STATUS OF POST HARVESTING REGENERATION OF MIOMBO WOODLANDS IN KILOSA, TANZANIA

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ABSTRACT

This study presents findings of post harvesting regeneration status of miombo woodlands of Kilosa,Tanzania specifically where sustainable charcoal project is implemented. The overall objective of the study was to undertake an assessment on the regeneration status of Miombo woodlands in harvested plots and kiln scars. A total of 67 circular plots with 15 m radius established in 2015 were identified for the purpose of making a follow-up study on regeneration. Forty four new circular plots with 5 m radius for the study of regeneration in kiln scars and 10 circular plots with 5 m radius for assessing effects of fire on soil physical and chemical properties were demarcated. It was observed that 87% of all stumps were regenerating through coppices, root suckers or both. About 42% stumps were found to develop coppices with an average of two (2) individuals per stump and with overall mean height of 254 ± 8.3 cm. Twenty three (23%) of the stumps were observed to have regenerated through root suckering with average of two (2) individual suckers per stump with an overall mean height of 252±7.9 cm.Twenty two (22%) stumps were observed to regenerate through both coppices and root suckers with an average of two individual coppices/suckers per stumps with an overall mean height of 251±6.3 cm. Only Thirteen (13%) stumps were not regenerating. Regeneration via seedlings were found to be lower if compared with sprouts. Student T tests and ANOVA were used to compare regeneration mechanisms, regeneration in kilns and effects of fire frequency and grazing intensity on regeneration (Tables in appendices). Signs of regeneration in kiln scars was noted as seedlings of *B.boehemii* and *B.spiciformis* were observed. Fire has effects on soil physical and chemical properties. It is concluded that regeneration has improved with reference to previously study; fire and grazing has direct beneficial and deleterious effects on tree regeneration. It is recommended that further monitoring in harvested plots is necessary.

DECLARATION

I, Peter Ansgar Myonga, do hereby 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 for a degree award in any other institution.

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DEDICATION

It is dedicated that this dissertation is for my wife Mecktids Ngolle and our beloved sons Brian and Peter and daughters Careen and Carol Myonga.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
BD	Basal Diameter
CEC	Cation Exchange Capacity
D.f	Degree of freedom
DBH	Diameter at Breast Height
FMUs	Forest Management Units
JFM	Joint Forest Management
KDC	Kilosa District Council
MJUMITA	Mtandao wa Jamii wa Usimamizi wa Misitu Tanzania
MNRT	Ministry of Natural Resources and Tourism
NAFORMA	National Forest Resources Monitoring and Assessment
NFRs	Natural Forestry Resources
PFM	Participatory Forest Management
RCBD	Randomised Complete Block Design
SNAL	Sokoine National Agricultural library
TAFORI	Tanzania Forest Research Institute
TFCG	Tanzania Forest Conservation Group
TFSA	Tanzania Forest Services Agency
TTCS	Transforming Tanzania Charcoal Sector
URT	United Republic of Tanzania
VNRC	Village Natural Resource Committee

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

The Miombo woodlands cover approximately 3.6 million km^2 in central and southern Africa (Byers, 2001). They have been identified to be among the five global wilderness areas that should be prioritized for conservation (Mittermeier *et al*., 2003). In Tanzania, they account for about 30% of the primary production of all terrestrial vegetation and they play a crucial role in supply of energy, support to local livelihoods, and carbon balance (Chidumayo, 2013; Schimel, 2010). They encompasse 44.7million ha or 92% of the total forest area of Tanzania (i.e 48.1million ha) and accounts for about 55% of the total land area of Tanzania mainland (MNRT, 2015). It is estimated that Tanzania loses about 1% (372 000 ha) of forests annually in which Miombo woodlands take a large part of it (MNRT, 2015). They are in a state of rapid change which is caused by human activities for their livelihoods while the major driver for their loss is the requirement of firewood and charcoal in order to meet cooking energy demands. This is owing to the fact that about 90% of the country's cooking energy needs are met through the use of wood based fuels (Desanker *et al*., 1997; MNRT, 2015).

Miombo woodlands have a remarkable capacity to recover after disturbance due to tree regeneration from the roots and stumps (Shirima *et al*., 2015a). Miombo woodlands tree species can regenerate largely through coppice regrowth and root suckering rather than seeds (Chirwa, 2015). They have shown to regenerate by themselves after Agricultural, charcoal production and selective logging activities (Chidumayo, 2002; Schwartz and Caro, 2003; Chinuwo *et al*., 2010, Kalaba *et al*., 2013). Sustainable Miombo woodlands management requires a detailed understanding of the implications of land use practices such as charcoal production, slash and burn agriculture and timber harvesting (Syampungan *et al*., 2015).

The Sustainable Charcoal Project is implemented in Kilosa District and uses a sustainable charcoal production model which aims at establishing a real life, pro-poor sustainable value chain that provides for self-employment opportunities, contributing to community development and provision of sustainable management of natural woodlands (MJUMITA, 2015). It facilitates the making of sustainable harvesting plans so that the trees are harvested in a sustainable manner but also, educating villagers on the use of improved methods of harvesting trees for charcoal making by using improved charcoal kilns. Monitoring of natural regeneration in the harvested areas is crucial in order to determine the best approach for effectively conserving the Miombo woodlands ecosystems.

1.2 Problem statement

Charcoal is primarily supplied from rural areas and provides affordable energy to 70–90% of the urban population (Milliken *et al*., 2018; Woollen *et al*., 2016). This drives many people to rely on this business hence a huge number of trees are cut illegally each year. Under sustainable charcoal production program in Kilosa District, trees were harvested for charcoal making in eight villages and assessment on regeneration was done in 2015 where result showed that regeneration was occurring to a sufficient amount (Sangeda and Maleko, 2018).

Chidumayo (2004) and Frost (1996) also observed that regeneration of Miombo woodlands via root suckers and coppices perform better than seedlings. Based on the study done in 2015 by Sangeda and Maleko, coppicing was sufficient followed by root suckers and seedlings.

Chidumayo (2004) reported that destruction of woody plant root stocks at kiln center during carbonization implies that regeneration originates solely from seedlings. Kilns scars are the favorable microhabitat in the first regeneration stages of plant species and their further growth is hindered by long term effects (Carrari *et al*., 2016; Cheng *et al*., 2012). Regeneration habits tend to differ between charcoal kiln areas and the rest of the forest areas (Dons, 2014). Sangeda and Maleko (2018) observed that there was no regeneration in kiln scars harvested two years earlier. De Bano *et al.* (1998) reported that burning fire in forests tend to change the physical and chemical properties of the soil. Fire and grazing intensity have shown effects on the regeneration of Miombo woodlands (Frost, 1996; Chidumayo 2004; Sangeda ana Maleko, 2018; Mtimbanjayo, 2018; Shelukindo *et al*., 2014). Although the sources of all the above information have been reported for various areas in Miombo woodlands, the current status of regeneration in the harvested plots in Kilosa District is still being assembled and monitored.

1.3 Justification of the study

The present study is part of the monitory protocol on the regeneration status of the Miombo woodlands that were harvested in 2013 in Kilosa District, Morogoro region, Tanzania. The first assessment was conducted in 2015 and this second assessment was done during the period of 2018. The present study will therefore highlight the trend of regeneration in the harvested areas for monitoring purposes so that the trend of regeneration resulting from sustainable harvesting can be known in a prolonged period of time. The study will provide information on the trend of regeneration. Continued monitoring and documentation of the Miombo woodlands and their outputs can in the future, assist policy makers and foresters in enhancing Miombo woodlands conservation and sustainable provision of firewood and charcoal to the communities.

1.4 Objectives

1.4.1 Overall objective

Undertaking an assessment on the regeneration status of Miombo woodlands in harvested plots and kiln scars in Kilosa, Tanzania.

1.4.2 Specific objectives

i. To assess the regeneration status of various tree species harvested four years earlier.

ii. To determine the regeneration status in the kiln scars.

iii. To examine the soil physical and chemical properties in kiln scars.

iv. To determine the effects of fire and grazing on the performance of the regeneration of Miombo trees in the harvested areas.

1.5 Research Questions

a. Is there any change in the regeneration status of Miombo woodlands in harvested plots between 2015 and 2017?

b. What are the effects of fire on the regeneration of Miombo in the harvested plots?

c. What are the effects of grazing on the regeneration of Miombo in harvested plots?

d. Is there any regeneration in kilns scars since 2013?

e. To what extent fire changes the physical and chemical properties of the soil in the kiln scars?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General overview of Miombo woodlands

Miombo woodlands is widely used to describe the Savanna woodlands of Southern Africa that are dominated by trees of the subfamily Caesalpinioideae of the Leguminoseae mainly of the genera Brachystegia, Julbernardia and Isoberlinia (Malmer, 2007). Their vegetation composition varies depending on climate, soil types and topography factors (Ulrich *et al*., 2014). The Miombo woodlands eco region covers approximately 3.6 million km^2 in central and southern Africa (Byers, 2001). It can be considered as a socio ecological system in which humans play a significant role in shaping woody vegetation structure and composition (Muboko, 2013). They are characterized with distinctive features such as having a low density of canopy tree species and they usually form new leaves mostly just before the rain season starts which is used by local people as an indicator of the onset of the rains (Chidumayo, 2004). It is a vital renewable resource that constitutes fundamental parts of living environment. Deforestation of Miombo woodlands is a temporary problem because of the presence of a large seedling pool in the herb layer and the sprouting ability of cut trees ensure fairly rapid recovery (Chidumayo, 2004).

It is estimated that Tanzania has Miombo woodlands and forest in 48.1 million ha which is equivalent to 55% of the total land. Recent results from the National Forest Resources Monitoring and Assessment of Tanzania (NAFORMA) show that all woodlands occupy about 44.7 million hectares (ha), which is equivalent to 92% of the total land area of the country. The main regions dominated by Miombo woodlands are Tabora, Rukwa, Kigoma , Iringa, Lindi, Mtwara, Ruvuma, Morogoro, Coast and Tanga (MNRT, 2015).

It is expected that there will be more pressure upon Miombo woodlands as the population of Sub-Saharan Africa is expected to double by 2050 (Eastwood and Lipton, 2011; Cabral *et al*., 2011; Dewees *et al*., 2010). According to Syampungani *et al*. (2009), over 100 million people in Africa are directly or indirectly dependent upon Miombo woodlands for their daily needs. The community depends to the Miombo woodlands in order to collect dead and live wood for cooking, construction, charcoal production and the collection of Non-Timber Forest Products (NTFP) for medicines, food and livestock fodder (Abbot and Homewood, 1999; Kutsch *et al*., 2011; Dewees *et al*., 2010). For Tanzania, Miombo woodlands support the livelihoods of estimated 87% of urban and rural population (Abdalah *et al*., 2007; Milledge, 2007).

Due to unsustainable forest practices Miombo woodlands are diminishing and many tree species are facing local extinction (Chidumayo and Frost, 1996). They receive increasing attention to land management practices (Williams *et al*., 2008). They are in a state of rapid change which is caused by human activities for their livelihoods while the major driver for their loss is requirement for firewood and charcoal in order to meet the national cooking energy demands. This is owing to the fact that about 90% of the country's cooking energy needs are satisfied through the use of wood based fuels (Desanker *et al*., 1997; MNRT, 2015).

2.2 Sustainable Charcoal production Model of MJUMITA

The model aims to establish a real life, pro poor sustainable charcoal value chain that provides for self-employment opportunity to investment in community development and incentivizes for more sustainable management of natural woodlands. Since 2012, TFCG and MJUMITA have assisted 8 villages in Kilosa District in Morogoro Region to integrate sustainable charcoal production into management of their village reserves

(MJUMITA, 2015). Villages prepare and agree to a village land use plan that includes a village land and forest reserve. The reserves need to use at least a few hundred hectares and should have some areas of mature woodlands in it. The community prepares a management plan and bylaws for village reserve. The management plan designates Forest Management Units (FMUs) as areas for sustainable charcoal production. The number of FMUs varies between villages from one to three depending on the size and distribution of the reserve. In Kilosa, 10% of the area of each village forest reserve is designated for charcoal production. The remaining 90% is for protection, beekeeping and in few cases selective timber harvesting (MJUMITA, 2015).

Within 8 pilot villages, the maximum area that can be harvested per year is 257 ha ranging from 11-79 ha per village. The rotation period is 24 years which means that the area harvested in the first year will be harvested again after 23 years. The FMUs is divided into 24 blocks known as coupes. Every year harvesting is done in one coupe and the boundaries of a coupe are marked by Village Natural Resource Committee (VNRC) and producers are only permitted to produce charcoal within a coupe. Trees are cut at knees height (50cm) leaving behind stumps and roots to encourage coppicing and suckering. Not all trees are cut down in a coupe as trees on steep slopes or closer to water source are left free. Also trees for valuable timber and particular biodiversity value are left (MJUMITA, 2015). All coupes need to be protected in order to allow the woodlands to regenerate naturally by completely excluding fire for at least two years from harvesting (MJUMITA, 2015).

2.3 Regeneration of Miombo woodlands

Miombo woodlands species can regenerate largely through coppice regrowth and root suckers rather than seeds. Stumps of almost all Miombo woodlands have the ability to produce coppices and root suckers. The majority of seedlings of Miombo woodlands trees experience a prolonged period of successive shoot dieback during their development phase in order to cater for water stress and/or fire during the dry season (Chidumayo, 1988). Miombo woodlands tree species have shown to regenerate by themselves after agricultural, firewood and charcoal production and selective logging activities (Chidumayo, 2002; Schwartz and Caro, 2003; Chinuwo *et al*., 2010; Kalaba *et al*., 2013). Some studies in other countries has shown that there has been a reduction in Miombo natural regeneration and tree species diversity due to poor management practices (Missanjo, 2014). Miombo woodlands tree species are capable of reproducing asexually and sexually (Chidumayo, 1997).

2.3.1 Vegetative regeneration of Miombo woodlands

Chidumayo (1997); Chidumayo and Frost (1996), reported that reproduction via vegetative regeneration is the most effective form of reproduction among Miombo woodlands species as root suckers and epicormic buds allow them to sprout once the aboveground parts of a tree has been removed or damaged. Number of coppicing shoots is always high during establishment periods and decreases due to inter-shoot competition and only shoots that have attained superior size contribute to the next generation (Chidumayo, 1997).

Regeneration by coppicing makes Miombo woodlands species remarkably resilient to disturbance and constitutes the most effective form of persistence (Boaler and Sciwale 1966; Grundy 1995; Frost, 1996) rather than depending on seed production. After tree cutting, they have the ability to regenerate through coppicing of stem remnants (stumps), root suckering and from the large bank of suppressed saplings (Luoga *et al.,* 2004). Miombo woodlands species are known to re sprout from roots and stumps once the above ground biomass is removed or killed by harvesting or fires (Luoga *et al*., 2004; Syampungani, 2008).

Harvesting methods play an important role in stimulating or retarding coppice formation and growth. A clean cut with a saw results in more vigorous coppicing than a jagged cut from an axe (Pearce, 1993). In other areas, studies show that harvesting method by allowing coppice with standard (Trees of all size classes are coppiced or pollarded, removing 70- 80 % of the basal area or canopy) is recommended as the system which give chance to all species to regenerate and grow as all species are exposed to light (Missanjo, 2014).

Sprouting via root suckers and coppices is most important regeneration methods in Miombo woodlands ecosystems on the fact that they grow faster than established seedlings. They are capable of quickly reoccupying their own gaps and therefore minimizing the effect of the disturbance and minimizing the population turnover often caused in plants that relay on seeds (Bond and Midgley, 2001).

2.3.2 Sexual regeneration of Miombo woodlands

The majority of Miombo woodlands have seeds that germinate immediately after dispersal as long as water supply is sufficient. There is no extended dormancy or seed bank in the soils among the canopy species. Some tree species like *Albizia* and *Pterocarpus* have seeds which are dispersed by wind but most of the dominant species, including *Brachystegia*, *Isoberlinia* and *Julbernardia*, have explosive seed dispersal with pods splitting open and scattering the seeds (Chidumayo and Frost, 1996). They have seeds that germinate immediately after dispersal as long as water supply is sufficient.

Seed production is sometimes affected by lack of flowering or flower abortion such as in some members of the Brachystegia which are susceptible to insect infection particularly in old growth of Miombo woodlands (Chidumayo, 1997). Chidumayo (1997); Ernst (1998) and Trapnell (1959), reported that tree seedling development is mostly impaired by biotic and abiotic factors and there is greater inter specific variation in the survival rate of Miombo woodlands tree seedlings especially during the establishment phase and mortality can be up to 70%.

Previous study in the sustainably harvested areas in Kilosa District, shows that regeneration was robust in coppicing and root suckering and *B.spiciformis* was regenerating better through root suckering and *B.boehmii* through coppicing and sustainable harvesting diameter class was between 20 and 30 cm DBH (Sangeda and Maleko, 2018). Coppicing was observed to be the most effective pathway of regeneration followed by root suckering and seedlings. Regeneration via seedlings was shown that much of seedlings were destructed by animals or burnt by fire and others were suppressed by grasses (Sangeda and Maleko, 2018).

2.4 Regeneration of Miombo woodlands in kiln scars

According to Carrari *et al*. (2015a), production of wood charcoal by the use of kilns is a traditional form of forest use that lasted for millennia in many countries and sites where kilns were installed are characterized by peculiar ecological conditions. Kilns are the favorable microhabitat in the first regeneration stages of plant species as their further growth is hindered by long-term effects that should be investigated with an experimental approach (Carrari *et al*., 2016; Cheng *et al*., 2012). Regeneration habits tend to differ between charcoal kiln areas and the rest of the forest areas (Dons, 2014).

High temperature in kiln centers (500-700 °C) during carbonization kills virtually all plant seedlings and root stocks. The kiln scar is therefore the most severely impacted portion of the deforested area (Chidumayo, 2004). Destruction of woody plant root stocks at kiln center during carbonization implies that regeneration on such scars will originate solely from seed (Chidumayo, 2004). Given the very slow growth rate of Miombo woodlands seedlings, such a regeneration process probably takes many years. Chidumayo (2004) found that little woody plant regenerations occurred on kiln center in a prolonged period. A study which was done in 2015 in the harvested areas in Kilosa showed that many of the kilns (two years from harvesting) had no seedlings (Sangeda and Maleko, 2018).

2.5 Effects of fire on physical and chemical properties of soils in kiln scars

High temperatures always clear alterations of texture of the soil material due to the charred woody remains. The condensed aromatic structure of wood charcoal allows fragments and particles to persist in soils over millennial time scales (Cheng *et al*., 2012). It is obvious that physical and chemical properties of the soil are being altered after making charcoal in kilns.

Miombo woodlands soils differ in physical and chemical properties. This is due to differences in topography, vegetation types, parent material, climate and human induced factors such as fires, grazing and deforestation (Shelukindo *et al*., 2014). Often Miombo woodlands are found on poor soils with low organic matter and Nitrogen contents and many tree species have established special survival mechanisms. They are equipped with ectomycorrhizae, which increase their probability of survival on poor soils (Frost, 1996). The Miombo ecosystem occur in soils which are predominantly alfisols, oxisols and ultisols which are highly acidic, low in cation exchange capacity, low total exchangeable bases and they are sandy, leached (Frost 1996). Msanya *et al.* (2014) reported that Miombo woodlands in Kitonga Forest reserve and in Tabora (Tanzania) indicated that soils had low fertility status and it could be attributed by charcoal burning among other factors. Syampungani *et al.* (2015) observed that charcoal production and slash and burn agriculture are necessary disturbances that enhance the establishment and development of the regeneration pool of the Miombo woodlands species.

2.5.1 Effects of fire in Soil physical properties

Soil texture

Soil texture is sensitive to change when subjected to high temperature. Clay minerals begin to change at temperatures of about 400 °C when clay hydration and clay lattice structure begin to collapse. At a temperature of 700 to 800 °C, the complete destruction of internal clay structure occurs. According to TFCG (2015), kilns for charcoal production are created in some steps as the initial and final temperatures at the kilns ranges between 100^0C-700^0C. Soil texture under high temperature usually tend to change from fine to coarser and erodible (De Bano *et al.*, 1998). Msanya, *et al.* (2014) reported that soils in Miombo woodlands at Kitonga Forest Reserve were a dominantly coarse textured and varies from sand to sandy loam texture at the surface and sandy clay loam in sub surface. They reported that a coarse textured soil was more than 65% sand and less than 18% clay which had low fertility status. Mtimbanjayo (2016) reported that soil texture in villages where sustainable charcoal operates (Ihombwe village) was Sandy Clay Loam. Vågen and Winowieck (2012) reported that sand contents control the variability of nutrient storage capacity of the soils by affecting physical and chemical properties of the soils.

Bulk Density and Soil porosity

Bulk density is the mass of dry soil per unit bulk volume (expressed in g/cm^3). Fire and associated soil heating destroys bulk density and total soil porosity of the soil (De Bano *et al.*, 1998).

2.5.2 Soil chemical properties

All chemical characteristics of soil are affected by fire, although the temperatures at which changes occur can vary widely (Beyers *et al.*, 2005). Chemical properties range from the inorganic cations like Calcium (Ca), Sodium (Na), Magnesium (Mg), and Potassium (K), and they are adsorbed on the surface of clay materials to those contained mainly within the organic matrix of the soil like organic matter, C, N, P, S. Different studies have concluded that soil chemical constituents increase, decrease, or remain the same (De Bano *et al*., 1998). This has been particularly true for studies reporting changes in N and other nutrients that can volatilize readily during a fire like Organic matter.

Cation Exchange Capacity

CEC is a measure of the capacity of soil to retain nutrients (against leaching) and gives an idea of the potential fertility of the soil (Misanya *et al*., 2001). Cation exchange is the interchange between cation in solution and different cation adsorbed on the surface of any negatively charged materials such as clay or organic colloids (humus). Cation exchange capacity is the sum of the exchangeable cation found on organic and inorganic soil colloids (Neary *et al.,* 2005). Ma *et al.* (2015) suggested that, CEC and soil microbial community composition are significantly related to the habitat (mean annual precipitation and temperature, radioactive dry index, elevation, soil texture, pH, soil nutrient content, water holding capacity) and land management (tillage, grazing, historical tillage, flooding). Cations found in the soil that are affected by fire include Ca, Mg, Na, K, and

NH_4 although these cations are not usually deficient in most wildland soils (De Bano, 1991). In many studies, a significant increase in soil cation concentration following either prescribed burning or a wildfire has been reported (Grove *et al*. 1986; Raison *et al*., 1990; Soto and Diaz, 1993).

Soil pH

It is a measure of the hydrogen ion activity in the soil and is determined at specified moisture contents. Neutral soils have a pH of 7, acidic soils have a pH less than 7, and basic soils are those with a pH greater than 7. The combustion of organic matter during a fire and the subsequent release of soluble cations tend to increase in pH slightly because basic cations are released during combustion and deposited on the soil surface. The increase in soil pH, however is usually temporary depending upon the original soil pH, amount of ash released, chemical composition of the ash, and wetness of the climate (Wells *et al.,* 1979). According to Msanya *et al.* (2014), majority of the soils in Miombo are rated as acidic with mean pH value of 5.9 (medium)

Nitrogen

Nitrogen is considered as the most limiting nutrient in wild land ecosystems and as such it requires special consideration when managing fire, particularly in N deficient ecosystems (Maars *et al.,* 1983). Nitrogen is unique because it is the only soil nutrient that is not supplied to the soil by chemical weathering of parent rock material. Almost all N found in the vegetation, water, and soil of wild land systems has to be added to the system from the atmosphere (Maars *et al*., 1983). It responses to soil heating by volatilization which is the chemically driven process most responsible for N losses during fire. There is a gradual increase in N loss by volatilization as temperature increases (Knight, 1966; White *et al*., 1973). The amount of total N that is volatilized during combustion is directly proportional to the amount of organic matter destroyed (Raison *et al.,* 1985a). It has been estimated that almost 99 % of the volatilized N is converted to N_2 gas (De Bell and Ralston, 1970).

2.6 Effects of fire and grazing on the performance of the regeneration of Miombo woodlands

2.6.1 Effects of Fire on regeneration of Miombo woodlands

Fire in Miombo woodlands has been used as a forest management tool in southern Africa. Farmers use fire mainly to improve the quality of grazing within the woodlands (Lowore and Abbot, 1995). Chidumayo (1993) reported that late dry season fires are favored by livestock keepers as this is the time when the grass is dry and unpalatable. The effects of fire are deemed to be most beneficial to their livestock. Late dry season fires have shown to be damaging trees, in particular young trees, than cooler fires early in the dry season or after the rains have begun. Late season fires burn at higher temperatures than fires after the end of the rains when there is still moisture in the grass and there is a less dry leaf litter. High intensive fire damage seedling, root suckers and coppices especially in areas with heavy fuel load (tall grass) and steep slopes. Less intensive fire stimulate development of new root suckers during dry season (Sangeda and Maleko, 2018).

2.6.2 Effects of Grazing on the performance of regeneration of Miombo woodlands

Herlocker (1999) pointed out that the degree of grazing strongly affects the structure, composition, quality, and productivity of the vegetation. Intensive grazing damage saplings and regeneration is not fast enough to cover losses (Dirninger, 2004). The vegetation of the Eastern Africa is well adapted to defoliation by grazing and browsing. This is probably due to its long association with herbivores, first wild herbivores and more recently livestock which entered Eastern Africa at least 3000 years ago (Phillipson, 1979). Earlier studies have reported that, light to moderate levels of grazing minimize both primary (vegetation) and secondary (herbivores) productivity and encourage perennial grassland at the expense of woody vegetation (Deshmukh, 1986). However, many grasses lose vigor and die early when periodically defoliated. Mtimbanjayo *et al.* (2018), reported light intensity cattle grazing in Miombo woodlands have no significant effects on plant species composition, similarity, diversity and but high grazing intensity has effects.

2.7 Research gap of the study

There is no information on the current regeneration trend of Miombo woodlands in sustainable harvested areas in Kilosa District in terms of coppicing, root suckering and seedlings. Regeneration in kilns scars and data on changes of physical and chemical properties prior to burning of charcoal is also unknown. Fire and grazing are persisting in harvested areas but current information on their effects in regeneration of Miombo woodlands species in harvested areas is not available.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.2 Location of the study area

Kilosa District is located in East Central Tanzania, about 148 km West of Morogoro town. Kilosa extends between latitudes 5°55’ and 7°53’ South and longitudes 36°30’ and 37°30’ East (Ishengoma *et al.*, 2016) (Fig. 1).

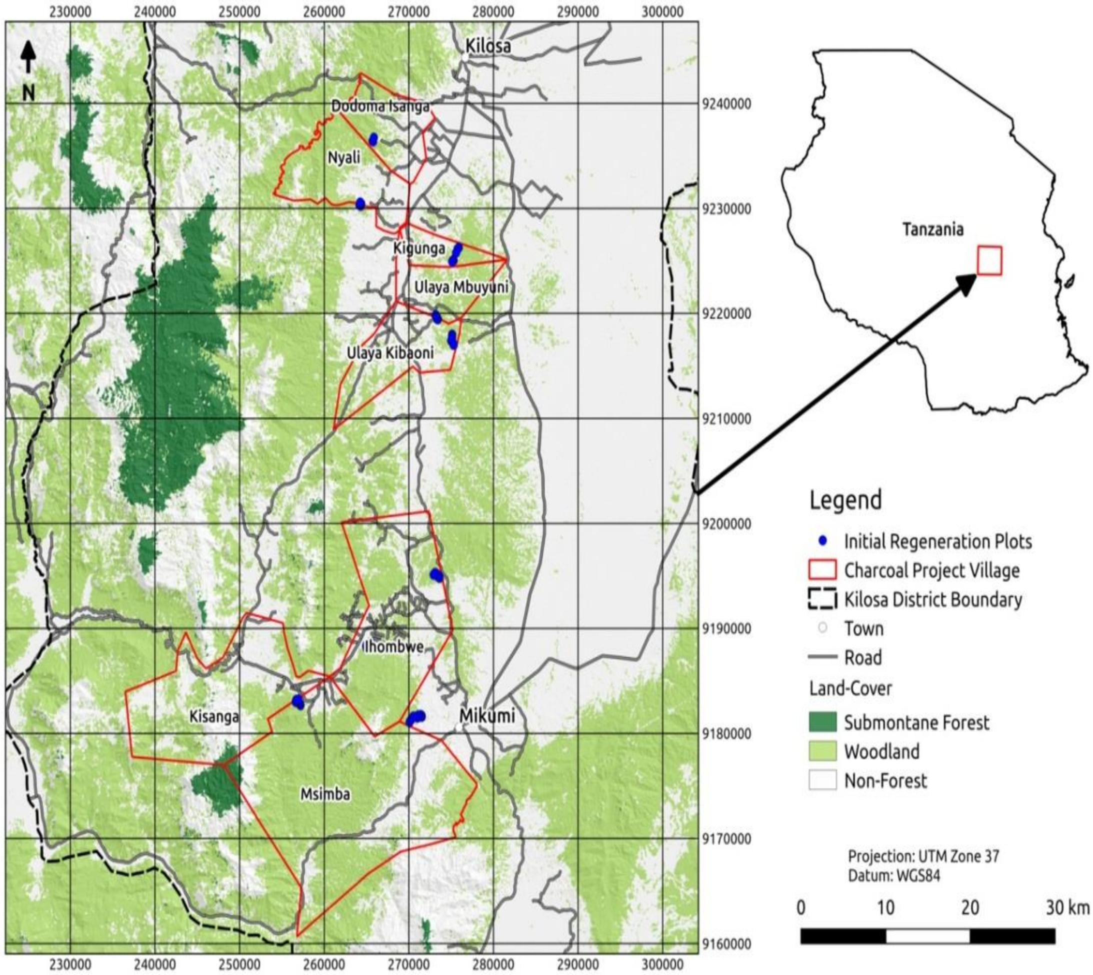

Figure 1: Map of the study sites showing locations of the study villages, Kilosa District, Morogoro, Tanzania.

The research was carried in 8 villages out of 10 project villages which are under the Sustainable Charcoal Production Programme. Seven villages are located between Mikumi and Kilosa (Ulaya Kibaoni, Ulaya Mbuyuni, Kigunga, Nyali, Dodoma Isanga, Ihombwe and Kisanga) but one village is located along Mikumi - Iringa road (Msimba) (Figure 1). A total of 67 out of 69 permanent regeneration plots established in 2015(in earlier monitoring study) were visited in all 8 villages. Their distribution per village is indicated in Table 1.

Table 1: List of regeneration plots in 8 Villages in Kilosa District, Morogoro, Tanzania

S/N	Village name	Permanent regeneration plots
1	Ulaya Mbuyuni	06
2	Ulaya Kibaoni	07
3	Dodoma Isanga	06
4	Kigunga	07
5	Msimba	11
6	Nyali	07
7	Ihombwe	14
8	Kisanga	09
	Total	**67**

3.1.2 Description of the study area

Climate

The climate is typically bimodal consisting of a short rain fall period that comes between November and January followed by a period of long heavy rainfall between March and May with an annual rainfall ranging between 800 mm and 1300 mm. The dry season is experienced in February, June, July, September and October (KDC, 2012). The average annual temperature is 24.6°C (NBS, 2013).

Population

The district has an area of 12,394 square kilometers and the population of 438,175 people (Ishengoma *et al*., 2016). It is divided into 35 wards and 118 registered villages with 752 hamlets. It has two parliamentary constituencies and two township authorities (Kilosa and Mikumi) (Ishengoma *et al*., 2016).

Vegetation

In Kilosa District, woodlands and forests cover about 40% of the total land area. The distribution of these woodlands and forests are as follows: 97,700 ha are managed by Tanzania Forest Services Agency (TFS), 24,654 ha are under the District Council Forest Reserves, 212,500 ha are managed by the Mikumi National Park and the remaining 124,335 ha are under the Village Land Forest Reserves (Ishengoma *et al*., 2016). The dominant tree species in the woodlands are *Brachystegia bohemii, Brachystegia spiciformis, Brachystegia microphylla, Commiphora spp, Combretum spp* and *Albizia spp*.

3.2 Methods

3.2.1 Research design and sampling procedures

Purposive and random sampling techniques were used. Purposeful sampling was used to select 8 villages where Sustainable Charcoal Project exists for the purpose of monitoring regeneration status in harvested plots that were assessed initially in 2015 and effects of fire and grazing on regeneration but random sampling was used to get one village (Kisanga) from 8 villages for the study of regeneration status in kiln scars and effects of fire on the physical and chemical properties of the soil.

3.2.2 Sampling size

According to TFCG/MJUMITA block model, blocks of 50X50 M had been made in 8 villages and within these blocks, 69 permanent plots were demarcated and coordinates were documented (TFCG, 2015). In this study, a GPS was used to identify these plots in order to monitor regeneration of stumps and effects of fire and grazing on regeneration.

For the case of assessing regeneration status in kiln scars and soil properties, identification of areas with kiln scars which were found in areas besides the demarcated plots which were harvested in 2013 was done and a total of twenty two (22) kiln scars were recorded. In each kiln scar, new plots of 5m radius were created (NAFORMA, 2015) and other 22 plots of 5m radius were demarcated at a distance of 15m from each kiln scar in order to get control plots. Thus a total of 44 plots (i.e.22 in kiln scars and 22 outside the kiln scar for control were demarcated. For soil chemical and physical properties a sample size selected was 5 kiln scars (23%) out of 22 kilns.

3.2.3 Plot layout

The same layout of circular plots with a 15 meter radius which were used in 2015 study were used to collect data on regeneration and effects of fire and grazing intensity on regeneration. For assessment of regeneration status in the kiln scars internal concentric circles of 5m radius were established as points to gather information about regeneration through tree seedlings (MNRT, 2015).

For assessment of soil physical and chemical properties, quadrats of 3×3 m were established in the center of the kiln scar and the control (Carrari *et al.*, 2016a). At each selected kiln scar, control points were created to the nearby surrounding. Soil was taken in the kiln scar center and in the control with a gap of 15m between each other. The aim of this was to compare soil properties in kiln scars and outside. In each kiln scar, three soil samples of about 400 gm each were taken and the same technic was done in the control areas. A total of 30 soil samples were taken at 0-5cm as top, 6-20c m as middle and 21-40 cm as bottom. Soil analysis was done in the soil Science Laboratory of the Sokoine University of Agriculture, Morogoro, Tanzania.

3.2.3 Data collection

Reconnaissance study

Reconnaissance study was done prior to main data collection in order to familiarize with the project area and project operations, to establish a field team, to test field tools and to familiarize with the harvested plots in the 8 villages.

Field survey

Sixty seven (67) plots which were previous demarcated by Sangeda and Maleko (2018) were identified by the use of a GPS and data on regeneration and the effects of fire frequency and grazing intensity were measured. Information on stump numbers, stump heights and diameters, coppice and root suckers diameter and heights, total number of coppices and root suckers, seedlings numbers with their heights were counted and measured. Also soil samples in kiln scars and control points were collected in 44 plots. Data were collected by the use of appropriate forms (Appendices 1-4)

3.2.4 Data analysis

Data on regeneration status of plant species in the harvested areas, soil properties and effects of fire and grazing on regeneration were analyzed by the use of Microsoft excel database in processing and generating descriptive statistics (Mean, frequencies and percentages).

Paired students T-test was used to compare different means of regeneration (i.e. coppicing, suckering and seeding in all plots) but also regeneration between kiln scars and control. RCBD Model were used to compare regeneration for stumps and effects of fire frequency and grazing intensity on regeneration.

CHAPTER FOUR

4.0 RESULTS

4.1 Regeneration of Miombo woodland tree species in areas harvested four years earlier

4.1.1 Number of stumps in harvested areas

The total of 688 stumps (145 stumps ha^{-}) of various Miombo woodland tree species were recorded. The mean stump height and diameter were 20.34 ± 0.43 cm and 46.36 ± 0.75 cm respectively (Table 2).

Table 2: Average tree stump height and diameter in harvested plots in Kilosa District, Morogoro(N=688)

	Average (cm)	SE (cm)
Stump Height	20.34	0.43
Stump Diameter	46.36	0.75

4.1.2 Means of trees regeneration

Coppicing and root suckering

Forty two percent (42%) of the measured stumps were found to have developed coppices with an average of two (2) individuals per stump with an overall mean height of 254±8.3cm. Twenty three percent (23%) of the stumps were observed to have regenerated through root suckering that averaged to two (2) individual suckers per stump with an overall mean height of 252±7.9 cm but also twenty two (22%) stumps were observed to regenerate through both coppices and root suckers with an average of two individual coppices/suckers per stump with an overall mean height of 251± 6.1 cm. Only thirteen (13%) stumps were none regenerating.

An ANOVA was used to contrast the capability of stumps to form coppices, suckers and both coppices and suckers but, also those which did not regenerate in different villages.

It was showing that there were no significant differences between them in all of the sites (villages) P>0.05 (Fig.2 and Appendices 5a, 5b, 6a, 6b, 7a, 7b, 8a and 8b).

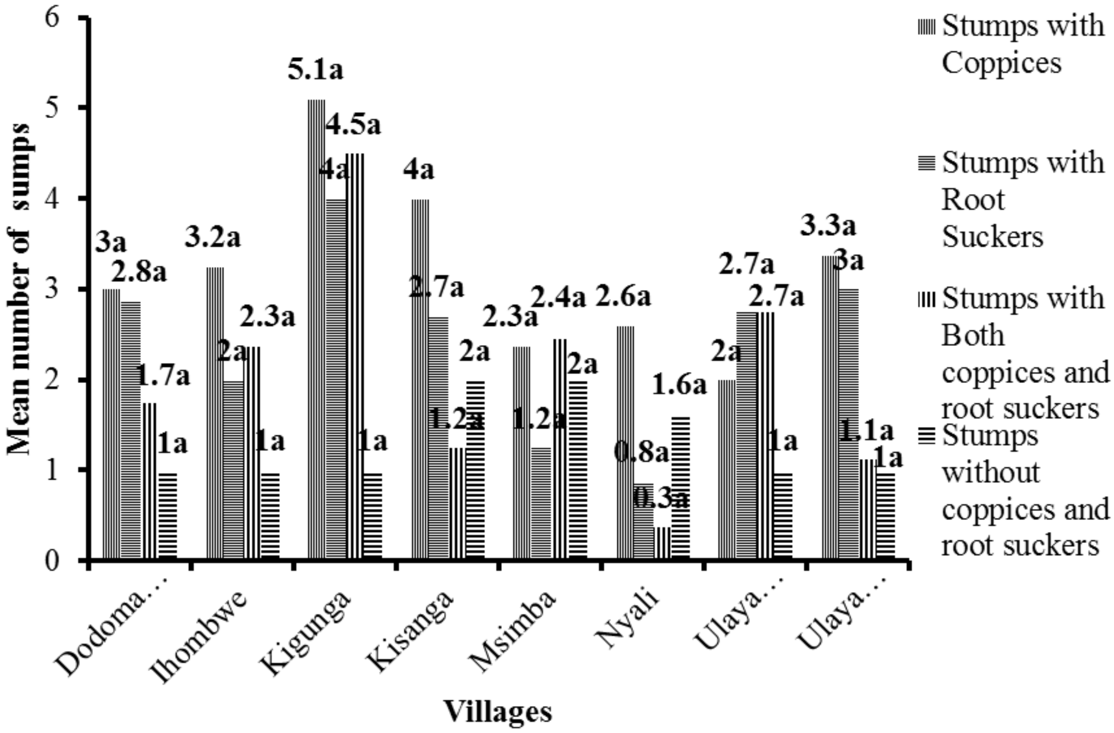

Figure 2: Stumps with coppices, root suckers, both coppice and root suckers and stumps with neither coppice nor root sucker (stumps that did not regenerate) in the harvested plots in Kilosa District, Morogoro

Stump diameter and regeneration capacity through coppicing and root suckering

Results showed that the regeneration capacity of the trees decreases with increasing stump diameter. Stumps within a diameter range of 6-15 cm did the best in the regeneration with an average of 29 sprouts out of 229 regenerating stumps. This was followed by a class of 16 to 25 cm. Other classes of stumps above 25 cm diameter are poor in regeneration by both coppicing and root suckering. A high amount of non-regenerating stumps was

found in the category of 26 cm and above with an average of 8 stumps (Fig. 3). An ANOVA was used to compare stump diameters categories vs. ability of stumps to regenerate or not-regenerating. Results showed a significant difference between diameter classes (P<0.005). (Data and ANOVA tables are in Appendices 9a, 9b, 10a and 10b).

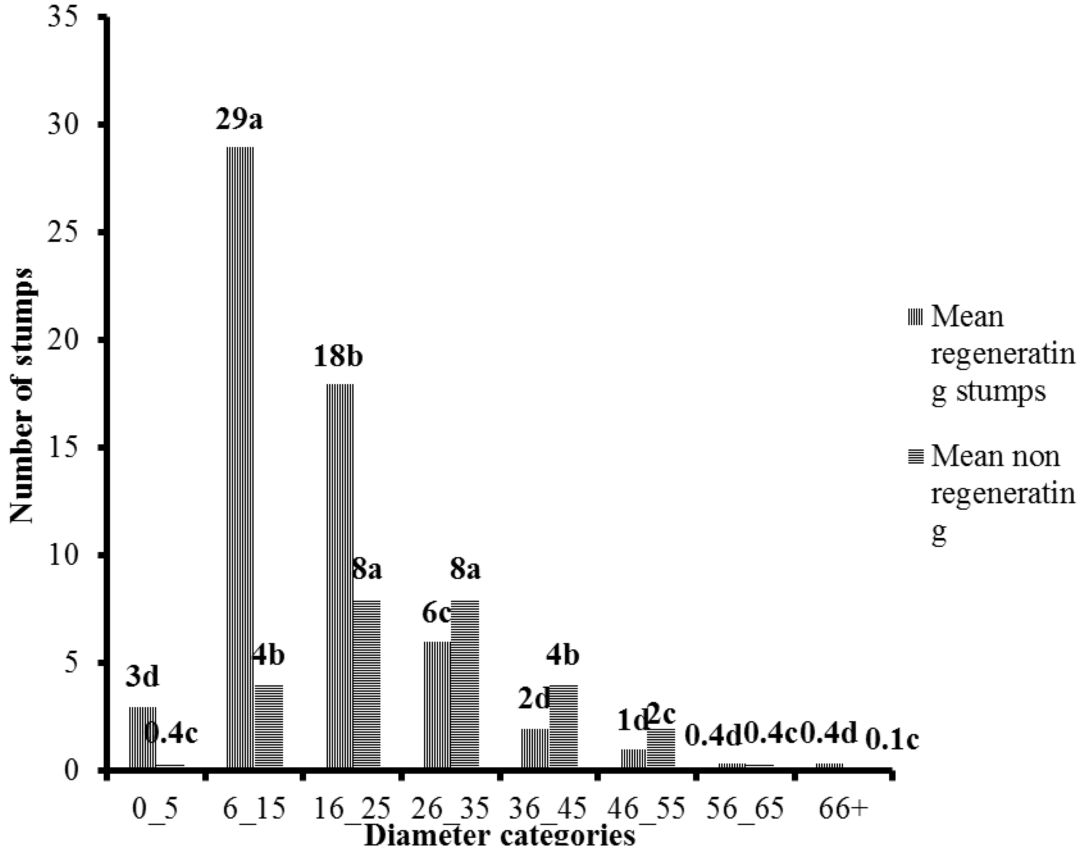

Figure 3: Regeneration capacities of various tree stump diameter classes in harvested plots in Kilosa District, Morogoro

Stump height and ability in coppicing and root suckering

The results showed that most stumps which were cut at the height between 0-20 cm regenerate best with an average of 43 regenerating stumps followed by a class of 21-40cm. A large number of non-regenerating stumps were mainly found in the category of 21-40 cm.

There was a statistically significant difference between regenerating stumps in various stump height categories (at P<0.05) (Fig. 4 and Appendices 11a, 11b, 12a and 12b).

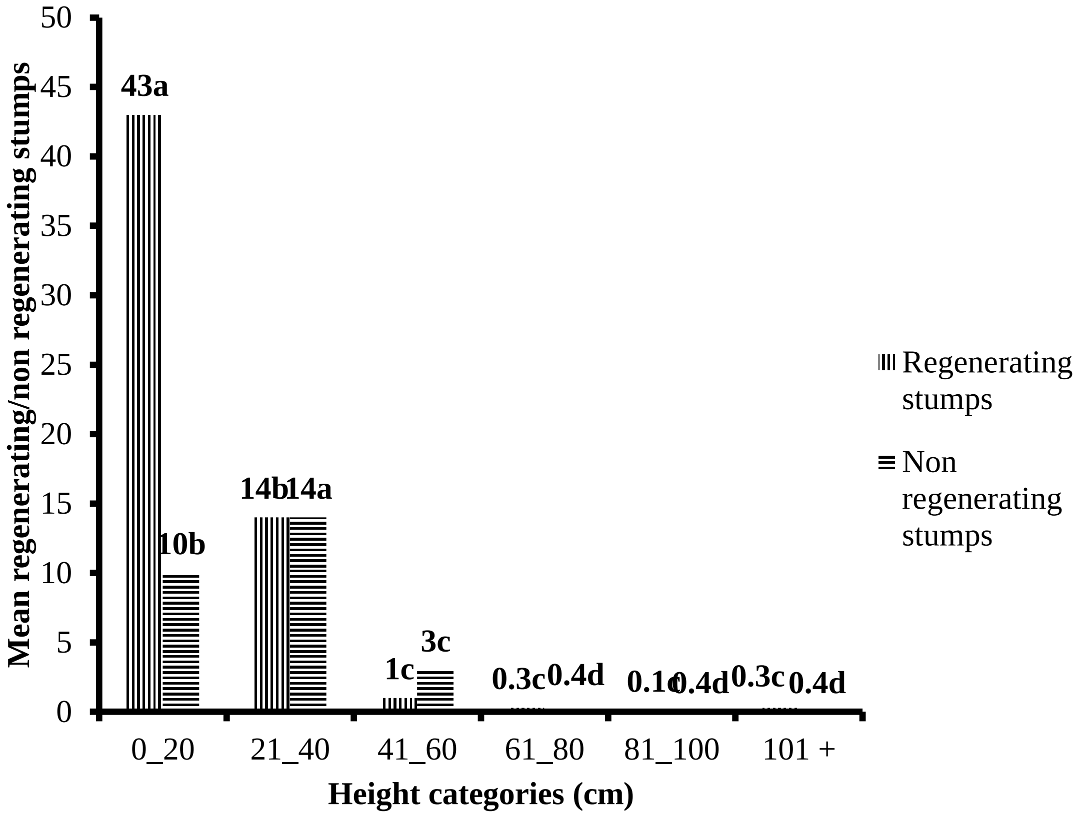

Figure 4: Stump height categories and regeneration capacities in harvested plots in Kilosa District, Morogoro

Regeneration through tree Seedlings

A total of 356 seedlings which correspond to 89 seedlings per hectare were recorede in all plots with an average height of 48 ± 1.58 cm. A large number of seedlings were recorded at Ulaya Mbuyuni followed by Kigunga, Dodoma Isanga, Ihombwe, Ulaya Kibaoni, Kisanga, Nyali and Msimba (Table 3).

Table 3: Distribution of Seedlings in 8 harvested villages in Kilosa District, Tanzania

Village name	Number of seedlings	Percent
Ulaya Mbuyuni	76	22
Kigunga	65	18
Dodoma Isanga	59	17
Ihombwe	50	14
Ulaya Kibaoni	33	9
Kisanga	29	8
Nyali	22	6
Msimba	22	6
Total	**356**	**100**

ANOVA was used to contrast the data in order to see if there is a statistical difference in the numbers of seedlings regenerated in all villages and it was showing that there is no statistical significant difference in all villages ($P>0.05$) (Fig. 5 and appendices 13a,13b,14a and 14b).

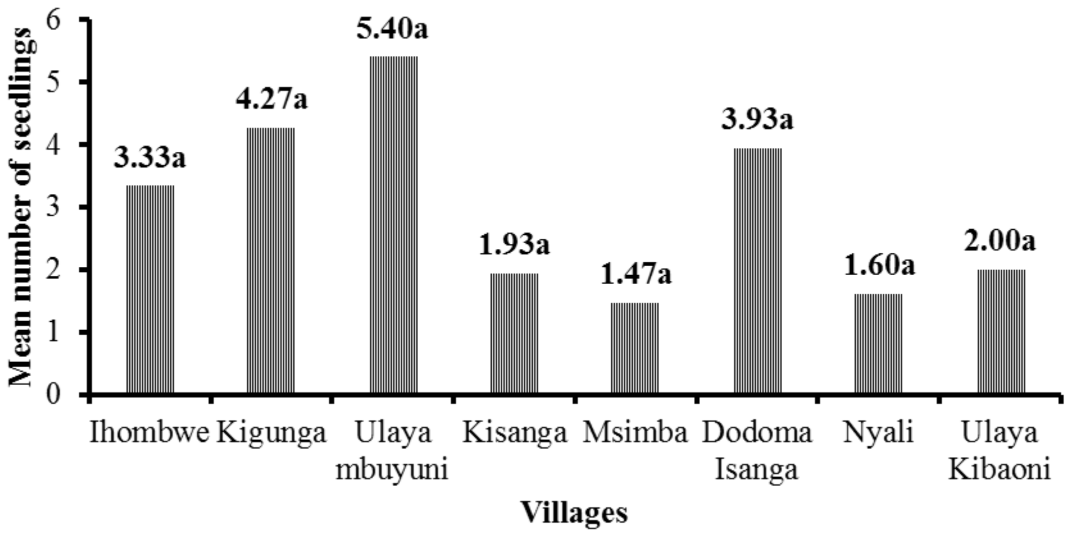

Figure 5: Mean number of regenerating tree seedlings per Village in harvested plots in Kilosa District, Morogoro

Regeneration of the different tree species by seedlings were 32% of *Brachystegia spiciformis* followed by *Brachystegia boehmii (*26%*), Combretum molle (12%), Diplorynchus condylocarpon (*10%*)* and others (Table 4). A total of 14 different seedling species were observed.

Table 4: Observed tree seedlings in the harvested plots in Kilosa District, Morogoro Region, Tanzania

Botanical Name	Number of seedlings	Percent
Brachystegia spiciformis	114a	32.0
Brachystegia boehmii	92b	26.0
Combretum molle	42c	12.0
Diplorynchus condylocarpon	41d	12.0
Combretum/Terminalia spp	22e	6.0
Brachystegia bussei/microphylla	12e	3.0
Combretum zeyhen	10e	3.0
Dalbergia melanoxylon	5e	1.0
Pseudolachnostylis maprouneifolia	5e	1.0
Dichrostachys cinerea	3e	1.0
Markhamia spp	3e	1.0
Flueggea virosa	3e	1.0
Pterocarpus angolensis	2e	1.0
Xeroderris stuhlmannii	2e	1.0
Total	**356**	**100**

The numbers of tree seedlings per species were statistically significant at ($P<0.05$) as presented in Fig.6.

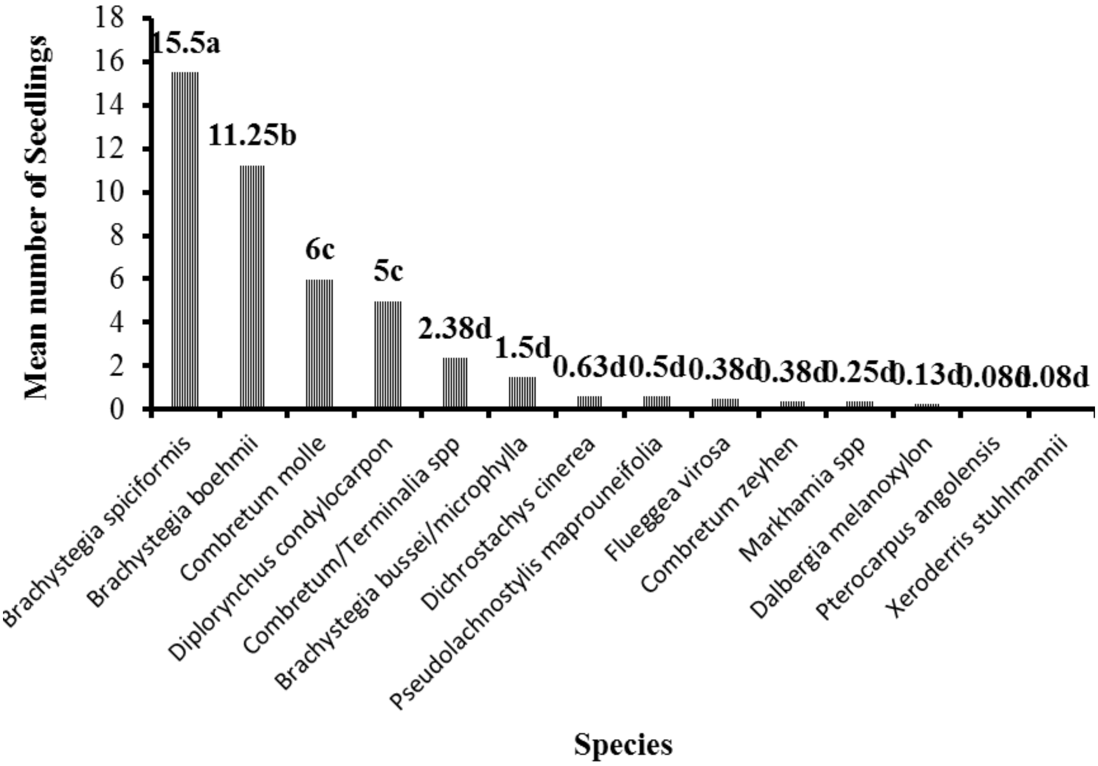

Figure 6: Mean number of regenerating tree seedlings per species in harvested plots in Kilosa District, Morogoro

Regeneration pathways at plot level were tested by the use of independent (Unpaired) student T test. It was shown that there was a statistical significant difference between root suckering and coppicing, Coppicing and seedlings, root suckers and seedlings and both sprouts and seedlings at $P<0.05$. (Table 5 and Appendices15a,15b, 16a,16b,17a,17b,18a,18b,19a, and 19b).

Table 5: Summary of the means of regenerating and non-regenerating stumps observed in harvested plots in eight villages in Kilosa, Morogoro

Regeneration type	Number of stumps	Number of regenerants	Number per ha	Height (cm)	Percent
Root Suckers	159	874a	184.6	252±7.9	33
Both (Root suckers and coppices)	153	773b	163.3	251±6.3	28
Coppices	290	665c	140.5	254 ± 8.3	25
Seedlings		356d	89	48±2	14
None	86	0e	0	0	0
Total	**688**	**2668**			**100**

Summary of various measurements are as in the following tables (7, 8, and 9).

Table 6: Stump measurements in harvested plots in Kilosa District, Morogoro

S/No	Parameter	Measurements
1	Number of stumps	688 (145Treees/Ha)
2	Mean stump diameter	20.34 ± 0.43cm
3	Mean stump height	46.36 ± 0.75 cm
4	Regenerating stumps	87%

Table 7: Stump coppicing, root suckering and both stump coppicing and root suckering measurements in harvested plots in Kilosa District, Morogoro

S/No	Parameter	Coppices	Root suckers	Both coppice and root suckers
1	Average number per stumps	2	2	2
2	Mean height	254 ± 8.3cm	252± 7.9cm	251±6.1cm
3	Stems ha^{-}	140.5	184.6	163.3

Table 8: Tree seedlings measurements in harvested plots in Kilosa District, Morogoro

S/No	Parameter	Measurements
1	Seedlings density ha^{-}	89
2	Mean seedling height	48 ± 1.58 cm

4.1.3 Regeneration ability by harvested tree species

About 19 different tree species were harvested for charcoal. *Brachystegia boehemi* was dominating (46% of all stumps) followed by *Combretum mole* (18%), *Brachystegia spiciformis* (11%), *Diplorynchus condylocarpon(7%)*. *Brachystegia boehemi, Combretum mole* and *Brachystegia spiciformis* have shown a capability of regenerating through both coppicing and root suckering (See Appendix 21). The largest number of tree species was found in Msimba Village with a mean number of 7 tree species and there were significant differences between the number of tree species found in the various villages (at P<0.05) (Fig. 7 and Appendices 20a and 20b).

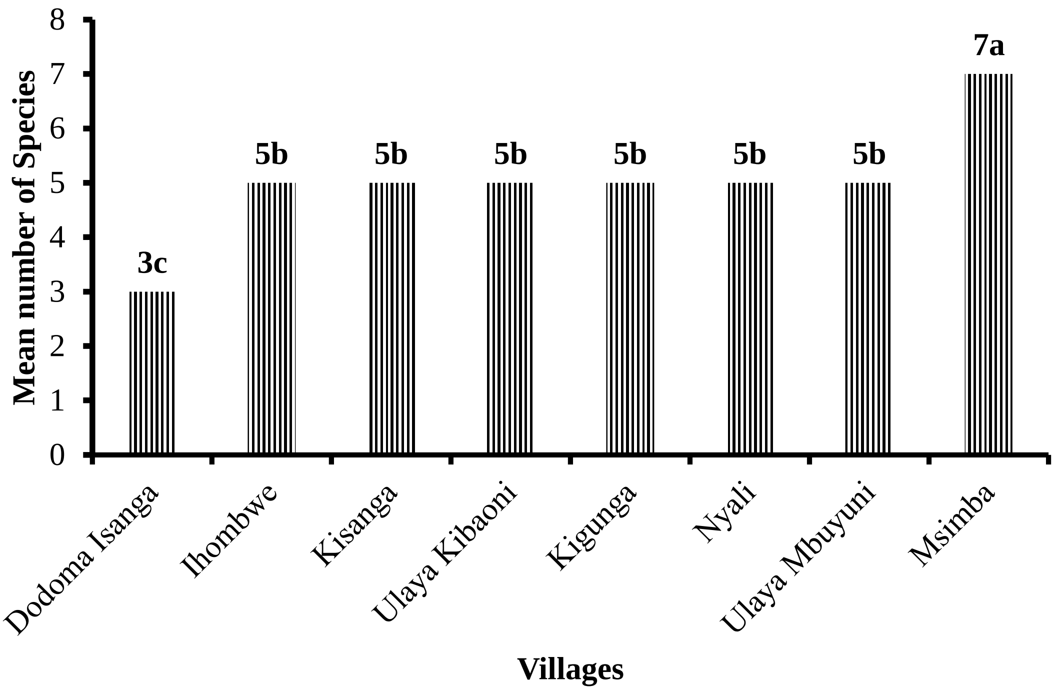

Figure 7: Mean number of tree species in 8 villages in Kilosa Distric, Mororgoro

4.2 Status of regeneration in Kilns

About 6 seedlings of various tree species were observed in kilns centre and 36 seedlings in control plots. The overall mean heights of seedlings in the two sites were 42.8±1.66 cm and 33.6± 3.77 cm respectively (Table 10).

Table 9: Distribution of tree seedlings in control plots and kiln centres in Kisanga Village, Kilosa, Tanzania

Location	Number of seedlings	Mean height (cm)	S.E (cm)
Kiln centres	6	42.8	1.66
Control	36	33.6	3.77

Thirty six tree seedlings were observed in the control points in 19 plots out of 22 while only six seedlings were observed in kiln scars in 6 plots out of 22.

Table 10: Distribution of tree seedlings in the Kilns and controls at Kisanga Village in Kilosa, Morogoro

Plot name	Number of plots	Percent
Control without seedlings	3	7
Control with seedlings	19	43
Kilns without seedlings	16	36
Kilns with seedlings	6	14
Total	**44**	**100**

A large amount of the seedlings in the kiln areas were *Brachystergia boehemii* and *Brachystegia spiciformis* with 31% each. Other seedlings were *Combretum molle* (17%), *Diplorynchus condylocarpon* (12%), *Markhamia spp* (5%) and *Acacia nigrescens* (5%) (Table 12). These species were found in both controls and in the kiln centres. In the kiln centres, grass species like *Hyperhheria ruffa* and *Themeda triandra* and herbs like *Amaranthus sp* and *Bidens pilosa* were dominating.

Table 11: Composition of tree seedlings and species in kiln centres and controls at Kisanga Village in Kilosa, Morogoro

No	Species name(Botanical)	Seedlings in Kilns scars	Seedlings in controls	Total number of Seedlings	Percent
1	*Brachystegia boehmii*	3	10	13	31
2	*Brachystegia spiciformis*	2	11	13	31
3	*Combretum molle*	1	6	7	17
4	*Diplorynchus condylocarpon*	0	5	5	12
5	*Acacia nigrescens*	0	2	2	5
6	*Markhamia spp*	0	2	2	5
	Total	**6**	**36**	**42**	**100**

Unpaired student T. test was used to compare regeneration status via seedlings in kiln centres and nearby environment (control plots) and the results were showing that there were a significant difference in regeneration rate of seedlings between them ($P<0.05$) (Appendices 22a and 22b). Higher regeneration rate was observed in the nearby environments (Controls)

4.3 Effects of fire on soil physical and chemical properties in kiln centres

4.3.1 Effects of fire on soil physical Properties

Soil texture

Results showed that soil in the kiln scars had a textural class of loamy sand while in the control plots were sand clay loam. Their particle size percentage distribution is shown in Table 13.

Table 12: Soil textural classes in kiln scars and control plots at Kisanga Village in Kilosa District, Morogoro

Collection point	%Clay	%Silt	%Sand	Textural Class
Kilns (0-40cm deep)	11.32	3.1	82.98	Loamy sand
Controls (0-40cm deep)	31.5	2.7	65.8	Sand Clay loam

Bulk Density

Results showed that the mean bulk density in kiln centres and control plots differ as in kiln centres were 1.21 gcm^3 while in control plots were 1.43 gcm^3. Trends show that bulk density was lower in kiln scars than in control plots (Table 14).

Table 13: Bulk density of the soils in kiln scars and in the control plots at Kisanga Village in Kilosa, Morogoro

Bulk density in kilns (gcm^3)	Bulk density in controls (gcm^3)
1.21	1.43

4.3.2 Effects of fire on soil chemical properties

Soil pH

Results in Table 15 showed that the mean soil pH in kiln centres was 7.5 and in the control plots were 6.5.

Table 14: Mean Soil pH in the Kiln centres and in control plots at Kisanga Village in Kilosa, Morogoro

Collection Point	Mean Soil pH
Kiln centres	7.5
Control plots	6.5

Soil Organic Carbon

Results in Table 16 showed that the mean carbon amount in kiln centre was 1.4% while in control plots was 0.96%. In all kilns scars, it was observed that villagers plant herbaceous plants like *Amaranthus* as a source of vegetables while working in the field in making charcoal.

Table 15: Mean Organic Carbon in the kilns and controls at Kisanga Village in Kilosa, Morogoro, Tanzania

Collection point	Amount of Carbon (%)
Kilns	1.4
Controls	0.96

Total Nitrogen

The mean Nitrogen amount in the kiln scars and controls were 0.13% and 0.12 respectively (Table 17). A lot of herbaceous plants like *Amaranthus* and *Bidens pilosa* were observed in most of the kiln scars. These herbaceous plants could have been the cause of higher content observed in the kiln centres.

Table 16: Mean total Nitrogen content in the kiln centres and in control plots at Kisanga Village in Kilosa District, Morogoro

Nitrogen in Kiln centres (%)	Nitrogen in control plots (%)
0.13	0.12

Cation exchange Capacity and Exchangeable cations

The results indicated a higher mean cation exchange capacity in the kilns of 8.13 Cmol (+) kg- compared to 5.56 Cmol (+) kg- for the controls (Table 18).

Table 17: Mean Cation Exchange Capacities for soils in the kiln scars and control plots at Kisanga Village in Kilosa, Morogoro, Tanzania

Mean cation exchange capacity in kiln centre (Cmol (+) kg^-)	Mean Cation exchange capacity in control plots (Cmol (+) kg^-)
8.13	5.56

The mean exchangeable cations released in the kilns and controls are shown in table (Table 19).

Table 18: Mean exchangeable cations in the kiln scars and control plots at Kisanga Village in Kilosa District, Morogoro.

Collection points	Ca^{2+} (Cmol)	Mg^{2+} (Cmol)	Na^{2+} (Cmol)	K^+ (Cmol)
Kilns	8.82	1.53	0.53	0.74
Controls	2.32	1.18	0.05	0.60

4.4 Effects of fire and grazing frequencies on the performance of the regeneration in harvested areas in Kilosa District,Morogoro

4.4.1 Effects of fire on regeneration in harvested areas

The results on the effects of fire on the harvested plots indicated that about 43 % of the plots had no fire, 27 % low fire, 21 % moderate fire and 9% intense fire.

Table 19: Fire occurrence frequencies in harvested plots in Kilosa District, Morogoro

Fire Occurrence	Frequency	Percent
No fire	31	43
Low fire	18	27
Moderate	14	21
High	6	9
Total	**67**	**100**

Three villages namely Dodoma Isanga, Nyali and Ihombwe had severe fire in some plots while other villages had either no, low, moderate fire or a mixture (Fig 7).

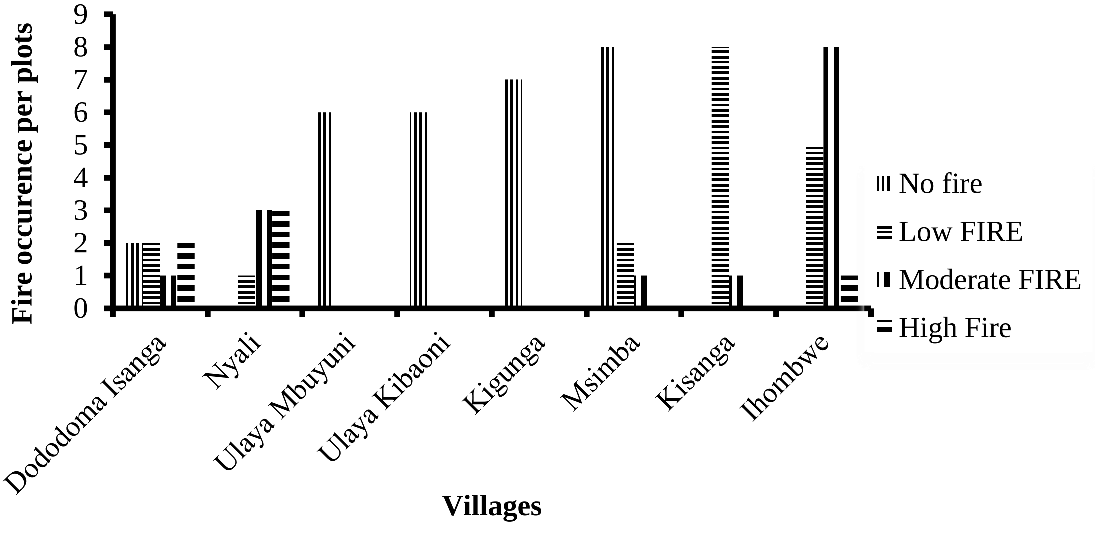

Table 20: Fire occurence in the harvested plots in eight villages in Kilosa District, Morogoro

The results of fire occurrence and regeneration via seedlings, coppices and root suckers show no significant differences between fire occurrence and regeneration via seedlings and coppices (P>0.05), but there is a significant differential on effect of occurrence of fire on root suckering (P<0.05) (Fig 6, Appendices 23a, 23b, 24a, 24b, 25a and 25b).

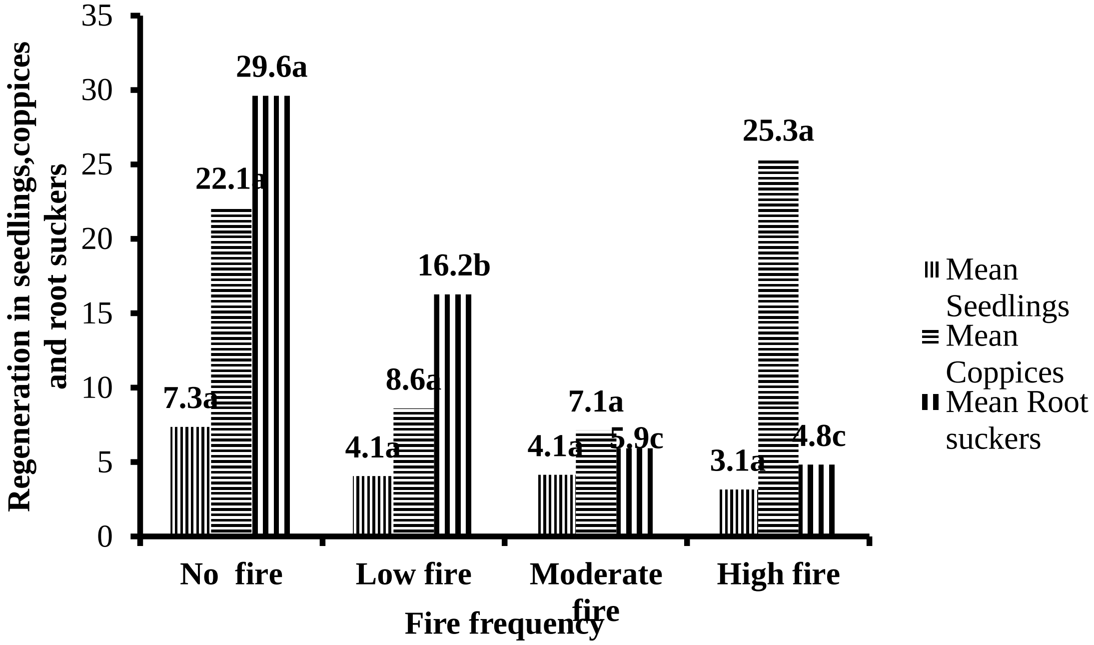

Figure 8: The relationship between fire frequency against mean seedling, coppice and root sucker numbers in harvested villages in Kilosa District, Morogoro

4.4.2 Effects of grazing frequencies on regeneration in harvested areas

The results on grazing frequencies in the harvested plots are presented in Table 21. It was observed that a large proportion of the plots indicate occasional grazing habits.

Table 21: Grazing frequencies in harvested plots in the study Villages in Kilosa District, Morogoro

Grazing Intensity	Frequency	Percentage(%)
No grazing	8	12
Occasional	41	62
Frequent	13	19
Extensive	5	7
Total	**67**	**100**

Grazing frequency in plots was different in each village. Some villages had no, occasional, extensive, frequent grazing. A large proportion of the plots had occasional grazing (Fig 9).

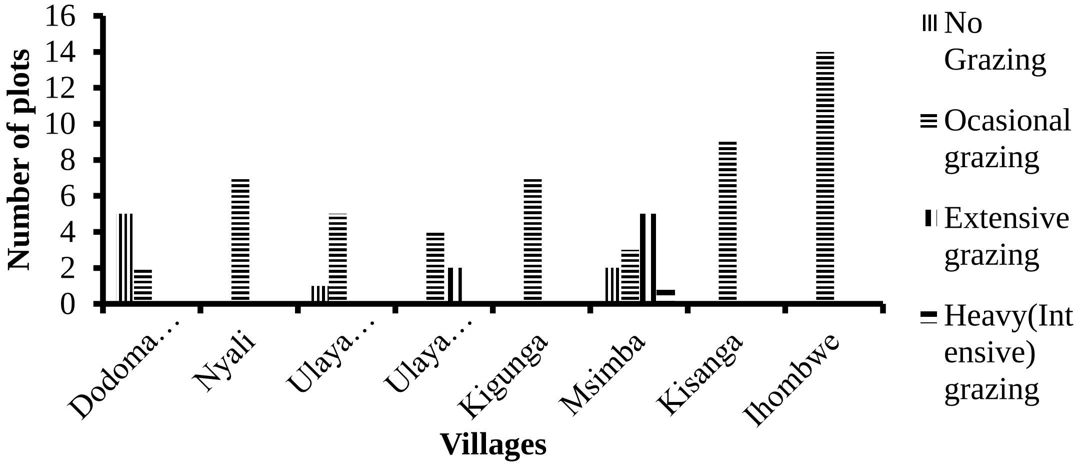

Figure 9: Grazing intensities in the harvested plots in the 8 villages in Kilosa District, Morogoro

ANOVA was used to compare the relationship between grazing frequencies on regeneration via seedling, coppicing and root suckering. The results show that there were a significant difference between grazing intensity and regeneration via seedlings ($P<0.05$) but insignificant in coppicing and root suckering (Fig 10, Appendices 26a, 26b, 27a, 27b, 28a and 28b).

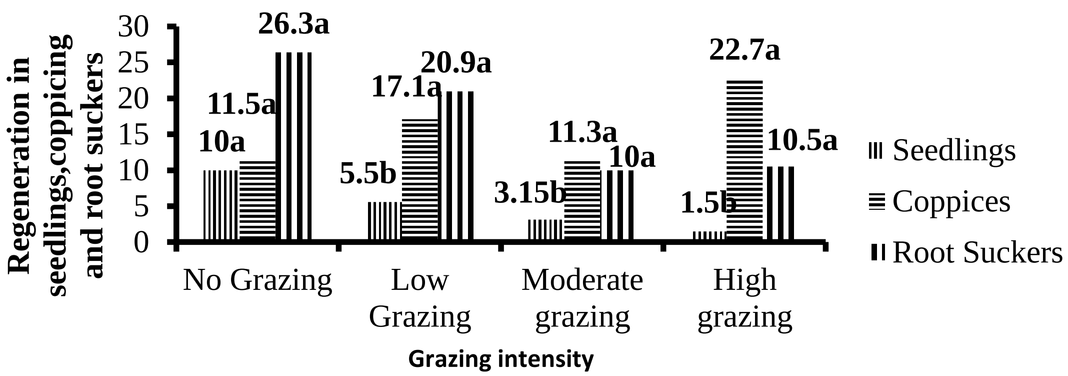

Figure 10: Relationship between grazing intensity and mean seedling, coppice and root sucker numbers in harvested villages in Kilosa District, Morogoro

CHAPTER FIVE

5.0 DISCUSSION

5.1 Regeneration of various tree species harvested four years earlier

Results on regeneration of various tree species in harvested plots are presented in Tables 2, 3, 4, 5, 6, 7 and 8, Figure 2, 3, 4, 5, 6 and 7 and Appendices 5-19.

Results shows that there is a difference in total number of stumps as currently there are fewer than previously. Sangeda and Maleko (2018), through their study in 2015 counted 904 stumps. The difference in number of stumps was probably due to fire and termite. Signs of activities in some villages like Dodoma Isanga and Nyali showed burnt stumps.

Sangeda and Maleko (2018) reported that 68% of all stumps were regenerating through coppices or root suckers. Luoga *et al*. (2004), observed that regeneration of Miombo woodlands in different districts of Tanzania ranged from 83 to 90%. In the present study (2017), it was shown that regeneration through coppicing and root suckering constituted 87% of all the regenerants. This information provides a positive trend of regeneration in the harvested plots in Miombo woodlands vegetation.Regeneration in harvested plots is sufficient.

Current results show that 140 coppices ha^{-}, 184 root suckers ha^{-} and 163.3 ha^{-} both coppices and root suckers. Sangeda and Maleko (2015) reported that there were 555 coppices ha^{-} and 342 root suckers ha^{-} but current study however shows that there are 221 coppices ha^{-} and 267 root suckers ha^{-}. It has been observed that 42% of regenerants were coppices with an average of 2 individual coppices per stump. It was also shown that 50% of stumps were regenerating through coppices with average of 6 individuals (Sangeda and Maleko 2018). For the case of root suckering, it has been observed that 23% of regenerants are root suckers with an average of two (2) individuals per stump but Sangeda and Maleko (2018) observed that 37% of regenerants were root suckers with average of five (5) individual root suckers per stamp. Twenty two (22%) regenerants are both coppice/root suckers. Luoga *et al.*, (2004) reported up to 6.6 regenerating shoots per individual stump.

The mean heights of root suckers, Coppices and both coppices/root suckers are 252±79cm, 254 ±8.3cm and 251± 6.3cm respectively. Sangeda and Maleko observed that the mean height for coppices and root suckers were 102.30cm ± 3.47cm and 87.53cm ± 3.33cm respectively. This signifies that the growth is taking place by increasing in height and width.

Chidumayo (1997) concluded that number of coppices and root suckers is always high during establishment period and decrease due to inter-shoot competition and only that attain superior size contribute to the next generation. Also the factors like competition for light and nutrients among themselves and disturbance of fire and animals could be the causatives. By comparing these results, it is evident that the number of coppices and root suckers per stump have decreased with time due to some factors like competition for light and nutrients among themselves and disturbance of fire and grazing animals. These reductions in the numbers of coppices and root suckers implies that there is a natural thinning of Miombo woodlands (Chirwa, 2015). Therefore silvicultural management like thinning and pruning which are labour intensive and expensive are not necessary in Natural Miombo woodlands. Also the regenerants are fewer than previous but they have improved in height due to continued growth and diameter due to increased growth and space by dying ones.

Stump diameter, height and regeneration capability through

According to these results, large proportion of trees with diameter class of 6-15 cm and 16-25 cm and heights of 0-20cm regenerates better. Sangeda and Maleko (2018) similarly observed the same trend. Besides the *Brachystegia boehemi, Combretum molle* and *Brachystegia spiciformis* having shown a large capability of regenerating through either coppicing and root suckering, they are also capable of regenerating by both coppicing and root suckering at the same time while Sangeda and Maleko (2018) observed that the stumps of *Brachstergia boehmii* and *Brachystergia spiciformis* exhibited both coppicing and root suckering abilities. *Brachstergia boehmii* was relatively more robust in coppicing especially the stumps with less than 30 cm diameter which were observed to develop thicker and taller coppices than old tree stumps (>35 cm diameter). *Brachystergia spiciformis* was observed to do better through root suckering and most stumps did not have coppices and, with the advance of dry season and upon exposure to fire, most immature coppices (<30 cm height) were found either wilted or dead. In this study all species were performing better in coppicing and root suckering. They found that in some instances, the coppices of these species were found to achieve a height of up to 3 m within two years after harvest and in contrast with the current study some coppices and root suckers have shown a height of up to 7m.This means that coppices and root suckers are growing fast with time if they are not disturbed.

Regeneration through Seedlings

Results from the previous chapter show that 14% of the total regenerants are from seedlings. A total of 356 seedlings were counted in all plots and they are corresponding to 89 seedlings ha^{-} with a mean height of 48.2 cm while Sangeda and Maleko (2015) counted 228 seedlings (57 seedling ha^{-}) with a mean height of 38 cm. *Brachystegia* *spiciformis* had more seedlings followed by *Brachystegia boehemii* among others. Regeneration via seedlings between villages was not significant by different. Chirwa (2015) reported that Miombo species can regenerate largely through coppice regrowth and root suckers rather than seeds. Chidumayo and Frost (1996) also reported that the majority of Miombo woodlands have seeds that germinate immediately after dispersal as long as water supply is sufficient. They reported that there is no extended dormancy or seed bank in the soils among the canopy species. Some tree species like Albizia and Pterocarpus have seeds which are dispersed by wind but most of the dominant species, including Brachystegia have explosive seed dispersal with pods splitting open and scattering the seeds. This means regeneration via seeds is possible but there are factors like fire and grazing which hinder regeneration via seeding. Chidumayo (1997); Ernst (1998) and Trapnell (1959), reported that tree seedling development is mostly impaired by biotic and abiotic factors. They concluded that Miombo woodlands tree seedlings during the establishment phase have a mortality rate up to 70%.These factors may be acting as the causatives of low seeding capacity in the harvested areas. The mean height of seedlings is still very low to show that seedlings regenerates but their mortality rate is high due to the above factors.

By comparing the number of seedlings, coppices and root suckers in the entire area, it is evident that regeneration through coppices and root suckers is better and rejuvenation of the ecosystem is achieved sooner than depending on seedlings.

Harvested tree by species

The results showed that a total of 19 tree species were harvested for charcoal and among them *Brachystegia boehemii* was a leading species by having a large number of stumps

(316) followed by *Brachystegia spiciformis*. Distribution of species per village was different. A large number of species was found at Msimba. Sangeda and Maleko(2018) observed the same trend of species. By comparing the previous study and the current one *Brachystegia boehemii* and others like *Brachystegia spiciformis* are found in miombo woodlands and they are capable of regenerating if disturbed but they serve as source of power and income to the people.

5.2 Regeneration in Kiln scars

Current study shows that seedlings start to regenerate in the kiln centres. *Brachystegia boehemii* and *Brachystegia spiciformis* are found in large amount. These species are natives of Miombo woodlands. Sangeda and Maleko (2018) in 2015 observed that most kilns harvested in 2013 (Two years from harvesting period) had no regeneration of tree species. They reported that only 10% of 2013 kilns were observed to have herb species such as wild *Amaranths* but 100% of the 2014 kilns were completely devoid of vegetation. Chidumayo (1993) reported that destruction of woody plant root stocks at kiln centre during carbonization implies that regeneration on such scars will originate solely from seed. Chidumayo & Frost, (1996) reported that Brachystegia have explosive seed dispersal with pods splitting open and scattering the seeds.

Natural condition of the areas has started to recover as most grasses like *Themeda triandra* (red grass) and *Hyparrhenia rufa* (thatch grass) was found to be growing and take over the presence of *Amaranthus*. Physical observations showed that as soon as the trees are harvested for charcoal, villagers plant *Amaranthus* for vegetable as they use it as their food while working in charcoal production (Garden within Miombo woodlands) and as soon as they leave the area the *Amaranthus* last for sometime. Later the soil stabilizes to its natural environment as native species including grasses and woody trees regenerate.

In contrast to the previous study by Sangeda and Maleko (2018), seedlings of various native species were found in the kiln scars (5 years from harvesting). The presence of these seedlings is associated with the presence of the dominant species of Miombo woodlands. Regeneration via seeding is higher in controls than in kiln scars but indications shows that regeneration in kilns scars has started to occur though in low amount (Plate 1 and 2).

Plate 1: Photo showing Amaranthus spp in kilns scars harvested in 2015 at Nyali Village in Kilosa District, Morogoro.

Plate 2: Photo showing Kiln scars with seedlings at Kisanga village in Kilosa District, Morogoro.

5.3 Effects of fire on soil physical and chemical properties

Data on effects of fire on soil physical and chemical properties are shown in Tables 13, 14, 15, 16, 17, 18 and 19.

Soil Texture

Soil texture differed between kiln scars and controls. In kiln scars the texture was coarser than in controls. Lide (2001) reported that under extreme heating quartz materials at the soil surface become fused and soil texture becomes more coarse and erodible. Mtimbanjayo (2016) reported that soil at the area where the study was done was found to be sandy clay loam. Normally soils of the Miombo woodland are generally leached, sandy and poor in nutrients (Backe´us *et al*., 2006). According to the above information the soil texture in kiln scars differs to that of control to show that temperature had some effects to the soil texture. The soil in the kiln scars is more vulnerable to erosion.

Bulk Density

Results show that bulk density in kiln scars was lower than in controls. De Bano *et al.*, (1998) reported that fire can destroy bulk density of a soil and affect infiltration and percolation. Singer and Munns (1996) concluded that balance in pore sizes allows a soil to transmit both water and air rapidly through macropores and retain water by capillarity in micropores. Mtimbanjayo (2016) reported that the bulk density of the soil at Kasanga was 1.4g/cm^3. Infiltration and percolation rate is higher in kilns than in controls. Fire has impacts on bulk density by lowering it.

Soil chemical properties

Soil pH

The mean soil pH in kiln scars and controls were different. Soil pH in kiln scars was higher (Mild Alkaline) while in control plots were low (Slight acid). Wells *et al.* (1979) reported that combustion of organic matter during a fire releases soluble cations which tend to increase in pH slightly as basic cations are released and deposited on the soil surface. They reported that the increase in soil pH is usually temporary depending upon the original soil pH, amount of ash released, chemical composition of the ash and wetness of the climate. Frost (1996) reported that Miombo woodlands ecosystem occur in soils which are acidic but also reports from Mtimbanjayo (2016), shows that the pH of the area was 6.15 (Slightly acid). This means fire burning during charcoal making increases soil pH in kiln scars.

Soil Carbon

Total carbon in kiln scars was observed to be higher (1.4%) than in controls (0.96). Beyers *et al*. (2005) reported that high heating of the soil destroys about 99 percent of the organic matter. Miombo woodlands are characterized with distinctive features such as having a low density of canopy tree species and they usually shed off their old leaves and form new leaves mostly just before the rain season start (Chidumayo, 2004). Frost (1966) reported that Miombo woodlands are found on poor soils with low organic contents. The scenario shows that after heavy burning in kilns centres all carbon is removed but other herbaceous species which are planted by villagers in the forest e.g. *Amaranthus* species and others like *Bidens pilosa* which regenerate naturally and soon they die. Shedding off of standing Miombo trees and dead herbaceous plants increase the Carbon content at a certain period of time. In this study, it shows that fire has a potential value in improving availability of carbon in kiln scars and creates environments for future regeneration of Miombo woodland species.

Soil Total Nitrogen

Total Nitrogen is higher in kiln scars (0.13%) than in controls (0.12%). Nitrogen content is a bit higher in kiln scars than in control but they are all in the same category as Low (NSST, 1992). Knight (1966); White *et al.* (1973) reported that Nitrogen is completely lost in the soil by volatilization if soil is subjected to high fire. Maars *et al.* (1983) reported that Nitrogen is unique because it is the only soil nutrient that is not supplied to the soil by chemical weathering of parent rock material. Miombo woodlands are found in soils with low Nitrogen content (Frost, 1996). Almost all N found in the vegetation, water, and soil of wild land systems has to be added to the system from the atmosphere (Grier, 1975). This signifies that Nitrogen was completely lost in the kiln scars but it has been recycled by natural processes to the normal. It appears to be found in the kiln scar and in the control as a natural balance.

Cation Exchange

Cation Exchange Capacity is higher in kilns scars than in controls. Grove *et al*. (1986); Raison *et al*. (1990); Soto and Diaz (1993), reported that in many studies there is a significant increase in soil cation concentration following either prescribed burning or a wildfire. Frost (1996) reported that soils of Miombo woodlands are low in cation exchange capacity and low total exchangeability. Ma *et al.* (2015) reported that CEC and soil are significantly related to the habitat (mean annual precipitation and temperature, radioactive dry index, elevation, soil texture, pH, soil nutrient content, water holding capacity) and land management (tillage, grazing, historical tillage, flooding). Syampungani *et al.* (2015) observed that charcoal production is necessary disturbances which enhance the establishment and development of the regeneration pool of the Miombo woodlands. He concluded that nutrients are found in large amount in burned area as the result there is a formation of other herbaceous plants. Msanya *et al.* (2014) reported that burning of charcoal cause changes in soil properties in Miombo woodlands and this has been observed in this study but changes of the soil in kiln scars is beneficial as it creates micro environment for establishment of other plants which sooner die off and woody plants generates.

This has been observed in this study as in controls the CEC was very low while in kilns scars were low (NSST, 1992). This mean the soil in kilns is more fertile than in control and has been caused by fire. Herbaceous plants like *Amaranthus* and *Bidens pilosa* are seen to be dominating in kiln scars in early periods after harvesting but they disappear as time goes. Native grasses start to dominate and with time woody plants regenerates.

5.4 Effects of fire and grazing on performance of regeneration in harvested areas

5.4.1 Effects of fire on performance of regeneration in harvested areas

Fire has shown higher effects in three 3 villages namely Dodoma Isanga, Nyali and Ihombwe. A large number of plots had no fire. In high fire vulnerable plots, a lot of stumps and root suckers were burnt completely but some with appreciable diameter survived. Sangeda and Maleko (2018) reported that less intensive fire stimulated development of new root suckers but high fire destruct root suckers. Pastoralists use fire mainly to improve the quality of grazing within the woodland (Lowore and Abbot, 1995). Chidumayo (1993) reported that late dry season fires have shown to be more damaging to young trees, than cooler fires which occur early before the dry season or after the rains have begun. He reported that late season fires burn at higher temperatures than early season fires.

Statistical evidence show that there is insignificant effect of fire on regeneration via seedlings and coppices but there is a significant difference between fire and root suckers. In areas with high fire, root suckers become fewer. Root suckers are more affected by moderate and high fire (Fig. 8).

Severe effects of fire

Reduction in stumps

Plate 3: Photo showing effects of fire in harvested plots in Nyali and Dodoma Isanga Villages in Kilosa District, Morogoro

5.2.2 Effects of grazing on performance of regeneration in harvested areas

Large proportion of plots (41) showed indications of occasional grazing intensity but few (5) had intensive grazing. Within a study it has been revealed that many areas where grazing is occasional, regenerants are observed to be growing but in other villages with extensive and intensive grazing the ground was mainly bare and indications of more severe soil erosion were observed (Plate 5).

Plate 4: Photo showing effects of grazing of animals in harvested areas at Nyali Village in Kilosa District, Morogoro

The statistical evidence shows that grazing has effects on regeneration via seedlings but not in coppicing and root suckering (Figure 10). In areas without grazing, number of seedlings was higher than in areas with occasional, extensive and intensive grazing but for coppicing and root suckering, grazing had no significant effect. Sangeda and Maleko (2018) noted that the effect of grazing on initial regeneration was minimal as the grazing intensity was low in most sites and the herbivores were noted to consume grasses while no signs of seedling consumption were noted. When grazing pressure increases, negative affects to tree regeneration increases (Kigomo 2003; Mtimbanjao 2017). By comparing the results, intensive grazing results in killing of seedlings but also results into bare soil with erosion. They all decrease the rate of vegetation regeneration.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

Regeneration of Miombo woodland trees in the harvested plots is improving and is dominated by root suckering followed by coppices and seedlings. The regenerants have improved in height and diameter within a short period of time. The regeneration is more efficient for stumps within a diameter and height classes of 6-15 cm and 0-20 cm. Continuous monitoring of the regeneration in the harvested plots should be done in order to see the trend of development. This monitoring should be done within a period of 2-5 years.

Regeneration in kiln scars is occurring and the regenerated trees are native to Miombo. This is an indication that in the future, the scars will be dominated by Miombo woodlands tree species. Forest enrichment by planting Miombo trees in harvested plots can be done in order to improve the forest stock.

Fire has effects on soil physical and chemical properties like soil texture, bulk density, pH, Carbon, total Nirogen and Cation Exchange Capacity. In general the environment in kiln scars is more fertile than in controls. This favour development of herbaceous plants that are replaced by native Miombo tree species through succession. Burning of charcoal should be done outside the forest as it change the soil physical and chemical properties but also it takes much time for the regeneration to occur in kiln scars. If this is seen to be difficult or has high cost implication, restoration programs on these sites are necessary.

Fire and grazing frequencies has negative effects in regeneration via root suckering and seedlings. Intensive fire tends to kill root suckers while Intensive grazing is harmful to seedlings (Seedlings are eaten by animals). Controlling fire and grazing frequencies is crucial. Avoiding high fire frequencies and intensive grazing is essential as the regeneration will perform better. Frequent fire and Intensive grazing should be stopped. Many villagers have adapted this but few are having problems. More education to these people and enforcement of laws related with forest protection must be well observed.

According to this study, stumps of various size were cut and many of them were falling at the category of 6-15cm diameter and 0-20cm height and the categories has shown to regenerate better. Other categories had fewer stump. Other studies should be done in order to conclude on the required heights and diameters for cutting trees for harvesting.

Regeneration in kilns has been observed but the data was carried only in one village out of 8. More research should be done in other villages in order to see if regeneration has started in kiln scars.

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APPENDICES

Appendix 1: Forms for quantification of the post regeneration in charcoal harvested plots in Kilosa District, Morogoro (15 m radius)

Plot Identifier: .... Date: ....

Year of Harvesting... Measured By: ....

Ward... Village: ....

Recorded By: .... Site Name: ....

Plot Id: .... GPS reference: Easting (X)....................................... Northing (Y) UTM .... Altitude: .... Slope (%)..: linear .... concave............................... convex ....land mark……………………

Site Notes (Including other disturbances such as fire, drought, grazing, erosion or farming)..
....

Species name	**Year of cutting**	**Stump diameter (cm)**	**Stump height (cm)**	**No. of coppices/branches**	**Coppices/branches height (cm)**	**No. of root sprouts/ suckers**	**Root sprout height/ suckers (cm)**	**Remarks on the species and gap dynamics (*Including associated species, performance and presence/absence of kilns)***

Appendix 2: Quantification of the post charcoal harvesting regeneration: plot data sheet for seedlings and root suckers (1m x 1m Sub-plot)

Sub-plot No.	Spp code	Species name	No. of seedlings/saplings	Seedling/sapling/ height (m)	Notes on the species and gap dynamics (*Including associated species, light demand, tolerance to shed, performance and presence/absence of kilns)*

Appendix 3: Forms for capturing information on fire frequeny in harvested plots in Kilosa District, Morogoro (15m radius plot)

Effect of fire on regeneration– 15m radius plot			
Tree Species	**Severity (circle 1)**	**Potential Source**	**Remarks**
	0 1 2 3		
	0 1 2 3		
0 = no fire 1 = low 2 = moderate 3=High			

Appendix 4: Quantification of the post charcoal harvesting regeneration in kiln scars at Kisanga Village in Kilosa District, Morogoro: (5m radius plot)

	Spp code	Species name	No. of seedlings/saplings	Seedling/sapling/ height (m)	Notes on the species and gap dynamics (*Including associated species, light demand, tolerance to shed, performance and presence/absence of kilns)*
Kiln No.					
Control Number					

Appendix 5a: Raw data for stumps regenerating via coppices in Eight villages harvested in Kilosa District, Morogoro

	Plots														
Village	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**Total**
Dodoma Isanga	2	3	5	5	4	3	0	0	0	0	0	0	0	0	22
Ihombwe	3	2	6	4	4	5	5	7	3	2	3	4	3	2	53
Kigunga	6	7	5	7	6	4	6	0	0	0	0	0	0	0	41
Kisanga	6	5	10	11	5	6	3	5	7	0	0	0	0	0	58
Msimba	5	6	4	8	6	4	3	6	6	4	6	0	0	0	58
Nyali	1	1	1	1	1	3	1	0	0	0	0	0	0	0	9
Ulaya Kibaoni	2	3	2	3	2	1	3	0	0	0	0	0	0	0	16
Ulaya Mbuyuni	5	4	6	6	8	4	0	0	0	0	0	0	0	0	33
Total	**31**	**33**	**42**	**49**	**41**	**36**	**28**	**26**	**25**	**16**	**20**	**16**	**16**	**16**	**290**

Appendix 5b: ANOVA table for stumps regenerating via coppices in eight villages harvested in Kilosa District, Morogoro

Source of variation	D.f	S.S	M.S	F
Villages	7	70.69	10.10	0.993
Treatments	56	3655.75	65.28	
Total	**63**	**3726.44**	**75.38**	

L.S.D 15.93

Appendix 6a: Raw data for stumps regenerating via root suckers in eight villages harvested in Kilosa District, Morogoro

	Plots														
Village	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**Total**
Dodoma Isanga	2	3	2	4	2	4	6	0	0	0	0	0	0	0	**23**
Ihombwe	1	3	2	0	0	3	2	2	2	0	0	0	0	0	**15**
Kigunga	4	6	6	5	5	7	4	0	0	0	0	0	0	0	**37**
Kisanga	3	5	2	6	0	0	4	0	0	0	0	0	0	0	**20**
Msimba	1	4	1	2	1	0	0	0	0	0	1	0	0	0	**10**
Nyali	1	0	2	1	3	0	0	0	0	0	0	0	0	0	**7**
Ulaya Kibaoni	0	3	5	2	0	0	0	0	0	0	0	0	0	0	**10**
Ulaya Mbuyuni	2	4	5	8	7	6	5	0	0	0	0	0	0	0	**37**
Total	**15**	**30**	**28**	**32**	**23**	**26**	**28**	**10**	**11**	**10**	**12**	**12**	**13**	**14**	**159**

Appendix 6b: ANOVA table for stumps regenerating via root suckers in eight Villages harvested in Kilosa District,Morogoro

Source of variation	D.f.	S.S.	M.s	F
Villages	7	95.50	13.64	0.977
Treatments	56	3330.25	59.47	
Total	**63**	**3425.75**	**73.11**	

L.S.D 7.724

Appendix 7a: Raw data for regeneration via Coppices and root suckers in Eight villages harvested in Kilosa District, Morogoro

Village	Plots														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	**Total**
Dodoma Isanga	0	3	1	2	4	4	0	0	0	0	0	0	0	0	**14**
Ihombwe	1	4	5	3	2	0	2	3	2	2	1	4	2	1	**32**
Kigunga	0	2	6	4	3	8	5	0	0	0	0	0	0	0	**28**
Kisanga	0	3	2	1	2	2	0	0	0	0	0	0	0	0	**10**
Msimba	3	5	2	4	1	4	1	1	2	3	2	0	0	0	**28**
Nyali	1	1	0	0	1	0	0	0	0	0	0	0	0	0	**3**
Ulaya Kibaoni	0	4	2	5	6	1	3	0	0	0	0	0	0	0	**21**
Ulaya Mbuyuni	1	3	2	5	3	1	2	0	0	0	0	0	0	0	**17**
Total	**7**	**27**	**23**	**28**	**27**	**26**	**20**	**12**	**13**	**15**	**14**	**16**	**15**	**15**	**153**

Appendix 7b: ANOVA table for regeneration via coppices and root suckers per stump in Eight villages harvested in Kilosa District,Morogoro

Source of variation	**D.f.**	**S.S**	**M.s.**	**F**
Village	7	90.75	12.96	0.973
Treatments	56	3031.00	54.12	
Total	**63**	**3121.75**	**67.08**	

L.S.D 7.369

Appendix 8a: Raw data for stumps without coppices and root suckers in Eight villages harvested in Kilosa District, Morogoro

Village	**Plots**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**Total**
Dodoma Isanga	0	0	0	2	5	1	1	0	0	0	0	0	0	0	**9**
Ihombwe	1	1	0	3	0	0	0	0	1	0	2	2	0	1	**11**
Kigunga	1	1	0	1	2	2	2	0	0	0	0	0	0	0	**9**
Kisanga	1	2	0	2	1	0	2	2	2	0	0	0	0	0	**12**
Msimba	2	3	2	1	1	2	2	1	0	0	0	0	0	0	**14**
Nyali	2	3	1	1	1	0	0	0	0	0	0	0	0	0	**8**
Ulaya Kibaoni	0	3	2	4	1	2	2	0	0	0	0	0	0	0	**14**
Ulaya Mbuyuni	0	0	3	2	1	2	1	0	0	0	0	0	0	0	**9**
Total	**8**	**15**	**11**	**20**	**17**	**15**	**17**	**11**	**12**	**10**	**13**	**14**	**13**	**15**	**86**

Appendix 8b: ANOVA table for stumps without coppices and root suckers in Eight villages harvested in Kilosa District, Morogoro

Source of variation	D.f.	S.S	M.s.	F
Village	7	95.75	10.96	0.973
Treatments	56	3020.00	50.12	
Total	**63**	**3115.75**	**61.08**	

L.S.D 7.123

Appendix 9a: Raw data for regenerating stump in various stump diameter classes in harvested plots in 8 Villages in Kilosa District, Morogoro

Village	Diameter categories(cm)								
	0_5	**6_15**	**16_25**	**26_35**	**36_45**	**46_55**	**56_65**	**66+**	**Total**
Dodoma Isanga	0	21	19	2	0	2	0	0	44
Nyali	0	16	5	3	2	0	0	0	26
Ulaya Mbuyuni	8	61	12	0	0	0	0	0	81
Ulaya Kibaoni	5	36	22	2	1	0	1	1	68
Kigunga	10	43	21	3	1	0	1	2	81
Kisanga	1	24	33	11	1	0	0	0	70
Ihombwe	0	14	21	9	5	1	1	0	51
Msimba	0	14	14	14	4	1	0	0	47
Total	24	229	147	44	14	4	3	3	468

Appendix 9b: ANOVA table to show regenerating stump in various stump diameter classes in harvested plots in 8 Villages in Kilosa District, Morogoro.

Source of variation	D.f	S.s.	M.s	F
Villages	7	336.25	48.04	0.0001
Treatments	49	2452.75	50.06	
Total	**63**	**2789**	**98.1**	

L.S.D 15.93

Appendix 10a: Raw data to show non-regenerating stumps in various stump diameter classes in harvested plots in 8 Villages in Kilosa District, Morogoro

Village	Diameter categories (cm)								
	0_5	**6_15**	**16_25**	**26_35**	**36_45**	**46_55**	**56_65**	**66+**	**Total**
Dodoma Isanga	6	3	4	1	0	0	0	0	14
Nyali	0	2	5	4	1	1	0	0	13
Ulaya Mbuyuni	1	4	4	9	3	1	0	0	22
Ulaya Kibaoni	0	10	28	10	1	1	2	1	53
Kigunga	2	10	6	4	1	0	0	0	23
Kisanga	0	2	10	19	5	1	0	0	37
Ihombwe	0	1	1	9	10	7	1	0	29
Msimba	0	3	6	9	6	2	0	0	26
Total	**9**	**35**	**64**	**65**	**27**	**13**	**3**	**1**	**217**

Appendix 10b: ANOVA table to show non-regenerating stumps in various stump diameter classes in harvested plots in 8 Villages in Kilosa District, Morogoro

Source of variation	**D.f.**	**S.S**	**M.s**	**F**
Villages	7	172.00	24.57	0.001
Treatments	35	823.50	23.53	
Total	**47**	**995.5**	**48.1**	

Appendix 11a: Raw data to show a difference between regenerating stumps in various stump Height classes in harvested plots in 8 Villages in Kilosa District, Morogoro.

Village	Height categories(cm)						
	0_20	**21_40**	**41_60**	**61_80**	**81_100**	**101+**	Total
Dodoma Isanga	28	11	4	2	0	2	47
Nyali	19	5	3	1	2	0	30
Ulaya Mbuyuni	65	4	3	0	0	0	72
Ulaya Kibaoni	47	5	2	2	1	0	57
Kigunga	69	7	4	3	1	0	84
Kisanga	47	9	3	2	1	0	62
Ihombwe	50	11	2	3	5	1	72
Msimba	19	11	2	1	4	1	38
Total	**344**	**63**	**23**	**14**	**14**	**4**	462

Appendix 11b: ANOVA table to show regenerating stumps and various stump Height classes in harvested plots in 8 Villages in Kilosa District, Morogoro.

Source of variation	**d.f.**	**s.s.**	**m.s**	**F**
Villages	7	567.6	81.1	
Treatment	5	11545.4	2309.1	0.001
Residual	35	3970.9	113.5	
Total	47	16083.9		

Appendix 12a: Raw data to show regenerating stumps in various stump Height classes in harvested plots in 8 Villages in Kilosa District, Morogoro.

Village	**Height categories(cm)**						
	0_20	**21_40**	**41_60**	**61_80**	**81_100**	**101+**	**Total**
Dodoma Isanga	6	15	9	2	0	2	34
Nyali	4	12	5	1	2	0	24
Ulaya Mbuyuni	5	13	3	0	0	0	21
Ulaya Kibaoni	7	11	3	2	1	0	24
Kigunga	7	12	5	3	1	0	28
Kisanga	7	14	13	2	1	0	37
Ihombwe	5	16	1	1	1	1	25
Msimba	12	14	2	1	3	1	33
Total	53	107	41	12	9	4	226

Appendix 12b: ANOVA table to show no regenerating stumps and various stump Height classes in harvested plots in 8 Villages in Kilosa District, Morogoro

Source of variation	**d.f.**	**s.s.**	**m.s**	**F**
Villages	7	530.6	69.1	
Treatment	5	1021.4	2104.4	0.001
Residual	35	3654.7	107.2	
Total	**47**	**5206.7**		

Appendix 13a: Raw data to show the number of seedlings in various plots in 8 Villages in Kilosa District, Morogoro.

Village	Seedlings in Plots														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	**Total**
Ulaya Mbuyuni	10	8	14	15	16	13	0	0	0	0	0	0	0	0	76
Kigunga	6	10	9	11	7	6	16	0	0	0	0	0	0	0	65
Dodoma Isanga	5	7	13	8	15	11	0	0	0	0	0	0	0	0	59
Ihombwe	0	3	9	5	7	2	6	2	6	0	0	0	7	3	50
Ulaya Kibaoni	3	8	4	2	9	3	4	0	0	0	0	0	0	0	33
Kisanga	2	3	1	3	4	2	0	5	9	0	0	0	0	0	29
Nyali	1	0	4	5	3	4	5	0	0	0	0	0	0	0	22
Msimba	0	3	5	1	1	1	2		3	2	4	0	0	0	22
Total	**28**	**44**	**62**	**54**	**67**	**48**	**40**	**15**	**27**	**12**	**15**	**12**	**20**	**17**	**356**

Appendix 13b: ANOVA table to show the number of seedlings in harvested plots in 8 Villages in Kilosa District, Morogoro

Source of variation	**D.f.**	**S.s.**	**M.s.**	**P**
Village	7	221.92	31.7	0.671
Residual	112	5063.07	45.21	
Total	**119**	**5284.99**		

Appendix 14a: Raw data to show a number of various seedlings species in harvested plots in 8 Villages in Kilosa District, Morogoro.

Species	Villages								
	Dodoma Isanga	Ihombwe	Kigunga	Kisanga	Msimba	Nyali	Ulaya Kibaoni	Ulaya Mbuyuni	Total
Brachystegia bussei/microphylla	3	0	0	0	0	0	0	0	3
Brachystegia boehmii	5	4	4	3	2	0	3	3	24
Brachystegia spiciformis	2	5	5	3	1	2	0	7	25
Combretum molle	3	3	3	2	2	2	2	1	18
Combretum zeyhen	0	0	2	0	0	0	0	0	2
Combretum/Terminalia spp	0	1	2	0	2	1	2	2	10
Dalbergia melanoxylon	0	0	0	0	0	0	0	0	0
Dichrostachys cinerea	0	0	0	0	0	0	0	2	2
Diplorynchus condylocarpon	0	1	3	3	2	1	3	3	16
Flueggea virosa	0	0	0	0	0	2	0	0	2
Markhamia spp	0	0	2	0	0	0	0	0	2
Dalbergia melanoxylon	0	0	0	0	0	0	2	1	3
Pseudolachnostylis maprouneifolia	0	0	0	0	0	2	0	1	3
Pterocarpus angolensis	0	0	0	0	0	1	0	0	1
Total	13	14	21	11	9	11	12	20	111

Appendix 14b: ANOVA table to show a difference between number of seedlings vs tree species in Kilosa District, Morogoro.

Source of variation	d.f	s.s.	m.s.	F pr
Villages	7	365.672	52.239	0.001
Treatment	13	2423.37	186.41	
Residual	99	2639.7	26.66	
Total	119	5428.742	265.309	

Appendix 15a: Raw data for regeneration via root suckering and coppicing in harvested Villages in Kilosa District, Morogoro

Number of Plots	Coppices	Root suckers	Total
67	665	874	1539

Appendix 15b: Student t-test to show a difference between regeneration via root suckers and seedlings in harvested Villages in Kilosa District, Morogoro

Sample	Mean	D.f	P
Root suckers	13a	130	0.004
Coppices	10b		

Appendix 16a: Raw data for regeneration via coppicing and seedlings in harvested Villages in Kilosa District, Morogoro

Plots	Coppices	Seedlings	Total
67	665	356	1021

Appendix 16b: Student t-test to show a difference between regeneration via coppicing and seedlings in harvested Villages in Kilosa District, Morogoro

Sample	Mean	D.f	P.value
Coppices	10	130	$0.4X10^{7}$
Seedlings	5		

Appendix 17a: Raw data for regeneration via root suckers and seedlings in harvested Villages in Kilosa District, Morogoro

Plots	seedlings	Root suckers	Total
67	874	356	1230

Appendix 17b: Student t-test to show a difference between regeneration via root suckers vs. seedlings in harvested Villages in Kilosa District, Morogor

Sample	Mean	D.f	P
Root suckers	13	130	$0.7X10^{12}$
Seedlings	5		

Appendix 18a: Raw data for regeneration via root suckers/coppices vs. seedlings in harvested Villages in Kilosa District, Morogoro

Village	Coppices/Rootsuckers	Seedlings	Total
67	773	356	1129

Appendix 18b: Student t-test to show a difference between regeneration via root suckers/coppices vs. seedlings in harvested Villages in Kilosa District, Morogoro

Sample	Mean	D.f	P
Coppices/Root suckers	11	130	$0.65 X10^{11}$
Seedlings	5		

Appendix 19a: Raw data for regeneration via root suckers and coppices vs. seedlings in harvested Villages in Kilosa District, Morogoro

Village	Coppices/Rootsuckers	Seedlings	Total
67	2312	356	2668

Appendix 19b: Student t-test to show a difference between regeneration via root suckers, coppices and both (Coppices and root suckers) vs. seedlings in harvested Villages in Kilosa District, Morogoro

Sample	Mean	D.f	P
Both Coppices/Root suckers	35a	130	$0.65 X10^{44}$
Seedlings	5b		

Appendix 20a: Raw data to show a comparison of mean number of seedlings in Eight villages harvested in Kilosa District, Morogoro

Species	Dodoma Isanga	Iho mbwe	Kigunga	Kisanga	Msimba	Nyali	Ulaya Kibaoni	Ulaya Mbuyuni	Total
Brachystegia bussei	12	0	0	0	15	0	0	15	42
Brachystegia bohemii	50	69	13	8	31	0	8	8	187
Brachystegia Spiciformis	29	75	30	16	32	6	0	42	230
Combretum Molle	12	7	7	3	8	6	6	1	50
Combretum Zeyhem	0	1	3	0	6	15	0	0	25
Combretum terminalia	0	2	3	0	3	2	6	0	16
Dalbergia melanoxylon	0	0	0	0	0	0	1	0	1
Dichrostachy cinerea	0	0	0	0	0	54	0	3	57
Diplonchus Condricarpon	0	0	7	8	5	2	11	7	40
Flugea Virosa	0	2	0	0	5	1	0	2	10
Markamia spp	0	0	3	0	6	0	0	0	9
Pseudolachstylis maproneufoia	0	0	0	0	5	4	0	1	10
Pterocarpus angolensis	0	0	0	0	6	1	2	0	9
Xeroderris stuhlamanii	0	0	0	0	1	0	0	1	2
Total	103	156	66	35	123	91	34	80	688

Appendix 20b: ANOVA table to showing comparison of mean number of harvested trees in Eight villages harvested in Kilosa District, Morogoro

Source of variation	**d.f**	**s.s.**	**m.s.**	**F**
Villages	7	365.672	52.239	0.001
Residual	688	6040.443	8.780	
Total	695	6406.115	61.09	

Appendix 21: List of harvested tree species and regenerating capacities in villages harvested for charcoal production in Kilosa District, Morogoro

Specie	Coppice	Suckers	Both	Non	Grand total	Percentage
Brachystegia boehemii	155	56	65	40	316	46
Combretum molle	43	35	36	7	121	18
Brachystegia spiciformis	35	19	18	5	77	11
Diplonchus condylocarpon	12	18	15	4	49	7
Pseudolachnostylis maprouneifolia	7	9	5	5	26	4
Xeroderis stuhlamanii	8	8	3	3	22	3
Combretum Terminalia spp	8	6	2	5	21	3
Pterocarpus angolensis	4	0	2	5	11	2
Combretum zeyhem	3	2	2	2	9	1
Pericopsis spp	3	0	1	4	8	1
Brachystegia bussei	3	1	1	1	6	1
Flueggea virosa	2	1	2	0	5	1
Buckea africana	4	0	0	0	4	1
Annona spp	1	2	0	0	3	0
Markhamia spp	1	2	0	0	3	0
Faidherbia albida	0	0	1	1	2	0
Dalbegia melanoxylon	0	0	0	2	2	0
Dichrostachys cinerea	1	0	0	1	2	0
Acacia nigrescens	0	0	0	1	1	0
Total	**290**	**159**	**153**	**86**	**688**	**100**

Appendix 22a: Raw data for regeneration in kiln scars and the nearby environment in Kisanga Villages in Kilosa District, Morogoro

Plots	Seedlings in Kiln centre	Seedlings in Control
1	1	0
2	1	1
3	0	3
4	1	2
5	1	1
6	1	1
7	0	2
8	0	1
9	0	1
10	0	2
11	1	1
12	0	2
13	0	1
14	0	3
15	0	1
16	0	2
17	0	2
18	0	3
19	0	1
20	0	1
21	0	3
22	0	2

Appendix 22b: Student t-test to show a difference between regeneration in kiln scars and the nearby environment in Kisanga Villages in Kilosa District, Morogoro

Sample	Mean	D.f	P value
Control	1.6364	87.8	0.001
Kiln	0.2727		

Appendix 23a: Raw data to show comparison between fire occurence and regeneration via seedlings in various plots in Kilosa District, Tanzania

Number	Fire Frequency	Number of Seedlings	Total
1	0	146	**146**
2	1	76	**77**
3	2	68	**70**
4	3	66	**69**
Total	**6**	**356**	**362**

Appendix 23b: ANOVA table to show comparison between fire occurence and availability of seedling in various plots in Kilosa District, Tanzania

Source of variation	D.f	S.s.	M.s.	P value
Fire frequence	3	178.95	59.65	0.156
Residual	63	2083.74	33.08	
Total	**66**	**2262.69**	**92.73**	

Appendix 24a: Raw data for fire frequence vs. Coppice in harvested villages in Kilosa District, Morogoro

Number	Fire frequency	Number of Coppices	Total
1	0	419	419
2	1	255	256
3	2	210	212
4	3	164	167
Total	**6**	**1048**	**1054**

Appendix 24b: ANOVA table for fire frequence vs. Coppice in harvested villages in Kilosa District,Morogoro

Source of variation	d.f.	s.s.	m.s	F.
Fire frequence	3	3675.4	1225.1	0.272
Residual	63	58008.0	920.8	
Total	**66**	**61683.4**	**2145.9**	

Appendix 25a: Raw data for fire frequency vs. root suckering in harvested villages in Kilosa District, Morogoro

Number	Fire frequency	Number of Root suckers	Total
1	0	679	679
2	1	393	394
3	2	133	135
4	3	59	62
Total	**6**	**1264**	**1270**

Appendix 25b: ANOVA table for fire frequency vs. root suckering in harvested villages in Kilosa District, Morogoro

Source of variation	**d.f.**	**s.s.**	**m.s.**	**F**
Fire frequence	3	6999.6	2333.2	0.001
Residual	63	19988.2	317.3	
Total	66	26987.8	2650.5	

Appendix 26a: Raw data for effects grazing vs. regeneration through seedlings in harvested villages in Kilosa District, Morogoro

Number	**Grazing Intensity**	**Seedlings**	Total
1	0	80	80
2	1	229	230
3	2	41	43
4	3	6	9
Total	**6**	**356**	**362**

Appendix 26b: ANOVA table for grazing vs. seedlings in harvested villages in Kilosa District, Morogoro

Source of variation	**d.f.**	**s.s**	**m.s.**	**F**
Grazing_Intensity	3	297.11	99.04	0.029
Residual	62	1910.64	30.82	
Total	**65**	**2207.76**	**129.86**	

Appendix 27a: Raw data for grazing vs.coppices in harvested villages in Kilosa District, Morogoro

Number	**Grazing Intensity**	**Coppices**	**Total**
1	0	398	398
2	1	320	321
3	2	177	179
4	3	153	156
Total	**6**	**1048**	**1054**

Appendix 27b: ANOVA table for grazing vs.coppices in harvested villages in Kilosa District, Morogoro

Source of variation	**d.f.**	**s.s.**	**m.s**	**F pr**
Grazing intensity	3	672.3	224.1	0.874
Residual	63	61011.1	968.4	
Total	**66**	**61683.4**		

Appendix 28a: Raw data for grazing vs. coppices in harvested villages in Kilosa District, Morogoro

Number	Grazing Intensity	Root suckers	Total
1	0	460	460
2	1	392	393
3	2	250	252
4	3	162	165
Total	6	1264	1270

Appendix 28b: ANOVA table for grazing vs.coppices in harvested villages in Kilosa District, Morogoro

Source of variation	D.f.	S.s	M.s.	P.
Grazing Intensity	3	1939.9	646.6	0.192
Residual	63	25047.9	397.6	
Total	**66**	**26987.8**		