLD, 2008).

2.4 Degradation assessment in REDD+

REDD+ is a climate change mitigation strategy based on international agreements of Reduced Emissions from Deforestation and Forest Degradation (REDD), *plus* the role of conservation, sustainable forest management, and forest carbon stock enhancement, in developing countries. The aim of REDD+, described in the

16th session of the Conference of Parties to the United Nations Framework Convention on Climate Change, is to encourage reduction of emissions from deforestation and forest degradation, conservation and enhancement of forest carbon stocks and sustainable management of forests in developing countries. REDD+ is an important and appropriate mitigation option, due to the fact that it could rapidly and cost-effectively reduce greenhouse gas emissions and could also protect biodiversity and benefit local and indigenous peoples (Stern, 2006).As REDD+ is a results-based payment mechanism, the UNFCCC decisions particularly the Durban decision (CoP17) states that achievements in REDD+ should be fully measured, reported and verified (MRV).

In order to do so, a benchmark is needed for REDD+ implementation against which the achievements due to the implementation of REDD+ activities will be credited. Under REDD+, developing countries that are already effectively protecting their forests through conservation, sustainable forest management and enhancement of forests carbon stock are recognized and eligible for carbon payment. Given the widespread dependence of a massive population on forest for subsistence livelihood, arresting forest degradation involves designing and implementing strategies that creates alternative livelihood opportunities and diminish their dependence on forest based activities. Whereas degradation is often obvious from the ground, it is more difficult to detect from space and this result to the complexity of assessing degradation relative to deforestation. Deforestation is easily detected from space, particularly when it occurs on a large scale. However, forest degradation, such as the removal of a few trees per hectare (selective logging) or undergrowth (by fire) or branches and small trees (for fuel wood) is much more difficult to observe remotely.

Measuring forest degradation (loss of biomass within a forest) remotely is much more challenging.

Fortunately, recent improvements in remote sensing technologies are increasing the ability to detect the effects of selective logging on canopy closure (Asner *et al.,* 2008). However, other sorts of forest degradation are and will remain invisible from satellites (Peres *et al.,* 2006) and, thus, ground-based studies will continue to be needed if the extensive, pervasive, and pernicious impacts of forest degradation are to be avoided. Furthermore, tree stumps can be used as a ground based method to assess the level of degradation in order to obtain the current status of forested areas. Quantifying the scale of the problem is difficult, however, because forest degradation has many causes, occurs in different forms and with varying intensity, and is perceived differently by different stakeholders. The International Tropical Timber Organization (ITTO, 2002) estimated that up to 850 million hectares of tropical forest and forest lands could be degraded.

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Case study regions

The study was conducted in four administrative regions of Tanzania: Tanga, Morogoro, Pwani and Dar-es-Salaam. These regions are located Eastern zone of Tanzania. Other zones in the country are; Southern, Southern highlands, Northern, Central, Western and Lake zone. The regions were selected principally because they are the major supplier of charcoal to Dar es Salaam, Tanzania's largest city which accounts for more than 50% of all charcoal consumed in the country (Ahrends *et al.*, 2010). About 85% of the total urban population depends on charcoal for household cooking and energy for small and medium enterprises (Sawe, 2004).

Patchy evidence suggested that forests in direct vicinity of Dar es Salaam might have already been affected to an extent that the original forest character is gone (e.g. Burgess and Hipkiss, 2002). It was feared with the depletion of nearby forests, charcoal burning might increasingly target areas at further distance to satisfy the high urban demand.

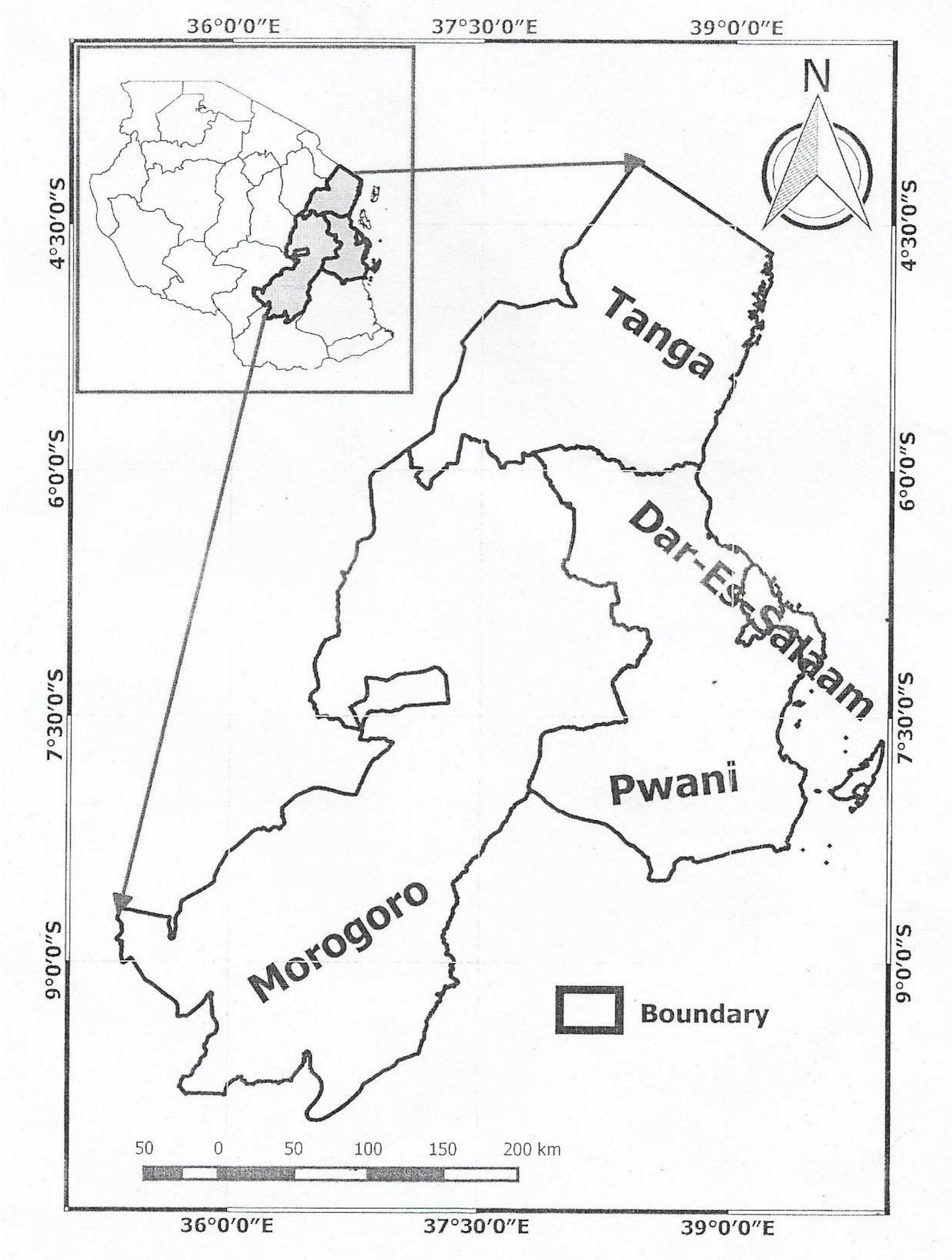

Figure 1: Case Study Regions

3.2 Sampling design, plot shape and size

The study utilized data collected by the National Forest Monitoring and Assessment (NAFORMA) (URT, 2015). Sampling design used by NAFORMA followed a stratified systematic cluster sampling. The sampling design takes account cost estimation and error estimation. These sampling strata were different with respect to distance between clusters and number of plots within a cluster. The number of plots in a cluster varied from 6 to 10, depending on the estimated difficulty to access the plots. However, the number of plots was always the same within one stratum. The distance between plots within a cluster was 250 m (Figure 2). The distance between clusters varied by stratum, from 5 to 45 kilometers.

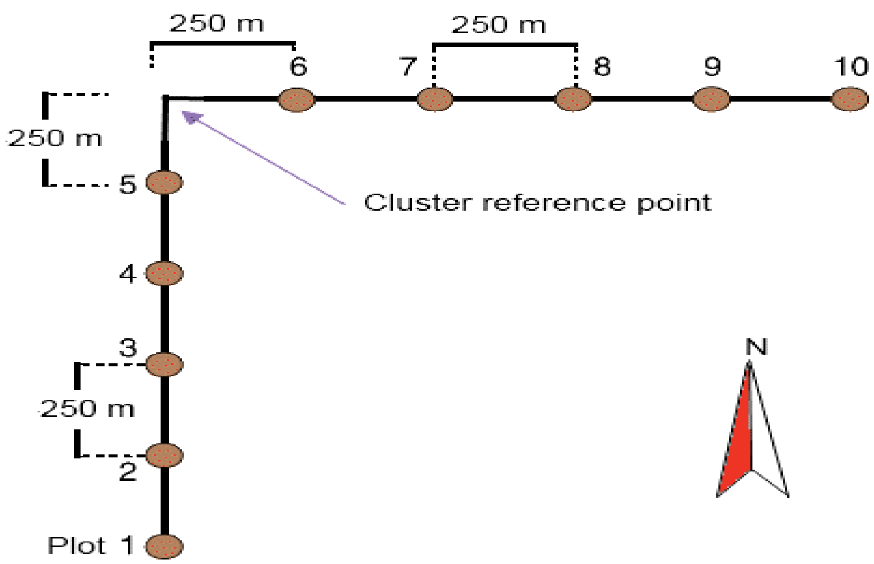

Figure 2: Cluster design

SOURCE: NAFORMA DOCUMENT: M01-2010

3.3 Plot shape and size

The sampling unit was a concentric circular sample plot (Figure 3). The plots were grouped into clusters for practical reasons in order to take into account the inventory costs. The concentric plot design ensured that small trees were measured in small plots and large trees (which constitute most of the biomass per unit area) were measured in large plots. Sample plot information collected in the plot area and for each tree inside the plot, species and breast height diameter (Dbh) were recorded.

The tally tree measurements were restricted by concentric circular plot (Figure 3). Every 5th tally tree in the cluster was selected as sample tree and more data were recorded i.e. Dbh, BD, total height and merchantable height. The following information about tree stump were collected and recorded: stump diameter, stump height, species name and possible uses and this was for all stumps with stump diameter ≥ 5 cm within plot radius of 15 m. A total of 1413 plots with stumps were recorded in the eastern zone.

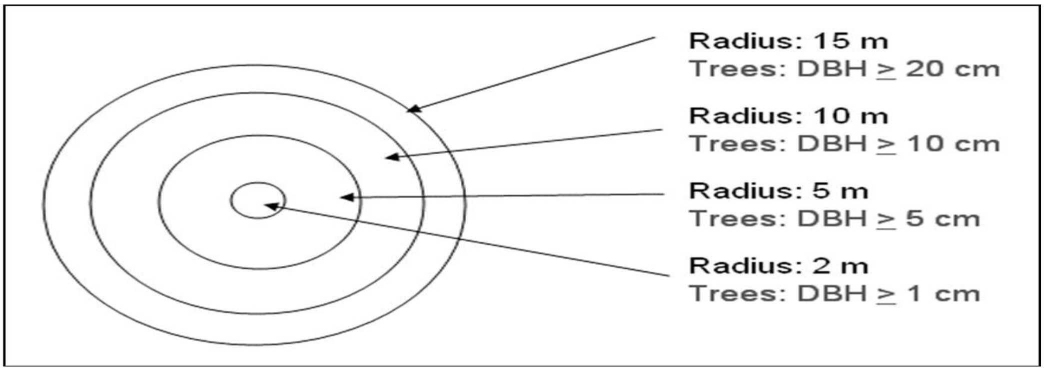

Figure 3: Concentric sample plot

3.4 Data description

In order to understand properly the pattern of the data collected, a preliminary data analysis was carried out to describe the data according to: plots with stumps by regions and vegetation types, number of stumps by species, number of species by vegetation type and drivers of degradation against number of stumps by vegetation types.

3.4.1 Plots with stumps by regions and vegetation types

The total number of sample plots studied was 1413 distributed according to vegetation types and regions as shown in Table 1. Tables also show clearly that some of the vegetation types were not present in other regions for example montane, lowland and plantation forests in Dar es salaam and montane forest in Pwani region.

Table 1: Plots with stumps in various regions and vegetation types

Regions	Vegetation types				
	Woodland	Lowland	Montane	Other	Total
Pwani	331	83	_	44	458
Dar	13	_	_	2	15
Tanga	264	48	53	27	392
Moro	397	86	55	10	548
Total	1005	217	108	83	1413

3.5 Data analysis

Data analysis aimed to the estimate Dbh of felled trees, height, and thereafter volume and biomass removed from the forest.

3.5.1 Estimation of Dbh of felled trees

By using sample trees from the NAFORMA data (see section 3.3). Regression analysis Dbh/BD from 4551 sample trees relationship resulted into the following equation;

Dbh=0.7782+0.7667BD…………………………………...………………...…… (1)

R^2=0.8298, n=4551, S.E=5.41

Where: Dbh and BD are diameter at breast height in cm (1.3m from the ground) and basal diameter in cm respectively.

3.5.2Height estimation

The estimation of single tree volume often requires Dbh and tree height as input variables. Since tree height is difficult to measure, usually all trees are measured for Dbh and only few for height. The estimation of unmeasured trees is done by regression models predicting heights from Dbh of the measured trees. The common height-Dbh models are for example:

i. $h=1.3+\exp[a+b\times dbh^c]$ (Wykoff *et al.*1982)

ii. $h=1.3+a\times[1-\exp(-b\times dbh^c)]$ (Yang *et al.*1978)

In this study height diameter models could be fitted using sample trees from the NAFORMA data (see section 3.3). However it was considered more convenient to use already developed height-dbh models for appropriate forest types as shown in Table 2.

Table 2: The parameter estimate for the relationship between diameter and height of trees in natural tropical forest in Tanzania

Forest type	Model
Miombo woodland	$h=1.3+\exp(10.5116+-10.6039\times dbh^{-0.0823})$…………..…(2)
Montane forest	$h=1.3+\exp(7.0818+-7.2141\times dbh^{-0.1639})$………….............(3)
Lowland forest	$h=1.3+61.8445\times[1-\exp(-0.0237\times dbh^{0.7759})]$……….............(4)

Source: (Mugasha *et al.* 2013).

3.5.3Volume and Biomass equations

In order to estimate both single tree volume and biomass removed, existing equations were used for different vegetation types.

For miombo woodland the equations used were:

Volume $=0.00011(dbh)^{2.133}(Ht)^{0.5758}$ (Mauya *et al* 2014)………………………… (5)

Biomass$=0.0763(dbh)^{2.2046}(Ht)^{0.4918}$(Mugasha *et al* 2014)………………………... (6)

For lowland and montane forests the equations used were:

$V=\exp[-8.12477+1.653497\ln(dbh)+0.852048\ln(Ht)]$ (Masota *et al* 2014)..…… (7)

$B=0.4020(dbh)^{1.4365}(Ht)^{0.8613}$(Masota *et al* 2015)...…………………………….... (8)

3.6 Volume removed per ha

Average volume was calculated using the following relationship

$$vj = \frac{\sum_{i=1}^{n} vi}{aj}$$

$$v = \frac{\sum_{j=1}^{m} vj}{m}$$

Where vi= individual volume of the ithtree in a plot calculated using the selected equation. The trees go from 1 to n.

vj= volume per ha of jthplot of known area. The plots go from 1 to m.

v= average volume per ha for *m* number of plots

The weighted average volume removed in the vegetation types i.e. woodland, lowland and montane (m^3/ha) was obtained using the following formula;

$$= \frac{A.\ woodland \times V.removed}{\sum A} + \frac{A.\ lowland \times V.removed}{\sum A} + \frac{A.\ montane \times V.removed}{\sum A}$$

Where; A, represents area of each vegetation type (NAFORMA data) while V represent volume removed (m^3/ha), ∑A Total area in hectare (ha) of all three vegetation types.

3.7 Removal per year

In order to obtain removal per year the weighted average was divided by the number of years lapsed since the tree was cut. It was assumed that the average age of stumps was 2 years.

3.8 Diameter classes used during analysis

Removal by diameter classes was determined in order to determine the most vulnerable size class for cutting. The diameter classes are shown in Table 3.

Table 3: Diameter classes used during analysis

Diameter class	Dbh range (in cm)
1	0-10
2	10.1-20
3	20.1-30
4	30.1-40
5	>40

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Volume and biomass removed in different vegetation types

Table 4 and Table 5 show clearly that degradation occurs mostly in montane forest subsequently lowland and woodland forests in the forested areas studied in Eastern zone (Tanga, Morogoro, Pwani and Dar es salaam regions).

Table 4: Volume removed in forest and woody vegetation in eastern zone

Vegetation types	Area (ha)	Volume (m^3/ha)
Montane	274,823	48.47
Lowland	618,772	22.27
Woodland	6,867,978	13.77

The weighted mean volume removed in the above vegetation types was (15.68 m^3/ha). Assuming the average stump age is 2 years the average volume removed is 7.84 m^3/ha/yr while the tree removals for example woodland represented an average volume of 6.89 ± 1.39 m^3/ha/yr. Similar study conducted by (Luoga *et al*. 2001) in Kitulangalo forest reserve reported harvested volume of 7.1 ± 1.2 m^3/ha which is not much different compared to this study.

Table 5: Biomass removed in forest and woody vegetation in eastern zone

Vegetation types	Area (ha)	Biomass (t/ha)
Montane	274,823	33.68
Lowland	618,772	14.87
Woodland	6,867,978	9.77

The weighted mean biomass removed in the above vegetation types was (11.02 t/ha). Assuming the average stump age is 2 years the average biomass removal is 5.5 t/ha/yr. Zahabu (2008) recorded a biomass loss of 1 and 3.5 t/ha/yr for the woodland forest at Kitulangalo and lowland and montane forest of Handei in Tanzania.

Based on information on volume and biomass illustrated in Table 4 and Table 5, montane forests contribute large percent to volume and biomass removed of all vegetation types as shown in figure 4 and 5 respectively.

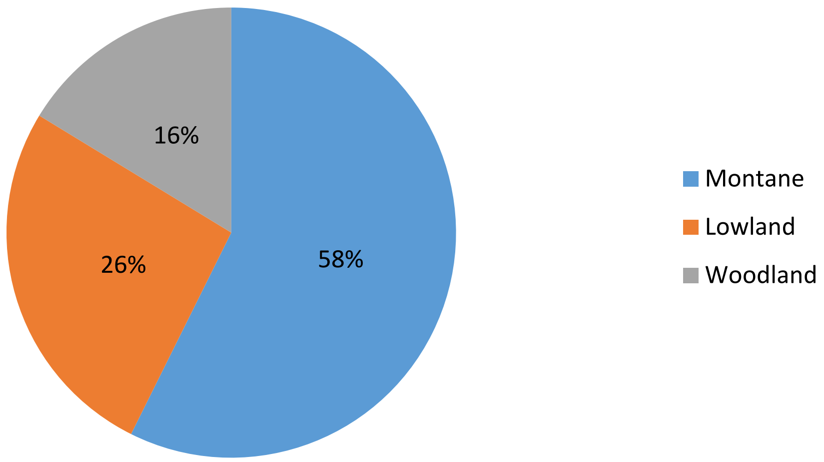

Figure 4: Percentage volume removed in various vegetation types

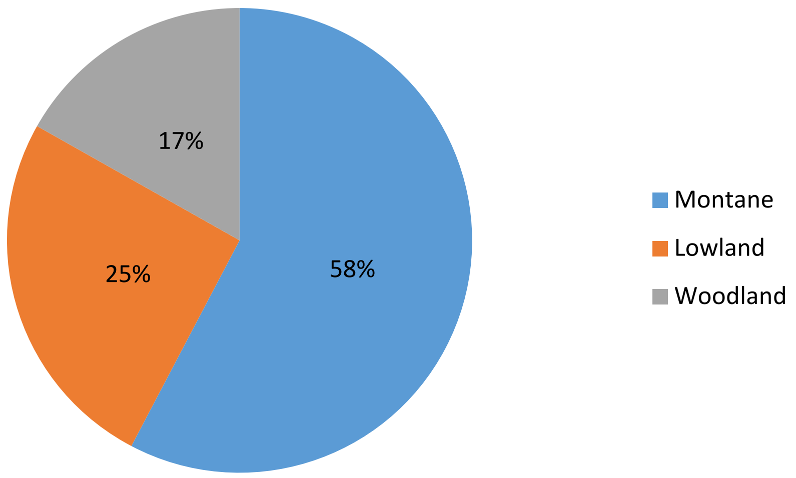

Figure 5: Percentage Biomass removed in various vegetation types in t/ha

4.2 The most degraded species in the forested areas

In order to understand the most degraded species in the forested areas analysis was carried out into three vegetation types namely woodland, lowland and montane forests. This include the most harvested species in term of volume removed and number of stumps removed by species

4.2.1 The most degraded species in various vegetation types

Average volume removed in woodland forests was (13.7 m^3/ha).The most harvested species was found to be *Brachystegia species* (2.56 m^3/ha) which form 18.7% of all woodland species. *Brachystegia species* is also found to be the most degraded species in the lowland forest (5.5 m^3/ha) followed by *Combretum species* (3.4 m^3/ha). The two species form 39.9% of all species in lowland forest. Based on the amount of volume removed in the montane forest the most harvested species was found to be *Ocotea usambarensis* (14 m^3/ha) which form 28.8% of all other harvested species in montane forest (see table 6).

Table 6: Most harvested species in various vegetation types

Harvested species	**Woodland volume (m³/ha)**	**Lowland volume (m³/ha)**	**Montane volume (m³/ha)**
Brachystegia species	2.57	5.5	_
Commiphora species	1.5	_	_
Brachylaena species	1.05	1.5	2.45
Combretum species	0.9	3.4	_
Acacia species	0.05	_	0.5
Ocotea usambarensis	_	1.08	14.0
Olea usambarensis	_	_	3.0
Albizia species	_	_	1.05
Others	7.63	10.79	27.47
Total	13.7	22.27	48.47

4.2.2 The distribution of volume and biomass removed by diameter classes

The distribution of volume and biomass removed by diameter classes in all vegetation types studied shows that the most harvested diameter class was 5. This may be explained by the fact that larger trees are required for different activities such as timber extraction. This qualify thus as a main driver of degradation in the studied vegetation types. In woodland forest trees with diameter class 5 contribute at most of the amount of volume and biomass removed i.e. 4.7 m^3/ha (34.3%) and 3.5 t/ha (35.8%) out of 13.77 m^3/ha and 9.77 t/ha volume and biomass removed respectively e.g. Figure 6. The most harvested species in lowland forest were found to be in diameter class 5 which contribute 7.608 m^3/ha (34.16%) and 4.39 t/ha (29.5%) out of 22.27 m^3/ha and 14.87 t/ha volume and biomass removed respectively e.g. Figure 7. The most harvested species in montane were found to be in diameter class 5 which contribute 34.43 m^3/ha (71.06 %) and 26.35 t/ha (78 %) out of 48.47 m^3/ha and 33.68 t/ha volume and biomass harvested respectively e.g. Figure 8.

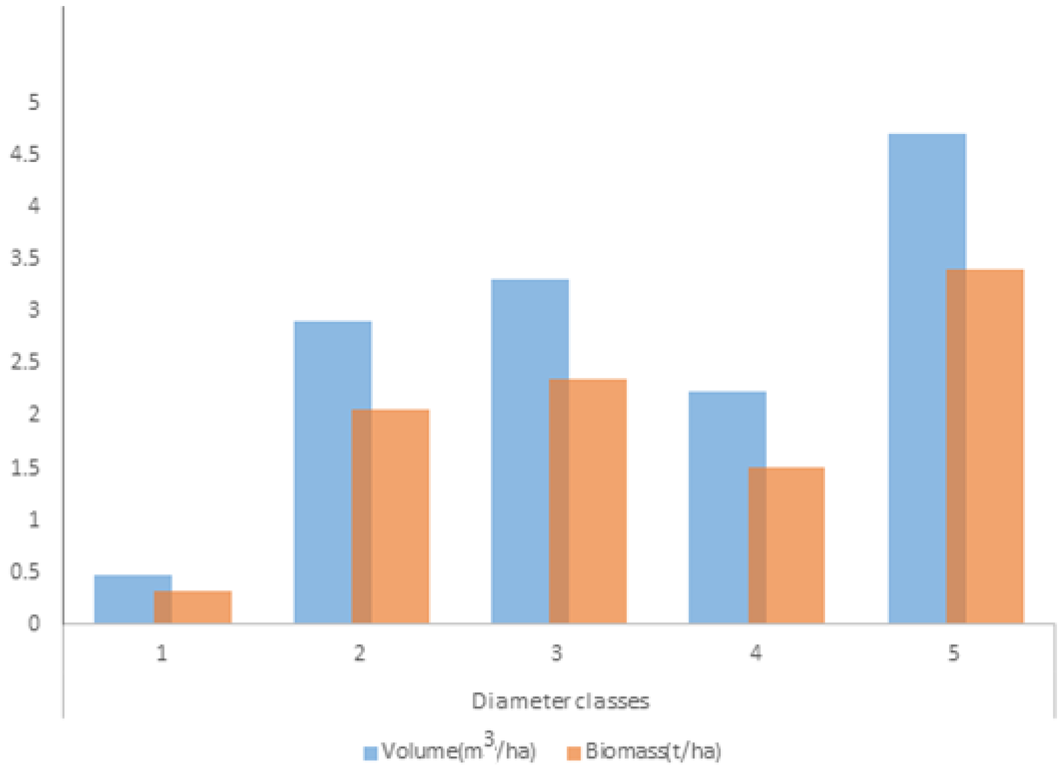

Figure 6: Distribution of volume and biomass lost by diameter classes in woodland forests

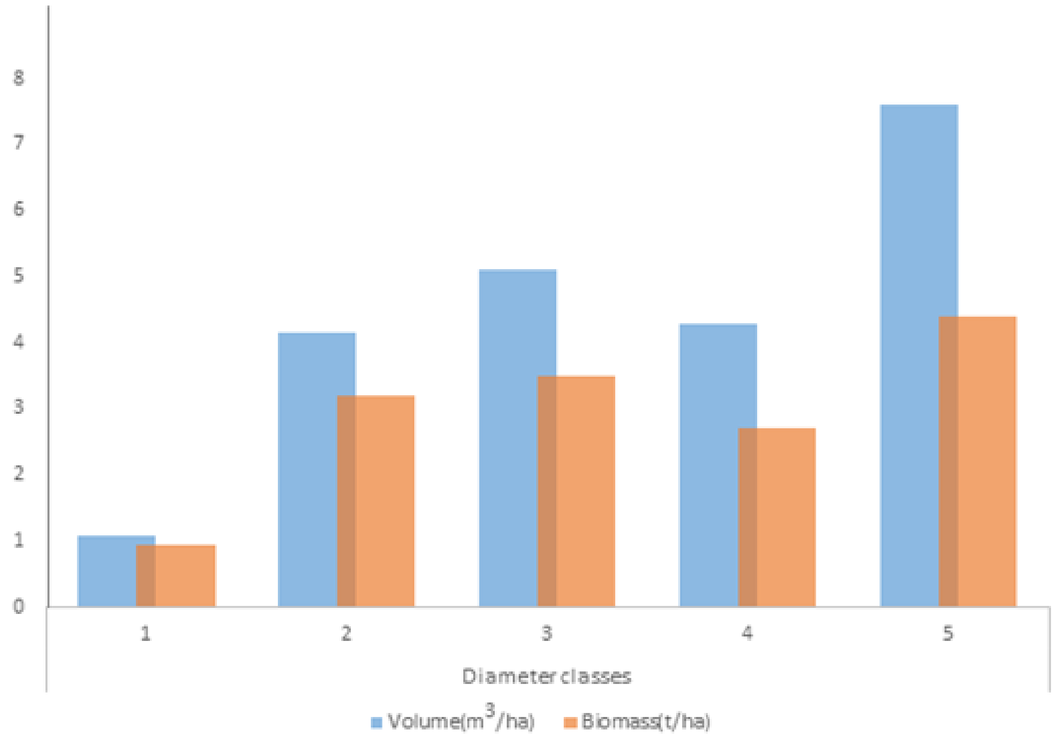

Figure 7: Distribution of volume and biomass lost by diameter classes in lowland forests.

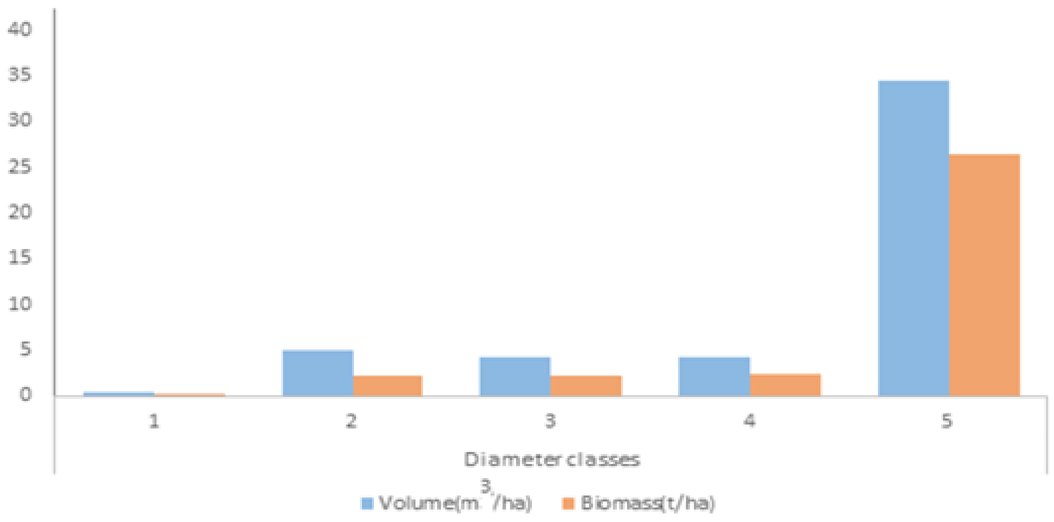

Figure 8: Distribution of volume and biomass lost by diameter classes in montane forests.

4.3 Most Harvested species based on stump removal

4.3.1 Number of stumps by genera

Based on the frequency of occurrence of stumps in the eastern zone genera *Brachystegia* were found to be the most removed in the respective forested area followed by genera *Combretum*. The two genera form 17.8% of all e.g. Table 7.

Table 7: Number of stumps counted by genera in eastern zone

Genera	**No. stumps counted**	**%**
Acacia	845	4.8
Albizia	637	3.6
Brachystegia	1739	9.9
Brachylaena	260	1.4
Combretum	1374	7.8
Diplorhynchus	764	4.3
Markhamia	748	4.2
Julbernadia	493	2.8
Others species	10609	60.7
Total	17469	100

Indeed, in genera *Brachystegia, Brachystegia spiciformis* were found to be the most removed species which form (25.2%) of all followed by *Brachystegia boehmii* (17.8%) there after *Brachystegia bussei* (10.8%) while others remaining *Brachystegia species* form (46.2%) as clearly shown in Table 8.

Table 8: Brachystegia species against number of stumps counted in eastern zone

Species	No. stumps counted
Brachystegia allenii	16
Brachystegia boehmii	309
Brachystegia bussei	189
Brachystegia fischeri	4
Brachystegia floribunda	14
Brachystegia longifolia	84
Brachystegia microphylla	83
Brachystegia sp.(Unspecified)	588
Brachystegia spiciformis	439
Brachystegia tamarindoides	6
Brachystegia zanguebarica	7

4.3.2 Number of stumps by genera in different vegetation types

i. Woodland

Based on number of stumps counted i.e. frequency of occurrence of stumps the genera *Combretum* seems to be the most removed with slight difference compared to genera *Brachystegia.* The two genera form 17.6% of all as clearly shown in Table 9.

Table 9: Number of stumps counted by genera in woodland

Genera	No. stumps counted
Acacia	231
Albizia	239
Brachystegia	311
Brachylaena	226
Combretum	327
Others	2282

Furthermore, *Combretum zeyheri* was the only species that was harvested in greater extent followed by *Combretum molle* as shown in Table 10. The two species form 64.2% of all *Combretum* removals.

Table 10: Combretum species against number of stumps counted

Species	No. stumps counted
Combretum collinum	24
Combretum grandifolium	4
Combretum imberbe	11
Combretum molle	103
Combretum sp. (other)	78
Combretum zeyheri	107

ii. Lowland

Based on frequency of occurrence of stumps *Rhizophora mucronata* was the most removed species in the lowland forest which form 14.2% of all lowland species removed as clearly shown in Table 11.

Table 11: Lowland species against number of stumps counted

Species	No. stumps counted
Brachylaena huillensis	28
Brachystegia sp.	35
Combretum sp.	49
Rhizophora mucronata	117
Sorindeia madagascariensis	48
Others species	548

iii. Montane

Based on the frequency of occurrence of stumps the most harvested species in montane forests were found to be *Brachylaena huillensis* which form 7.2% of all harvested species in montane forests as shown in Table 12.

Table 12: Species against number of stumps counted in montane forests

Species	**No. stumps counted**
Acacia sp.	16
Albizia sp.	18
Brachylaena huillensis	23
Ocotea usambarensis	19
Pinus patula	16
Other species	228

4.3.3 Drivers of degradation against number of stumps by vegetation types

Anthropogenic activities have been a part of ecosystem dynamics in the forest. NAFORMA data provide the possible uses of trees felled down as well as estimated time since the tree was cut. Based on frequency of occurrence of stumps charcoal making qualify as the most driver of degradation in both woodland (38.8%) and lowland forest (54.8%) as clearly shown in Table 13 and Table 14 respectively. On the other hand agriculture practices such as land preparation form (32.4%) therefore qualify as the most agent of degradation in montane forest e.g. Table 15.

Table 13: Drivers of degradation against number of stumps counted in woodland forest

Drivers	No. stumps
Charcoal making	390
Agriculture practices	296
Timber	142
Firewood	102
Others	75

Table 14: Drivers of degradation against number of stumps counted in lowland forest

Drivers	No. stumps
Charcoal making	119
Timber	42
Agriculture practices	28
Firewood	14
Others	14

Table 15: Drivers of degradation against number of stumps counted in montane forest

Drivers	No. stumps
Agriculture practices	35
Firewood	27
Timber	18
Charcoal making	12
Others	16

4.4 Drivers of degradation

The findings revealed that timber species harvested illegally were used for different purposes in different vegetation types including charcoal making, timber extraction, agriculture activities and other factors. It has been reported in selected forest reserves that the removal of poles for commercial and subsistence uses accounted for more than half of available stocks (Hall and Rodgers, 1986). However, the study discover that volume removed in the woodland forest is mostly due to charcoal making (2.92 m^3/ha) followed by timber extraction (2.09 m^3/ha). The remaining volume (8.76 m^3/ha) include firewood collection and agriculture activities e.g. Table 16. Charcoal production is the main source of the income in the eastern Tanzania (Luoga *et al.*, 2000) and can result in severe local disturbance of woodland. For lowland and montane the study reveal that forest timber extraction is the most degradation factor which account for about 5.03 m^3/ha (22.5%) and 14.82 m^3/ha (30.57%) out of 22.27 m^3/ha and 48.47 m^3/ha, respectively. e.g. Table 17 and Table 18. This is supported by Dallu (2006) and Mbonde (2005) who list the threats currently facing forest management in Tanzania as illegal harvesting and trade in timber and other forest products, forest encroachment due to small-scale shifting agriculture, and the impacts of refugees, livestock, mining and fire.

4.4.1 Drivers of degradation in woodland forest

Charcoal burning and cutting trees for timber and agriculture activities are the main source of degradation. Based on various anthropogenic activities the drivers of degradation against volume removed in woodland are shown in Table 16.

Table 16: Drivers of degradation against volume removed in woodland forest

Drivers	Harvested wood	
	Volume (m^3/ha)	%
Charcoal making	2.92	21.21
Timber	2.09	15.17
Agriculture practices	1.86	13.5
Firewood collection	0.91	6.6
Building materials (poles)	0.4	2.9
Others	5.59	40.6
Total	13.77	100

4.4.2 Drivers of degradation in lowland forest

There are different drivers of degradation such as timber harvesting, charcoal production, and agriculture activities just to mention few. Based on the amount of volume removed, cutting of trees for timber is the most driver of degradation in lowland forest e.g. Table 17.

Table 17: Drivers of degradation against volume removed in lowland forests

	Harvested wood	
Drivers	Volume (m^3/ha)	%
Timber	5.03	22.58
Charcoal	3.72	16.7
Agriculture practices	3.1	13.9
Firewood	0.94	4.22
others	8.32	37.35
Total	22.27	100

4.4.3 Drivers of degradation in montane forest

Table 18 shows that timber species harvested illegally confirm a greater extent of volume removed in the montane forest (30.57%) followed by agriculture practices (15.88%). Due to this phenomenon extraction of timber is the most driver of degradation in the provided forest. Zahabu and Malimbwi, (1997) investigated that the most common human activities triggering degradation in montane forests include, clearing for new farmland, pitsawing, illegal timber harvesting, collection of building poles, cutting trees for medicine, collecting fuel wood, and mining activities

Table 18: Drivers of degradation against amount of volume removed in montane forests

Drivers	Volume (m^3/ha)	Harvested wood %
Timber	14.82	30.57
Agriculture practices	7.7	15.88
Natural death (trees)	6.3	13.0
Firewood	2.56	5.28
Building materials(poles)	2.56	5.28
Charcoal	0.5	1.03
Others	14.03	28.95
Total	48.47	100

CHAPTER FIVE

5.0 CONCLUSION AND RECCOMENDATION

The extent of forest degradation is the result of different anthropogenic activities. Findings of this study confirmed that forest degradation in the eastern zone is widespread, caused mostly by timber extraction, agriculture practices and charcoal making. The volume and biomass harvested from the forest is much higher in the montane forest subsequently lowland and thereafter woodland forest. The reason might be large diameter trees required by adjacent communities for different purposes such as timber extraction and charcoal making as their income generating activities since most vulnerable size class for cutting was found to be trees with Dbh>40cm. In the study the tree species preferred for charcoal making and building materials consists of *Brachystegia boemii*, *Brachystegia spiciformis*, *Brachystegia bussei* and *Combretum molle*. Efforts need to be taken to combat shifting farming practices and illegal logging and activities that lead to the spread of fires on an annual or even more frequent basis. The uncontrolled forest resource exploitation does not only entail threats to the forests themselves, but also results in a degradation of the livelihoods of the forest adjacent local communities. These existentially depend on forest products such as timber, poles, medicinal plants, fruits, food protein, etc. and the ecosystem services provided such as water catchment, erosion prevention and stream stabilization.

Given the widespread dependence of a massive population on forest for subsistence livelihood, arresting forest degradation involves designing and implementing strategies that creates alternative livelihood opportunities and diminish their dependence on forest based activities. Apart from adhere to the JFM agreement with critical emphasis on modalities of benefit sharing the Government should commit enough resources to safeguarding the reserves.

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