MAKERERE UNIVERSITY

EFFECTIVENESS OF FOREST ZONING ON CONSERVATION OF THREATENED TREE SPECIES IN BUDONGO FOREST RESERVE, UGANDA

BY

STELLA KOMUGABE

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DECLARATION

I, STELLA KOMUGABE, hereby declare that the work presented in this dissertation is my original work, except cited references, and never has it been submitted to Makerere University or any other institution for any award.

Signature .... Date 20/4/2022 ....

This dissertation has been submitted to the Directorate of Research and Graduate Training at Makerere University for examination with our approval as supervisors:

Signature .... Date 20/4/2022 ....

Associate Professor Fred Babweteera

Department of Forestry, Biodiversity and Tourism, Makerere University

Signature .... Date 20th April 2022 ....

Dr. Enock Ssekuubwa

Department of Forestry, Biodiversity and Tourism, Makerere University

DEDICATION

I would like to honor my family, colleagues and friends for having been supportive throughout this study**.**

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ABSTRACT

Forest zoning involving subdividing the forest to serve multiple purposes has been implemented in forest reserves to halt on forest degradation. Despite its introduction, community valued tree species are threatened with extinction. However, little is known on the effectiveness of forest zoning on conservation of threatened valuable tree species. Thus, the study assessed the effectiveness of forest zoning on conservation threatened valuable tree species in Budongo Forest Reserve, western Uganda. Specifically, the forest structure, stocking density, basal area and diameter size class distribution of threatened valuable tree species were compared among different management zones. In addition, the effect of forest structure on stocking density and basal area of these tree species was assessed. The study was carried out in August 2020 in Nyakafunjo block in the Production, Nature Reserve, Buffer and Special scientific interest zones, each serving a different purpose. Systematic sampling was adopted in laying of line transects and plots where a total of 160 plots of 600 m^2 (40 in each zone) were established. Data were collected on selected threatened valuable and least concern less valuable tree species. To assess the effectiveness of forest zoning on conservation of threatened valuable tree species, the results on threatened valuable species was compared to least concern less valuable species. The results showed significant variation in forest structure among the zones. Further, the threatened valuable species and least concern less valuable species had no significant variation in stocking density among the management zones. However, the basal area of least concern less valuable species differed significantly among the management zones. Threatened valuable tree species had a nearly inverse J-shape pattern in strict nature reserve. While, least concern less valuable tree species showed a bell-shape distribution pattern in all management zones. In addition, the stocking density of threatened valuable tree species had significant positive correlation with under growth density in Special scientific interest zone. However, stocking density of least concern less valuable tree species had negative significant correlation with canopy closure in the Buffer zone. The results indicate an element of easy access combined with extractive activities in nature reserve. Implying that forest zoning is not serving the intended purpose of conserving threatened valuable tree species in Budongo forest. Therefore, conservation initiatives should be improved and strengthened among others to consider relocation of nature reserve zone and investing in more sustainable livelihood alternatives to forest adjacent communities in order to reduce on extractive pressure on the forest.

CHAPTER ONE: INTRODUCTION

1.1 Back ground to the study

Tropical rain forests support more than a half of terrestrial biodiversity (Newton, 2006); however, they are being destroyed through deforestation and forest degradation leading to loss of associated biodiversity and destabilizing forest structure (Obua et al., 2016; Weldemariam et al., 2017). More, the World has lost 178 million hectares of forest between 1990-2020 (FAO, 2020). Similarly, Uganda has lost 1.5 million hectares of natural forest between 1990 to 2020 (FAO, 2020a). Yet, tropical rain forests provide habitats for many native flora and fauna species, as well as, crucial ecosystem services that support human well-being and quality of life (Obua et al., 2016). Besides, valuable tropical tree species on which people depend for their livelihoods and well-being are being threatened with extinction (MTWA, 2018). Notable, among the key threats to trees in tropical rain forests are agricultural expansion and uncontrolled extraction of forest products like timber, poles and medicine (Mwavu et al., 2009). Hence, there is urgent need for intervention to conserve forest biodiversity, more so, threatened valuable tree species in tropical forests.

Sustainable forest management (SFM) practices have been adopted globally in conservation of tropical forests (FAO, 2016). For example, Uganda adopted SFM practices believing they would integrate the concerns of all stake-holders while conserving the diversity of native structures, functions, and species in tropical forests (Turyahabwe et al., 2013). Furthermore, their introduction was ignited by the 1992 Convention on Biological Diversity (CBD) (MWLE, 2002). Notable, among SFM practices is forest zoning that is implemented in forest reserves to control the ongoing forest degradation, while conserving biodiversity and promoting sustainable use of forest products (Turyahabwe et al., 2013). Besides, zoning is based on Man and Biosphere principle that aims at establishing a scientific basis for the improvement of relationships between people and their environments (Obua et al., 2016).

In Uganda, forest zoning was adopted by the Forest Department with the aim of conserving the biodiversity, environment and providing timber and other forest products (MWLE, 2002). Within a zoned forest about 20 percent of the forest area is set aside for biodiversity preservation as

Strict Nature Reserves; 30 percent is a buffer zone for light or low impact forest uses and 50 per cent of the forest is a production zone for extraction of forest products (Obua et al., 2016). Equally important, zoning provides clear, specific and effective management directions and minimizes conflicts among forest users (Weldemariam et al., 2017). Thus, zoning allows for comprehensive conservation of tree species diversity and population structure. However, in spite of the advantages of zoning, continued harvesting of tree species is affecting their distribution and may lead to numerous extinctions over the next century (Sloan & Sayer, 2015).

Despite the adoption of zoning, several tropical tree species are threatened with extinction (MTWA, 2018) due to, the ever increasing human population coupled with increasing demand for wood products (Banla et al., 2019). Moreover, little is known of the effectiveness of zoning in the management of threatened valuable tree species in tropical forest reserves. Therefore, the question whether forest zoning is effective in conserving threatened valuable tree species has remained unanswered to current ecologists and forest managers. This, study will assess the effectiveness of forest zoning on conservation threatened valuable tree species in order to support conservation initiatives.

1.2. Problem statement

Tropical deforestation and degradation are global environmental problems and forest zoning has been one of the strategies used to address these challenges (FAO, 2005). Despite the implementation of zoning, the state of tropical rain forests is deteriorating leading to loss of forest biodiversity including tree species estimated at over 1% per year (Pomeroy et al., 2017). This consequently, casts doubt about the effectiveness of zoning for sustainable management of tropical rain forests. Few studies have examined the effectiveness of zoning on forest conservation. Those few studies reported inconsistent effects of zoning on species conservation. For instance, a study by Tittler et al., (2010) on possible benefits of TRAID in boreal forest in Canada found that zoning minimizes negative impacts on native species as well as, structure and functions of the forest. Whereas, Weldemariam et al., (2017) in a study on implications of zoning in Mabira Forest in Uganda found that zoning reduced tree species population, due to the closed forest canopy and human disturbances. Thus, our knowledge on the effective of zoning on forest conservation is inconclusive.

In Uganda, zoning has been practiced in natural forest reserves, presuming it to offer use right option for sustainable management of tropical rain forests (Obua et al., 2016). In Budongo Forest Reserve (BFR) zoning has been practiced since the 1990's. The forest is categorized as a prime conservation forest, rich in biodiversity with relatively high rarity value of species (MWLE, 2002). Regardless, populations of locally recognized useful tree species especially timber species were found to be affected by anthropogenic disturbances (Mwavu et al., 2009) through continued illegal and legal harvesting for timber (MWE, 2016). Moreover, there is limited information about how zoning of the forest has influenced the densities, distribution as well as regeneration potential of tree species and how these effects are mediated by variations in forest structure among the management zones. Therefore, the study aims at assessing the stocking and population structure of tree species in order to evaluate the effectiveness of forest zoning on conservation of timber species in Budongo Forest Reserve.

1.3. Objectives of the study

1.3.1. General objective

To assess effectiveness of forest zoning on conservation of threatened valuable tree species in Budongo Forest Reserve in order to support conservation initiatives of tree species.

1.3.2. Specific objectives

1. To assess the forest structure in the different management zones of Budongo Forest Reserve.
2. To determine and compare the stocking density and basal area of threatened valuable and least concern less valuable tree species in the different management zones of Budongo Forest Reserve.
3. To determine and compare the size class distribution of threatened valuable and least concern less valuable tree species in the different management zones of Budongo Forest Reserve.
4. To determine the influence of forest structure on the stocking density and basal area of threatened valuable and least concern less valuable tree species in different management zones of Budongo Forest Reserve.

1.3.3. Study hypotheses

Ho: Forest structure is not different among the management zones of Budongo Forest Reserve.

Ho: The stocking density of the threatened valuable and least concern less valuable tree species is not different among the management zones of Budongo Forest Reserve.

Ho: The size class distribution of the threatened valuable and least concern less valuable tree species is not different among the management zones of Budongo Forest Reserve.

Ho: Forest structure has no significant effect on the stocking density and basal area of threatened valuable and least concern less valuable tree species in the management zones of Budongo Forest Reserve.

1.4 Significance of the study

The study is significant in generating scientific information on the effectiveness of zoning on conservation of threatened valuable tree species in Budongo Forest Reserve and elsewhere in the tropical forests. Reason being, valuable tree species are threatened with extinction due to their demanded use values and the poor regeneration and growth potential in natural forest. Moreover, conservation of these tree species is crucial not only for Budongo biodiversity, but also for meeting the basic needs of the local population. The results on threatened valuable and least concern less valuable tree species provide a reliable data base to conservation researchers and forest managers for planning. These further serve as baselines against which to conduct future studies on forest conservation. The generated information provides a basis for the Ministry of Water and Environment to influence policy making and National Forest Authority to improve conservation approaches. This further contributes to attaining Uganda's vision 2040 of sustainable and ecologically stable forests. The results further exposes the extinction risk of targeted tree species which is a primary step to achieve Aichi biodiversity targets especially of establishing conservation plans for threatened tree species (UN, 2020).

CHAPTER TWO: LITERATURE REVIEW

2.1. Threats to conservation of tropical rain forests

2.1.1. Forest logging

According to FAO, (2016) logging has put a greater strain on tropical rain-forests despite enhancing the regeneration of some tree species like *Entandrophragma* spp in Africa (Bahati, 1998). Logging disturbances when combined with high harvest pressure may create unfavorable environment for species' abundance and composition especially for high valuable species (Mawa et al., 2020). Furthermore, the gap sizes created due to logging determine which species regenerate. For example, medium size gaps favor regeneration of timber species which are mostly light demanding. While, small and large gaps result in declining regeneration of timber species in tropical forests (Hawthorne et al., 2011). Owing to the fact that, high irradiance in large gaps influence nutrient cycling by increasing surface soil temperatures that lead to reduction in humidity (Mugabi et al., 2003). Such conditions create opportunity for establishment of fast-growing pioneer species that form extensive monospecific patches in tropical forests (Hill, 2001; Baret et al., 2008). In addition, selective logging of preferred mature seed trees which are potential seed sources reduce the ability of the forest to regenerate after logging (Mwavu & Witkowski, 2009). In the long run, impacting on the abundance of preferred species with-in the tropical rain forests (Bongers et al., 1999). Thus, logging has for long been recognized to impact on commercial valuable tree species and more so leading to extinction of targeted tree species (Tabor et al., 2018).

2.1.2. Deforestation

Deforestation is the biggest threat to tropical rain forests as large amounts of native tree species are being cut for timber and wood (Obua et al., 2016 and Josephat, 2018). Largely induced by poverty-driven agriculture, large scale agriculture, infrastructure expansion and mineral projects (Laurance, 2015). To illustrate, small-scale crop cultivation by poor farmers has been replaced by conversion of tropical rain forest for commercial crop monoculture (Corlett, 2016). Consequently, leading to forest fragmentation which cause ecological changes to the plant community especially composition by increasing small tree mortality and damage (Muthuramkumar et al., 2006). Not only that, deforestation leads to reduction of forest area which consequently lessens habitat for species of concern hence causing failure to conservation strategies mostly in tropical rain forests (Tabor et al., 2018; Banla et al., 2019; Laurance, 2015). Therefore, deforestation has for long been noted to contribute to tropical biodiversity loss of which the reference forest is not an exceptional (Josephat, 2018).

2.1.3. Invasive species

Invasive tree species are a potential threat to tropical rain forest (Corlett, 2016). By their vigorous vegetative reproduction, they colonize disturbed areas through forming thick monospecific patches (Baret et al., 2008). Moreover, once their invasion they grow rapidly upwards into the canopy favored by their ability to tolerate harsh conditions, and as a result, the normal cycle of regeneration mostly in larger gaps is disrupted. Given that, soils in the gaps are rich in nutrients especially in areas adjacent to decaying fallen trees (Baret et al., 2008). Consequently, hindering the abundance of other indigenous light demanding species growing in association with them (Weldemariam et al., 2017). Thus, reducing native tree species diversity, as the most efficient competitors dominate (Corlett, 2016; Jyotsna & Kumar, 2015). Hence, presenting a possibility of losing native tree species resulting from the spread of invasive species (FAO, 2005). Therefore, invasive species have for long been recognized to hamper the regeneration of native species in tropical rain forests like Budongo Forest (Pomeroy et al., 2017).

2.2. Sustainable forest management practices

Many vital ecosystem services provided by forests are being altered by human activities through forest degradation (Tittler et al., 2010). Therefore, the specific effects of human disturbance to tropical rain forests become of concern that deserve urgent intervention of implementing sustainable forest management strategies (Banla et al., 2019). Besides, these are practices maintain and enhance long term health of forest ecosystems while addressing social, environmental and economic concerns of present and future generations (John et al., 2007). Importantly, sustainable management of our native forest is a focal point in meeting our community’s needs. More, notable among sustainable management practices; are forest zoning, collaborative forest management, forest certification and appropriate policy (Newton, 2006).

2.2.1. Forest zoning

Forest zoning a “multiple use concept” that allows both production and conservation is preferred by many mangers as the best practice to meet multiple needs of society since it balances social, economic and environmental values (Sloan & Sayer, 2015; Nitschke & Innes, 2015). In addition, it’s a strategy to halt the ongoing degradation of tropical rain forests given its primary objective of clearly separating conservation areas from production areas (Weldemariam et al., 2017; Tittler et al., 2010). For example, Uganda’s natural forests have been zoned into different zones with the hopes of reducing deforestation and degradation resulting from open access (Obua et al., 2016). However, forest zoning is mostly complemented by policy making a crucial element in sustainable forest management (FAO, 2015). Therefore, understanding the performance of forest zoning in the reference forest will be crucial in the management of tree species (Nitschke & Innes, 2015).

2.2.2. Appropriate policy and regulatory frameworks

Globally forestry policies and regulations are being formulated as technique of acquiring and exercising authority by forest officials and institutions in the sustainable management of forest resources (John et al., 2007). Further, it involves implementation of government regulation and law enforcement within the organizational, political and cultural frameworks for sustainable forest management through which diverse interests in the resources are coordinated and controlled (Nyadoi et al, 2013). For example, the government of Uganda after realizing with concern patterns of unsustainable forest exploitation, developed a National Forest Policy 2001 and the National Forestry and Tree Planting Act 2003, (MWE, 2016). Being looked at as instruments to forest protection as well addressing destructive consequences of open access (Turyahabwe et al., 2013). Furthermore, these led to the emergency of National Forest Authority that is being charged with regulation and enforcement of rules in the protection of central forest reserves and provision of technical training services to the sector’s stakeholders (MWLE, 2001). Nevertheless, these forest policies and regulations require ecological monitoring and regular forest patrols to reduce illegal activities, (Ratsimbazafy et al., 2012). As well, controlling extraction of trees to a specific number or basal area per unit area (Hawthorne et al., 2011). However, it should be noted that, even though strong forest institutions help in conserving forests, weak forest management institutions make forests vulnerable to clearance and degradation (Sloan & Sayer, 2015). In addition, the level and the extent of engagement of local communities and other stake holders in the management of the forest as provided by existing policies and regulations determine level of sustainable forest management (Ratsimbazafy et al., 2012). Nevertheless, forest law enforcement and governance is the bottom line of attaining sustainable forest management (Ruhombe, 2007).

2.2.3. Collaborative forest management

Collaborative forest management (CFM) a practice where local people are placed at the center of forest resources management, basing on the fact that, local communities are significant players in forest management and they are believed to have a significant understanding of their local environmental problems (Turyahabwe et al., 2013 and Mark et al., 2009). Furthermore, it aims at creating structured partnership between key stake holders like; forest users, governments, development agencies, and other private interests in the management of local forests (Carter & Gronow, 2005). To elaborate, in Uganda, Community Based Organizations (CBO's) enter agreement with a National Forestry Authority and District Forestry Services to manage part of or the whole Central Forest Reserve and Local Forest Reserve (Turyahabwe et al., 2013). Believing, communities have a strong complementary role in law enforcement efforts of the institutions responsible for forest management while substantially improving their livelihoods (MWLE, 2001).

2.2.4. Forest certification

Forest certification is a tool for encouraging responsible forestry practices through setting and implementing standards (Marx & Cuypers, 2010). This was embarked on as a result of failure to attain sustainable forest management through public policy and intergovernmental processes following effects of logging on biodiversity conservation (Cashore et al., 2006). Further, the quality of sustainable management is concluded against a series of agreed standards (Egeru, 2011). For example, it's one of the key strategies in Uganda towards achieving the vision of forestry policy of ensuring sufficient forested, ecologically stable economically prosperous Uganda, (MWLE, 2001). Through enabling consumers to recognize and preferentially purchase forest products that originate from forests whose production generates grater environmental and social benefits (Gullison, 2020). Nevertheless, the role of forest certification in protecting tropical wood cannot be under estimated in the conservation of valuable tree species in the reference forest (Egeru, 2011).

2.3. Forest zoning and conservation

Globally with the intention of halting on deforestation and degradation of tropical rain forests, the United Nations Conference on Environment and Development (UNCED), welcomed forest zoning in order to conserve the diversity of useful and economically valuable tree species (FAO, 2005). In so doing natural forest reserves were portioned into management zones to serve different purposes, for example the strict nature reserve for conservation purpose, buffer zone for low impact harvesting , production zone for sustainable harvesting of forest products (Nitschke,.C.R.,& Innes, 2015) Given that some indigenous tree species are threatened due to demand for their valuable timber and poor regeneration rate (Moestrup et al.,2006). Therefore, forest zoning strategy is based on a goal of protecting valuable and rare forest biodiversity whilst maintaining timber supply (Tittler et al., 2010). Further, in its implementation open access as well as amount and type of resources that could be harvested within a tropical rain forest was limited (Ratsimbazafy et al., 2012). In addition, it further suggested that tropical rain forests be divided into a number of zones for different but complementary uses (Tittler et al., 2010). For instance, strict nature reserve zone dedicated to conservation by acting as a permanent reservoir, for seed materials, dispersal agents and ecological services. As well for protecting viable populations of all species especially threatened species. Similarly, buffer zone for protection while production zone for subsistence use. (Obua et al., 2016). However, this favors dominance of strict nature reserve and buffer zone with mature trees which limit regeneration especially for light demanding species due to little canopy opening (Weldemariam et al., 2017). Similarly, frequent human interference in production zone may affect population structure as well as species availability. Equally important, the level of human disturbance received by different management zones influence the stocking density of preferred species tree species (Adekunle, 2006). In divergence, although forest zoning minimizes anthropogenic fragmentation canopy opening in production zone may stimulate the regeneration of valuable tree species (Tittler et al., 2010). Therefore the effectiveness of forest zoning to conservation of tropical forests is still undefined (Banla et al., 2019).

2.4. Factors affecting horizontal structure of tropical rainforest

Horizontal structure refers to spatial distribution of trees in a forest (Cáceres, 2019). This can be caused by a number of factors including: Seed dispersal is major factor determining spatial structure of tropical rain forests (Dalling et al., 2002). In such a way that, dispersal process like ballistic dispersal, wind dispersal and frugivores may influence the horizontal structure (Jasper, 2008). For example, wind-dispersed species have uneven higher dispersal probabilities into gaps due to local wind turbulence pattern hence, spatially structured communities (Dalling et al., 2002). Equally important, seed dispersal improves recruitment of tree species by aiding escape density and distance dependent mortality factors under and near mature conspecifics (Babweteera & Ssekuubwa, 2017). Furthermore, the variation in attractiveness of a fruit to frugivores may in long term impact on tree regeneration and species diversity as well horizontal forest structure (Jasper, 2008). A case in point, the passage of some tree species' seeds through primate's gut increases the rate of seeds germination and shortens germination time hence coexistence in the entire forest (Jasper, 2008). In addition, the consequences of seed size, where by small-seeded species have much lower seed to seedling transition probabilities given their sensitivity to drought (Dalling et al., 2002). However, large-seeded tree species have a limited range of dispersers, mainly large-bodied vertebrates that have the capacity to swallow or carry large seeds intact (Babweteera & Ssekuubwa, 2017). Thus, limiting local distribution and abundance of tropical tree species (Makana & Thomas, 2004). In addition, species with short seed dormancy prior to gap creation suffer high mortality rate than those with prolonged seed dormancy that results in density of tree patches forming at distance from adult conspecific (Dalling et al., 2002). However, to crown it all, dispersal limitation hinders seedling establishment and subsequent change in horizontal forest structure community (Daniel et al,. 1998; Makana & Thomas, 2004).

Habitat variation especially influenced by locality is vital in structuring tropical rain forest communities. Moreover, different locations differ in topography, soils and vegetation characteristics (Phillips et al., 2003). To illustrate, topographic factors like terrain, relief, slope and curvature influence spatial distribution of tree species (Ralph et al, 2015). Through affecting moisture regime and soil formation processes, thus causing local variation in soil nutrients with in which trees grow (Lewis & Phillips, 2018). As a result, individual tree species divide photographic ridge- valley gradients an indicator of geological variation (Valencia et al., 2004). As a case in point, low- lying alluvial valleys support variety of tree species while ridges and steep slopes results in a steady decline in tree species (Lewis & Phillips, 2018). This is because, some tree species respond to soil type although others are generalists (Valencia et al., 2004). For example, some species may physically dominate tropical rain forests regardless of soil conditions by tolerating low nutrients rather than depending on them (Phillips et al., 2003). Nevertheless, lower densities in the richer soil habitats may be resulting from inter specific competition. Importantly, very large number of similar species occupy homogeneous topographic and soil conditions (Valencia et al., 2004). Equally important, spatial heterogeneity in soil resources contribute to spatial distribution of species in the forest (John et al., 2007). Furthermore, micro site conditions determine establishments of seeds, like, the germination of small seeded pioneer species is inhabited by leaf litter on soil surface compared to large seeded pioneer that are able to germinate under litter (John et al., 2007). Crucially, the light regimes may also influence the horizontal structure of tropical rain forest (Jennings et al., 1999). Light regimes determine tree species' tolerance to shade and their ability to recruit below adult conspecifics. To give an example, pioneer species may germinate but rarely survive for long under a closed canopy. But non pioneer species although they require gaps for regeneration, they are capable of growing under closed canopy while, shade-tolerant species are capable of establishing beneath adult conspecifics(Babweteera & Ssekuubwa, 2017). Furthermore, lower densities in the richer soil habitats may be due to the effects of inter-specific competition for light (Phillips et al., 2003). Surprisingly, shade-tolerant species are less sensitive to shading because of being able to allocate resources to growth hence maximizing survival leading to heterogeneous size structure of the forest (Yeshitela & Bekele, 2008). In addition, variation in light within the forest produces colonization-based niches (Valencia et al., 2004). However, despite of light regimes forest disturbance may also influence horizontal structure of tropical rain forest (Kumar & Ram, 2005) . Forest disturbance which includes old-age tree fall and wind throw as well as human induced disturbances influence horizontal forest structure. For instance, tree fall gaps create light allowing tree species coexistence across the continuum. Further, frequent disturbance results in community invasion by the so-called "opportunistic", pioneer species (Hill, J., & Hill, 2001). Thus, forming monospecific patches with in the forest that prevent native tree species from regeneration because of their vigorous vegetative reproduction especially in open canopy areas

(Baret et al., 2008). Nevertheless, intermediate disturbance promotes uniform forest structure since little time is given to allow competitive dominance by any one species. Although human induced disturbances like logging put pressure on valuable species creating chance for least valuable species to dominate the forest (Mugabi et al., 2003). Therefore there are a combination of factors that influence conservation of threatened tree species in tropical forests with the reference forest being unexceptional (Phillips et al., 2003)

2.5. Effects of forest structure on distribution of tree species

Forest structure which includes measures of basal area, stem density, canopy closure and undergrowth density, is a key element in understanding the distribution of tree species in tropical rain forests. Given that, variation in forest canopy is one of the chief determinants of growth and survival of tree species (Jennings et al., 1999). Importantly, native species are mainly classified into; pioneer species (requiring gaps for seedling establishment and growth) and non-pioneer (able to establish and grow under forest shade) and shade bearers (Hawthorne et al., 2011). Besides, reduced canopy cover allows in light to reach forest floor hence favoring recruitment of tree species unlike closed forest canopy (Mwavu & Witkowski, 2009). In addition, pioneer tree species hardly survive for long under closed forest canopy and undergrowth shade (Kang et al., 2014). For example, Although, African mahoganies seedlings might survive in a closed forest canopy, but seedlings in gaps that are not over topped by herbaceous and pioneer vegetation are able to grow to higher heights. Similarly, seedling in understorey experience stunted growth, a significant sign of negative growth. Hence affecting the distribution of such species in undisturbed tropical rain forests (Makana & Thomas, 2004). Nonetheless, closed forest canopy favors the availability of frugivore community (birds and primates) which help in random dispersal of seedlings in the forests (Kirika & Katrin, 2008). Though, canopy closer limits dispersal distance especially for species dispersed by wind, the maximum dispersal distance for *Khaya anthotheca* is over 50m with 75% of all seeds dispersed within 30m from the parent tree (Makana & Thomas, 2004).

2.6. Categories of tree species vulnerability

Vulnerability is the likelihood of tree species loss to prevailing threats to conservation action (Newton, 2006). Important to note, is the geographic range of species in question, the intensity of human activities in the range, regeneration characteristics of the species and the competitive ability of the specie in open as well in understorey habitats. Further, vulnerability is categorized based on risk of extinction (IUCN 2015). The categories; Critically Endangered, Endangered, and Vulnerable are collectively referred to as threatened (vulnerable to extinction). In addition, these categories are complemented by several categories; Near Threatened, Data Deficient, and Least Concern. Whereby, Least Concern, for species widely distributed and whose numbers are not declining significantly (IUCN, 2015). For example, timber species are being threatened by logging activities (Obua & Oryem-origa, 2001). In the sense that, high value timber species (table 1) with limited geographic range, poor dispersal ability, and slow growth are vulnerable in heavily disturbed forests (Babweteera & Ssekuubwa., 2017). Besides, competition- colonization and seedling establishment requirements influence species vulnerability (Dalling et al., 2002).

Table 1: The threat status of valuable timber tree species in Budongo Forest Reserve

Species name	National threat status
Albizia ferrugunea	Endangered
Chytranthus atroviolaceus	Endangered
Cordia millenii	Endangered
Dialium excelsa	Endangered
Entandrophragma angolense	Endangered
Entandrophragma cylindricum	Endangered
Entandrophragma utile	Endangered
Guarea cedrata	Endangered
Irvingia gabonensis	Endangered
Khaya anthotheca	Endangered
Khaya grandifoliola	Endangered
Lovoa swynnertonii	Endangered
Lovoa trichiliodes	Endangered
Milicia excelsa	Endangered

(MTWA, 2018)

CHAPTER THREE: STUDY AREA AND METHODS

3.1 Study area

3.1.1. Location and zones

Budongo Forest Reserve (1°37’ 20°3’N, 31°22’31°46’ E) is located in Masindi, Buliisa and Hoima Districts above the escarpment North East of Lake Albert in the western rift valley (Bahati,1998). The gazetted forest area covers $853km^2$ (Babweteera and Ssekuubwa, 2017). Budongo Forest Reserve is subdivided into five blocks; Siba, Biiso, Nyakafunjo, Waibira, and Kaniyo Pabidi (Bahati, 1998) which are further subdivided into compartments. The study was conducted in Nyakafunjo block which neighbors’ Biiso block to the East and Waibara block to the West. Nyakafunjo block is subdivided into 15 compartments, of which, N15 is strict nature reserve zone, N3 site for special scientific interest N1 and N4 buffer zone and N2, N5, N6, N7, N8, N9, N10, N11, N12, N13, N14 are production zone compartments.

Physical features

Budongo forest reserve occupies gently undulating terrain with a gentle slope NNW towards the rift valley, at an average altitude of 1050m above sea level (Babweteera & Ssekuubwa, 2017). The forest is bisected by four small rivers (Sonso, Waisoke, Wake and Bubwa) which drain into Lake Albert. Nyakafunjo block is drained by Sonso river and the terrain is not different from the rest of the reserve (Obua & Oryem-Origa, 2001).

Geology and soils

Underlying rock throughout most of Budongo forest consist of gneiss, schist’s and granulite of the basement complex, overlain by Bunyoro series sediments. Soils may be broadly classified into two types: ferralitic mainly sandy soils and sandy clay loams (Fairgrieve, 1995).

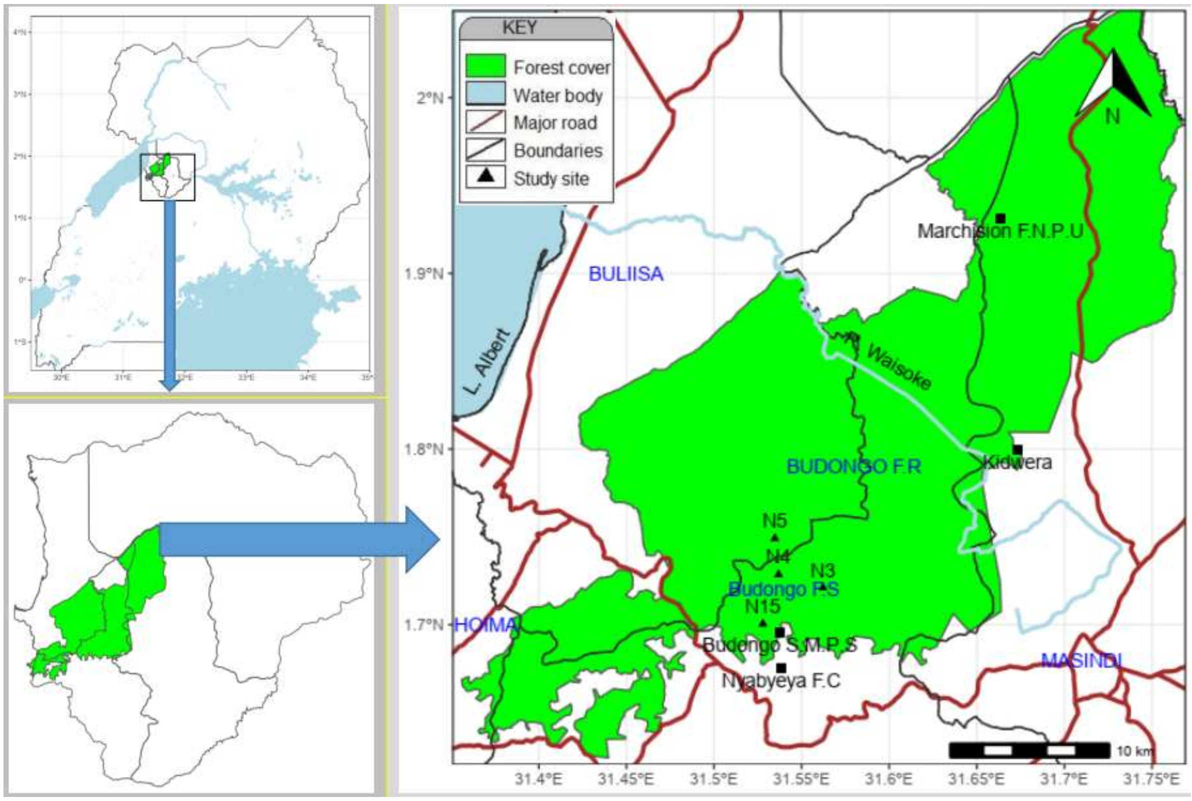

Figure 1: Location of management zones in Budongo Forest Reserve, western Uganda. The management zones include; Special scientific interest (N3), Buffer (N4), Production (N5) and Strict nature reserve (N15).

3.1.4. Climate

Rainfall in Budongo is bimodal with two peaks from March to May and from September to November with monthly rainfall more than 150 mm. Besides, there are two dry seasons from June to August and from mid-December to mid-February with monthly rainfall not more than 50 mm and annual rainfall is between 1200-1800 mm. Further, the annual minimum mean temperature of Budongo Forest Reserve ranges from 17 to 20°C and maximum mean temperatures range from 28 to 29°C (MWLE, 2002).

3.1.5. Biodiversity

Budongo Forest Reserve is a medium-altitude moist semi-deciduous tropical forest dominated by *Cynometra alexandri, Celtis mildbraedii, Celtis zenkeri*, and four mahogany species (Khaya and three Entandrophragma species) (Babweteera et al., 2018). Nevertheless, Budongo Forest Reserve has a high biodiversity with exceptional botanical importance. Further, it supports 42 species found in no other Ugandan forest (including 32 tree species, four bird species, four moth species and two butterfly species). Three species of butterflies and three of trees are endemic to the Albertine rift region (MWLE, 2002).

3.1.6. Management history of Budongo Forest Reserve

The management of Budongo Forest Reserve started in 1930 when it was first declared a forest reserve. Earlier, sustainable practice like selective removal of timber species was practiced in order to meet both economic and conservation purposes (Fairgrieve, 1995). This was accompanied by establishment of Budongo sawmill which by 1960's was turning out timber at a rate of 600 m^3 per month (Bahati, 1998). Besides, this widespread selective logging targeted mainly mahogany species, the large crop of Budongo. Nevertheless, timber harvesting continued throughout the 1970s and 1980s, at a time when the effectiveness of the Forest Department was considerably eroded due to a general decline in law and order in the country together with greatly reduced funding. Consequently, this presented considerable impact on plant and animal communities, resulting in significant changes in vegetation and primate communities. For instance, following the 60 years of selective logging the original main vegetation type of; D2 (medium-altitude semi-deciduous, Cyrometra-Celtis forest) that covered 50%, and 46% K (Combretum savanna,) were replaced by 'mixed forest' type estimated at 85% of the whole forest area (MWLE, 2002). This prompted Forest Department in late 1980's and 1990's to make attempts to restore the ability of Budongo after realizing that commercial value and general biodiversity of Budongo had been depleted. In so doing the saw mill was later closed and research towards conservation encouraged. However, the problem of illegal logging targeting timber species still exists (MWE, 2016).

3.1.7. Population around Budongo

The Uganda Bureau of Statistics (UBOS, 2016) estimated district population of Masindi at 291113, Hoima 572986 and Buliisa 113161. Further, the districts have a diverse ethnic composition with Banyoro and Bagungu tribes dominating in Hoima and Masindi as well as Banyoro and Alur in Buliisa (Lammeck, 2013). Similarly, villages neighboring Budongo forest reserve are multi-ethnic, largely depending on subsistence farming for their livelihood (MWE, 2016).

3.1.8. Community use value

Budongo Forest reserve has been a source of livelihood to adjacent communities through legal activities like collection of thatching material, wild foods, poles, herbal medicine, tree seedlings, tree seeds as well as beekeeping (Turyahabwe et al., 2013). Furthermore, Budongo Forest Reserve has been one of the main sources of hardwood for the country since 1925, on account of being well endowed with high quality mahogany trees (Babweteere et al., 2018).

3.2. Methods

3.2.1. Sample design

Systematic sampling was employed in this study. Nyakafunjo block was selected from five blocks that form Budongo Forest Reserve, because all the four management zones are present within this block. Similarly, to avoid differences in population structure due to spatial differences, compartments that are close to one another were selected. The selected compartments were, N15 for Strict Nature Reserve, N4 for Buffer, N3 for Special Scientific Interest and N5 for Production zone.

3.2.2. Tree species for the study

The selection of tree species depended on their growth characteristic and use value to the community. The selected threatened valuable tree species are *Cordia millenii, Entandrophragma cylindricum, Entandrophragma utile, Khaya anthotheca,* and *Lovoa trichilioides.* Whereas tree species selected for the least concern less valuable tree species category included *Celtis durandii, Ricinodendron heudelotii, Holoptelea grandis, Antiaris toxicaria* and *Alstonia boonei.* However, it is important to note that most threatened valuable tree species are light demanding requiring gaps, for seedling survival and growth (Adeline et al, 2015), although they are susceptible to being colonized by competing vegetation (Road & Edindurgh, 2004). Therefore, the selection of tree species was intended to match the growth requirements to eliminate any distribution difference brought about by growth requirements.

3.2.3. Data collection

Data were collected in August 2020. First, field reconnaissance survey of the four management zones; strict nature reserve zone, Buffer zone, Production zone and Special Scientific Interest zone was performed. This helped in selecting the best way and route for laying transects as well as for representing different conservation scenarios in Budongo Forest Reserve. Following; Banla et al (2019) a total of 16 line transects were established in the study area, with four line transects each measuring 600 m long laid in each management zone. The transects were 200 m from each other and were laid in a direction that captures at least three topographic positions (lower slope-swamp/riparian, mid-slope, upper-slope and flat ridge-top) determined using a compass transverse.

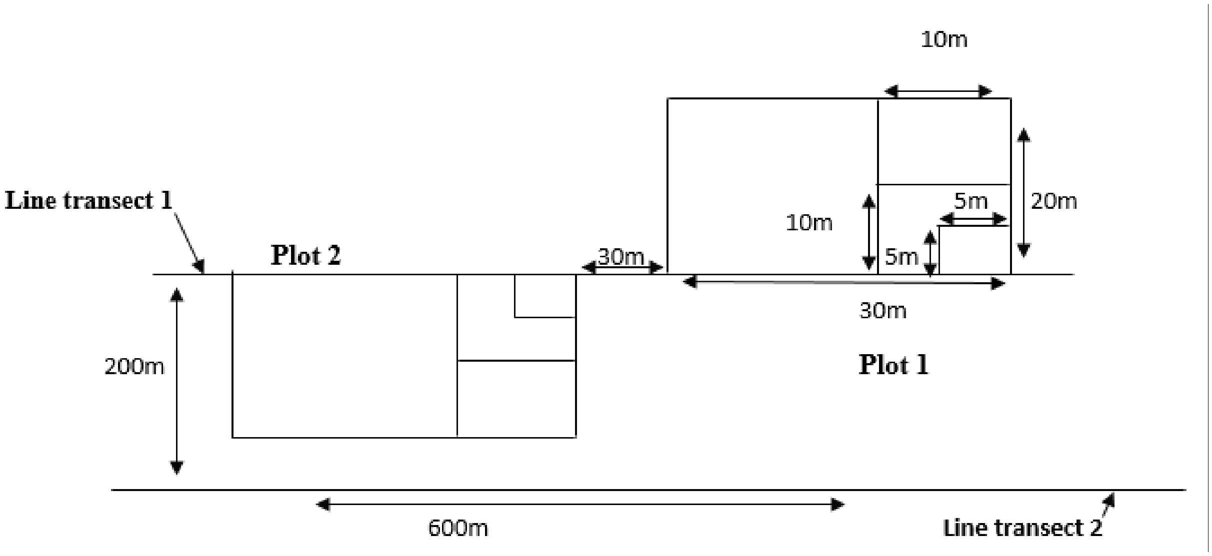

Figure 2: Illustration of line transect and plot layout

Following Weldemariam et al. (2017), a total of 160 plots were laid in the study area, 40 plots for each management zone. Along each transect line, 10 rectangular plots of 30 x 20 m were laid systematically to capture variation in species population in each management zone at 30 m interval in an alternate pattern. In addition, three sub plots i.e., 5 x 5 m for recording seedlings (diameter < 3 cm), 10 x 10 m subplot for recording saplings (3 ≥ dbh < 13 cm), 10 x 20 m subplot for recording poles (13 ≥ dbh < 23 cm) were nestled in the larger plot of 20x 30m where mature trees (23 ≥ dbh) were sampled (USDA, 2000 and FAO, 2011).

Seedlings were counted and identified to species level. Saplings, poles and mature trees were identified to species level and their stem diameters were measured. Stem diameter was measured using a diameter tape at breast height (1.3 m), unless there were irregularities at this height or trees were shorter. For individuals with buttresses or other stem irregularities at breast height, dbh was measured above the buttresses. Species identification followed Katende et al. (1995)

and Eggeling, (1940). Plot location was recorded using a global positioning systems (GPS) device. Importantly, all plot laying starting points in all compartments were away from forest edge.

3.2.4. Assessment of the forest structure

Canopy closure, undergrowth density, basal area and stocking density were measured indicators of forest structure. Canopy closure was measured using a spherical densiometer in 20mx30m plot (Road, & Edindurgh, 2004). The instrument consists of a convex or concave hemispherical mirror etched with a grid of 24 squares (Randolph & Stolte, 2007). The observer scores the canopy closure by assessing whether the sky or foliage is visible at four equally spaced points within each plot. Strickler (1959) suggested that four readings should be taken at each point, one for each of the cardinal directions. Undergrowth density was measured using a chequered board consisting of 25 squares of the same size (10 x 10 cm). The board was held at the center of each plot and observed at a distance of 10 m. The number of squares obscured by undergrowth were counted as a measure of undergrowth density. Undergrowth density was measured at 1m above the ground to correct for grasses and sedges on the floor. In addition stocking density was taken by counting seedling in 5x5m subplot followed by measuring the DBH of sapling, poles and mature trees in their respective sub plots. The data on basal area was also collected by measuring DBH of sapling, poles and mature tree in their respective subplots at 1.3m height using a diameter tape.

3.3. Data analysis

3.3.1 Forest structure in the four management zones

To compare canopy closure and undergrowth density among the forest management zones, separate generalized linear models with a Gaussian distribution of errors were fitted with canopy closure and undergrowth as dependent variables and forest management zone as the independent variable (Pinheiro et al., 2014). Post hoc testing was done using Tukeys test to uncover specific differences in stock densities and basal area among forest management zones.

3.3.2 Stocking density and basal area of the selected threatened valuable and least concern less valuable tree species

Stocking density per hectare of threatened valuable and least concern less valuable tree species were calculated per plot in the four management zones of Budongo Forest Reserve. Basal area was determined following the formula by Torres and Lovett (2013).

$g = \frac{\pi d^2}{4}$, where g = basal area of a tree (m^2), π = constant 3.142, d = diameter at breast height (cm)

The basal area of each species per hectare was determined using a formula

$G = \Sigma(\frac{g}{a})$ where G = basal area of a plot, g = basal area of a tree, a = is plot area in hectares given that plot area differed depending whether the tree was a sapling, a pole or a mature tree.

To compare stocking density among the management zones, negative binomial models with stocking density of threatened valuable and least concern less valuable tree species as the dependent (response) variables and management zone as the independent variable (fixed effect) were fitted in MASS package in R version 4.0.3 (R Core Team, 2020). Negative binomial models were used as the Poisson models were over-dispersed (Zuur et al., 2013). To compare basal area among the forest management zones, generalized linear models with a Gaussian distribution of errors were fitted with basal area of threatened valuable and least concern less valuable tree species as response variables and forest management zones as the independent variable (Pinheiro et al., 2014). Post hoc testing was done using Tukeys test to uncover specific differences in stock densities and basal area among forest management zones. For both sections 3.3.1 and 3.2.2, models were tested for compliance with regression assumptions (Zuur et al., 2013).

3.3.3 Diameter size class structure

Following Akbar et al., (2014), stem diameters of seedlings, saplings, poles and mature trees of threatened valuable and least concern less valuable species were tallied into size classes as follows: 0–24, 25–49, 50–74, 75–99, 100–124 cm, etc. This grouping helped in balancing the samples across size classes, since the number of individual declines with increasing stem diameter size. To display straight-line plots of the species diameter size-class distributions (SCDs), the Ni for each size class was transformed by ln (Ni + 1) because some classes had zero individuals. Then the transformed number was plotted against the mid-point of the respective size class (Mwavu & Witkowski, 2009). Furthermore, SCDs was analyzed using linear regression with the size-class mid- point as the independent variable and the mean number of individuals in that class (Ni) as the dependent variable (Banla et al., 2019). Note, to compute Ni the number of individuals in each size class were divided by the width of that class. For each selected species the SCDs slopes were calculated in the four management zones.

3.3.4 Influence of forest structure on stocking density and basal area of threatened valuable and least concern less valuable tree species.

Following Mugabi et al., (2003) Pearson correlation was used to determine the relationship between canopy closure with stocking density as well as basal area of threatened valuable and least concern less valuable tree species in each management zone. Similarly, Pearson correlation was used to assess the relationship of undergrowth density with stocking density and basal area of threatened valuable and least concern less valuable tree species in each management zone.

CHAPTER FOUR: RESULTS

The ten species prioritized for this study belonged to seven families of which *Holoptelea grandis* had the smallest number of individuals while *Meliaceae* had the highest (Table 2). These were further categorized into two risk categories of threatened valuable tree species (TVS) and least concern less valuable tree species (LLVS). The individual species stocking densities in different forest management zones ranged from 0 to 1885 N/hectare.

Table 2. Number of individuals per hectare of threatened valuable tree species (TVS) and least concern less valuable tree species (LLVS) in different forest management zones of Budongo Forest

Species	**Family**	**Risk category**	**BZ**	**NR**	**PZ**	**SZ**
Alstonia boonei	Apocynaceae	LLVS	148	151	85	119
Antiaris toxicaria	Moraceae	LLVS	751	800	200	985
Celtis durandii	Celtidaceae	LLVS	236	34	150	418
Cordia millenii	Boraginaceae	TVS	0	0	0	51
Entandrophragma cylindricum	Meliaceae	TVS	50	34	0	50
Entandrophragma utile	Meliaceae	TVS	250	117	0	0
Holoptelea grandis	Ulmaceae	LLVS	0	0	17	0
Khaya anthotheca	Meliaceae	TVS	603	267	1885	818
Lovoa trichilioides	Meliaceae	TVS	0	0	0	100
Ricinodendron heudelotii	Euphobiaceae	LLVS	84	17	0	34

4.1 Forest structure in the management zones of Budongo Forest Reserve

Overall, there was significant variation in canopy closure among the management zones at (F = *df* = 3, *P* = 0.001). Further, the Tukeys HSD revealed that canopy closure in the production zone was significantly lower than in the nature reserve and buffer zone (Table 2). There was no significant difference in canopy closure between the Special interest zone versus the nature reserve, buffer zone and production zone. Similarly, canopy closure did not differ significantly between the nature reserve and buffer zone. In addition, the under-growth density also varied in different management zones at (F = *df* = 3, *P* = 0.01). Further, Tukeys HSD revealed that the production zone had significantly higher undergrowth density than the special scientific interest zone (Table 3). The under-growth density in the special interest zone was not significantly different from that in the nature reserve and buffer zone (Table 3). There was no significant difference in undergrowth density among the nature reserve, production zone and buffer zone.

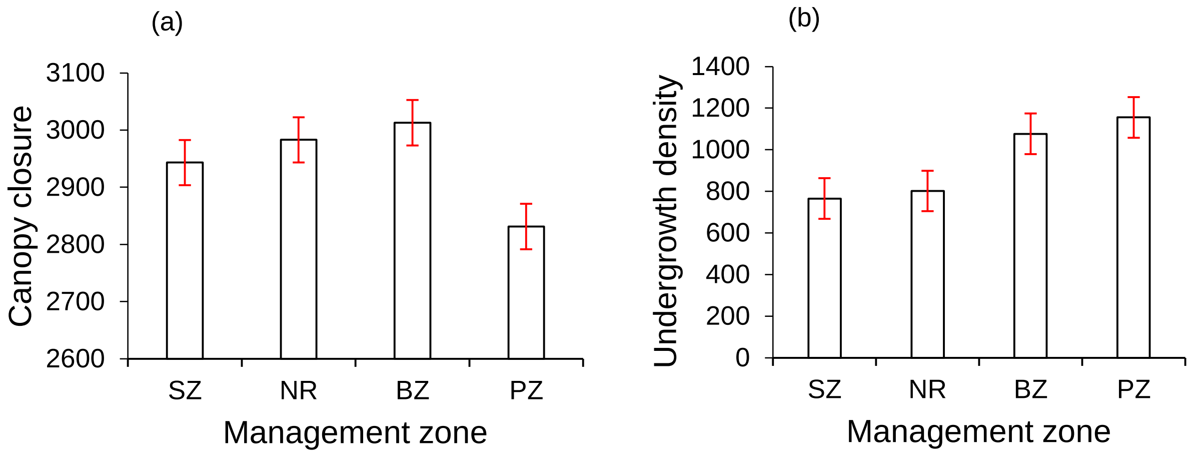

Figure 3. Mean canopy closure and undergrowth density in different forest management zones (SZ = special scientific interest zone, NR = nature reserve zone, BZ = Buffer and PZ = production).

Table 3. Variations of means differences of canopy closure and undergrowth density in different forest management zones of special scientific interest (SZ), Nature reserve (NR), Buffer (BZ) and Production (PZ). The mean differences were considered significant when $p < 0.05$

	Canopy closure			**Undergrowth density**		
Zones	Mean difference	*SE*	*P*	Mean difference	*SE*	*P*
SZ–NR	-0.99	1.17	0.829	-1.21	3.56	0.986
SZ–BZ	-1.74	1.17	0.445	-8.08	3.56	0.110
SZ–PZ	2.79	1.17	0.082	-10.06	3.56	**0.027**
NR–BZ	-0.74	1.17	0.919	-6.87	3.56	0.221
NR–PZ	3.79	1.17	**0.008**	-8.85	3.56	0.066
BZ–PZ	4.53	1.17	**0.001**	-1.98	3.56	0.944

4.2. Stocking densities of threatened valuable and least concern less valuable tree species in the different management zones

Overall threatened valuable tree species had no significant variations in stocking densities among the different forest zones (Fig, 3b, *LRT* = 3.183, *df* = 3, *p* = 0.364, Table 3). Similarly, there was no significant difference in stocking density of Least concern less valuable tree species among the zones (*LRT* = 1.768, *df* = 3, *p* = 0.622, Table 3).

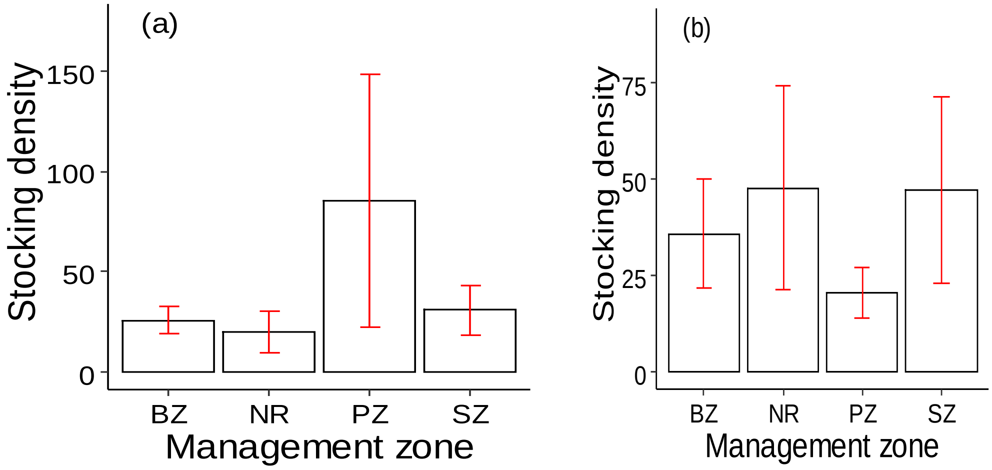

Figure 3. (a) Threatened valuable tree species and (b) least concern less valuable tree species in the buffer (BZ), nature reserves (NR), production (PZ) and special scientific interest (SZ) management zones of Budongo Forest Reserve. Error bars show ± 95% CI for the mean.

Table 4. Fixed effects for negative binomial models on variation of mean values of stocking densities (stems/ha) of threatened valuable tree species and least concern less valuable tree species in the different forest management zones (BZ= buffer, NR= nature reserve, PZ= production and SZ= special scientific interest). Differences were considered significant when *p* < 0.05.

Fixed effect	**Estimate**	***SE***	***z***	***p***
TVS				
Intercept	3.250	0.552	5.890	< 0.001
Zone (NR-BZ)	-0.306	0.889	-0.344	0.731
Zone (PZ-BZ)	1.200	0.888	1.352	0.176
Zone (SZ-BZ)	0.180	0.792	0.227	0.821
LLVS				
Intercept	3.5795	0.3974	9.008	< 0.001
Zone (NR-BZ)	0.2857	0.6487	0.440	0.660
Zone (PZ-BZ)	-0.5569	0.6404	-0.870	0.384
Zone (SZ-BZ)	0.2738	0.5703	0.480	0.631

4.3. Basal area of threatened valuable and least concern less valuable tree species in the different management zones

There was no significant variation in basal area of threatened valuable tree species among the different forest management zones (*df* = 3, *p* = 0.603; Fig 4a, Table 4). However, there was significant variation in basal area of least concern less valuable tree species among the forest management zones (*df* = 3, *p* = 0.010). Tukeys test showed that the special scientific interest zone had a higher basal area than nature reserve (*p* = 0.009). However basal area of least concern less valuable tree species was not significantly different in production and nature reserve (*p* = 0.842) also not different in production and special scientific interest zone (*p* = 0.085).

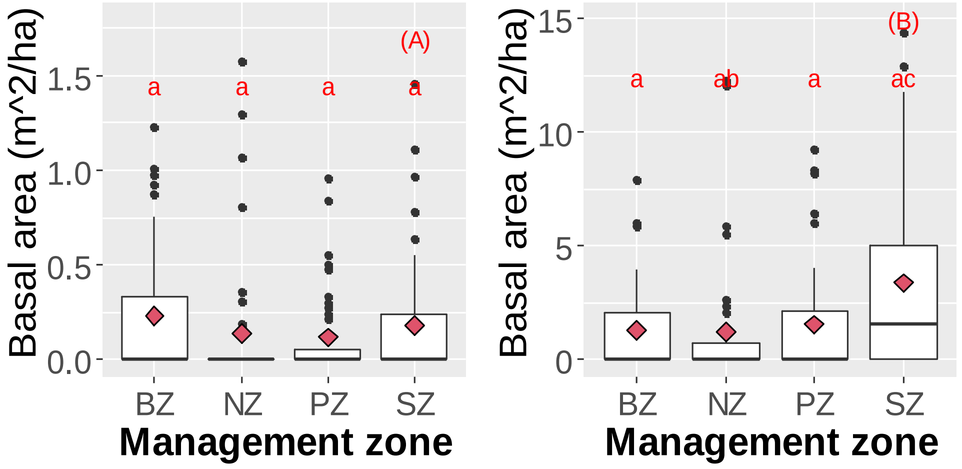

Figure 4. Basal area of (a) threatened valuable tree species and (b) least concern less valuable tree species in buffer (BZ), nature reserve (NZ), production (PZ) and special scientific interest (SZ) zones of Budongo Forest. Different letters indicate significant differences among the zones.

4.4. Diameter size class of threatened valuable and least concern less valuable tree species in the different management zones

Threatened valuable tree species had inverse J-shape distribution pattern in production, buffer and special scientific interest zone and nearly inverse J-shape pattern in strict nature reserve (Fig 5a) with SCD value of -0.002 in production, -0.001 in strict nature, -0.002 in buffer and special scientific interest zone. However, least concern less valuable tree species showed bell-shape distribution pattern in all management zones (Fig 5b) with SCD slope values of -0.002 production zone, -0.001 nature reserve, -0.003 Buffer, -0.013 in special scientific interest zone.

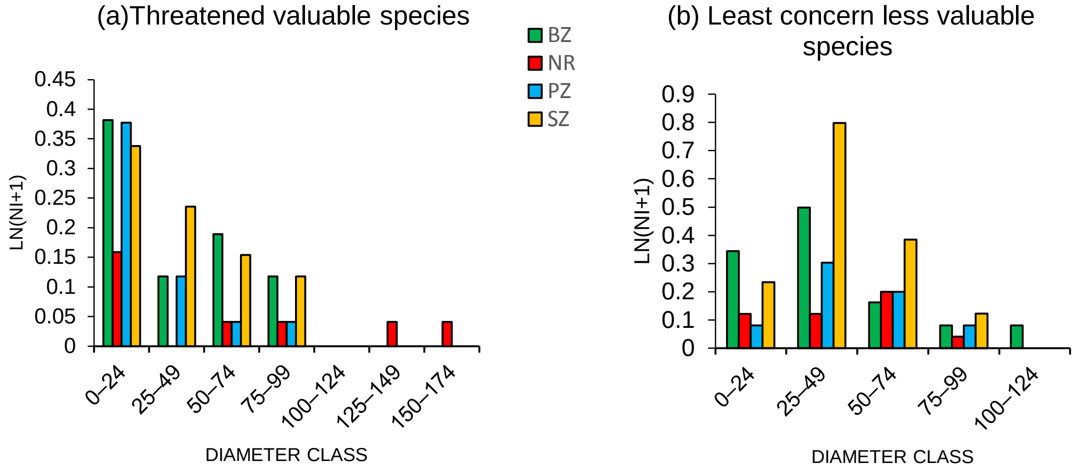

Figure 5. Diameter size class distribution of (a) threatened valuable tree species and (b) least concern less valuable tree species in Buffer (BZ), Nature reserve (NR), Production (PZ) and Special scientific interest (SZ) zones of Budongo Forest.

4.5. Effect of forest structure on stocking density and basal area of threatened valuable and least concern less valuable tree species

The stocking density of threatened valuable tree species had significant positive correlation with under growth density in Special scientific interest zone. However, stocking density of least concern less valuable tree species had negative significant correlation with canopy in Buffer zone. Nonetheless, basal area had no significant correlation with forest structure in the different zones.

Table 5. Correlation coefficients (r) for the relationship between forest structure with stocking density and basal area of threatened valuable and least concern less valuable tree species in different forest management zones.

		Stocking density					Basal area			
	Zone	canopy closure		under growth density			Canopy closure		Under growth density	
		r	***p***	***r***	***p***		***r***	***p***	***r***	***p***
TVS	SN	0.035	0.832	0.384	<**0.014**		-0.249	0.122	0.037	0.821
	NR	0.002	0.992	-0.155	0.338		-0.061	0.708	-0.027	0.869
	BZ	0.201	0.215	-0.144	0.376		0.149	0.358	-0.122	0.453
	PZ	0.055	0.738	-0.151	0.354		0.188	0.246	-0.083	0.611
LLVS	SN	-0.204	0.207	-0.051	0.755		-227	0.16	0.174	0.283
	NR	0.306	0.055	0.013	0.934		-0.169	0.296	-115	0.48
	BZ	-0.321	<**0.044**	-0.266	0.097		-0.054	0.742	-0.203	0.21
	PZ	-0.161	0.321	-0.312	0.05		0.005	978	0.44	0.788

CHAPTER FIVE: DISCUSSION

5.1. Forest structure in the management zones of Budongo forest reserve

The results indicated that canopy closure in the production zone was significantly lower than that in nature reserve and buffer zone. These observations do not support the study hypothesis of no significant difference in forest structure among the management zones. However, the results indicated no significant difference in canopy closure between nature reserve and buffer zone, and also between the Special scientific interest zone versus the nature reserve, buffer zone and production zone. These observations are in agreement with findings of previous studies, for instance Weldemariam et al., (2017) in Mabira forest in Uganda. The lower canopy closure in production zone than in nature reserve and buffer zone may be linked to the initial purpose of production zone of allowing large tree harvesting practices. In addition a study by Valverde & Silvertown, (1997) in Dancers End nature reserve in Buckinghamshire, UK. linked changes in canopy closure to rate of disturbance in a forest.

In addition, the results showed that the production zone had significantly higher undergrowth density than the special scientific interest zone. This observation does not support the study hypothesis of no significant difference in forest structure. The observation could be linked to the difference in the designed purposes of the zones that influence degree of canopy cover. Accordingly, the tree extraction activities in production zone potentially influence canopy opening which allows regeneration of light-demanding understorey species. This observation is in agreement with the previous studies, for instance Muthuramkumar et al., (2006) linked high undergrowth density to high disturbance levels in different fragments of tropical rain forest in India. Further, Rist et al., (2011) attributed undergrowth density to logging that is commonly followed by growth of impenetrable undergrowth in tropical forests of Ipixuna in Brazil, Zega in Cameroon and Malinau in Indonesia.

5.2. Stocking density and basal area of threatened valuable and least concern less valuable species in the different management zones

The results indicated that mean stocking densities of threatened valuable species and least concern less value species were not significantly different in all management zones. These results support the study hypothesis of no significant difference in stocking densities in the management zones. Similarly, threatened valuable species had no significant variation in basal area among the zones. Accordingly, these results discredit the effectiveness of forest zoning. However, least concern less value species had a higher significant difference in basal area in special scientific interest than nature reserve. This indicates harvesting of large trees in nature reserve than in special scientific interest zone. This could probably be attributed to location of nature reserve adjacent to the community that makes it vulnerable to unrestricted extractive human activities. Also, perhaps special scientific interest zone being a research zone where Budongo conservation field staff carry out their daily work coupled with the movement of researchers with in the forest deters illegal timber dealers. This observation is consistent with findings of previous studies for instance , the study done by Naidu,& Kumar, (2016) in tropical forests in Eastern Ghats of Andhra Pradesh, India. Linked variation in basal area to difference in location of the species. Further, Bogale et al (2017) in Berbere Afromontane Moist forest ,Ethiopia attributed the difference in basal area to the level of exposure to human activities. In addition, Weldemariam et al., (2017) in Mabira forest, Uganda, linked difference in basal area to disturbance from the adjacent community in trying to meet their social economic needs.

5.3. Diameter size class distribution in the management zones

The results indicated that threatened valuable species had inverse-J shape in buffer, production and in special scientific interest zone. However, the nature reserve had a nearly inverse-J shape characterized by systematic absence of some middle classes. This contradicts with the study hypothesis of no difference in diameter size class distributions among zones. This complete absence of individuals in the middle and large classes of (25-49) and (100-124) indicates extractive activities in nature reserve probably because these are community valued species that are commonly harvested illegally and legally for timber and poles. This could probably be supported by the fact that nature reserve is located adjacent to local communities. This observation is consistent with findings of previous studies for instance a study by Mekonen et al., (2015) in Woynwuha Natural Forest, North west Ethiopia. linked nearly inversely J-shape curve to harvesting of middle and high diameter class trees for various purposes by local communities. Nevertheless, (Rist et al., 2011) in tropical forests of Ipixuna in Brazil, Zega in Cameroon and Malinau in Indonesia linked the exploitation of restricted timber species by local communities to few livelihood options available to the forest-adjacent communities.

In addition, the nearly inversely J-shape in nature reserve indicates unlimited access to the forest. This could be attributed to a decline in law enforcement both at community and institutional levels. This observation is in agreement with results by Never et al., (2013) that decline in law enforcement resulted into heavy illegal anthropogenic activities targeting preferred species in Mapembe nature reserve, Eastern Zimbabwe . In addition, the nearly inversely J- shape curve indicates inconsistence in regeneration of threatened valuable species in nature reserve. This could also be attributed to differences in species phenologies, light guilds, and their responses to seasonal soil moisture variation. This could also imply shortage of mature trees to produce enough seed sources to support continuous regeneration of these species. In addition, Babweteera et al., (2018) linked inconsistence to regeneration in Budongo forest, Uganda to decline of fruiting in pioneer species that impacts on the rate of dispersal in a forest. However, least concern less value species had bell shape in all zones negative negligible SCD slope values which corroborates the hypothesis of no significant difference in diameter size class distribution structure among the management zones.

5.4. Effect of forest structure on stocking density and basal area of threatened valuable and least concern less valuable species

The stocking density of threatened valuable tree species had significant positive correlation with under growth density in Special scientific interest zone. This observation does not support the study hypothesis of no significant effect on stocking density and basal area of threatened valuable and least concern less valuable species. This implies that the declining undergrowth density in special scientific interest zone favors the regeneration and growth of threatened valuable species in this zone. The observation is in agreement with previous study by Rist et al., (2011) that low undergrowth density resulted into regeneration of timber species in tropical forests of Ipixuna in Brazil, Zega in Cameroon and Malinau in Indonesia. However, stocking density of least concern less valuable tree species had negative significant correlation with canopy cover in the Buffer zone. This implies that the increasing canopy closer affects the growth and survival of least concern less valuable tree species. This observation is related to previous study by Mugabi et al., (2003) who reported that canopy closure limits regeneration and growth of seedling and saplings of tree species in Budongo forest, Uganda.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

I. The study has shown that stocking density and basal area of threatened valuable tree species is not different among the management zones implying that forest zoning is ineffective in conserving threatened valuable tree species.
II. The study has also shown that basal area of least concern less valuable tree species was significantly higher in special scientific interest zone than in nature reserve implying that forest zoning is not serving its intended purpose
III. The study further showed that threatened valuable tree species had absence of individuals in middle and large diameter classes in nature reserve zone implying that forest zoning is not effective in conserving threatened valuable tree species.
IV. All in all, although forest zoning was implemented among others to conserve tree species the results indicate that threatened valuable tree species are not adequately protected

6.2 Recommendations

i. The presence of similar stocking density and basal area of threatened valuable tree species among the management zones suggests the need to strengthen law enforcement both at community and institutional level in the management of the forest. This will reduce potential impacts on threatened valuable tree species resulting from unrestricted extractive human activities.

ii. The extraction of middle and large diameter classes of threatened valuable tree species in nature reserve suggests the need to relocate nature reserve. This will eliminate extractive human activities that are occurring due to its location being closure to local communities. Further studies should be done on sustainable livelihood options that serve both subsistence and commercial purpose for forest adjacent communities in order to reduce extraction pressure on the forest.

iii. The presence of threatened valuable species with discontinuous regeneration suggests the need for the Budongo Forest management to develop and implement forest management plans/activities that will enhance species to maintain their populations in a forest.

iv. Future studies should look at overall species richness variation in the different management zones to further evaluate the effectiveness of forest zoning

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APPENDIX

Research study in Budongo Forest Reserve

Data sheet

Date				
Zone	Plot	Transect No	Gps	
Canopy closure	1	2	3	4
Understorey	1	2	3	4
No	species name		seedling count	DBH
1				
2				
3				
4				
5				
6				
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8				
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