THE COPPERBELT UNIVERSITY

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DEPARTMENT OF PLANTS AND ENVIRONMENTAL SCIENCES

THE EFFECTS OF WILDFIRE FREQUENCY ON BUSANGA FLOOD PLAIN VEGETATION WITH SPECIFIC EMPHASIS ON TERMITARIA AND OPEN FLOODED GRASSLAND

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DECLARATION

I, Ng'andu Lackson do hereby declare that other than the work of other people which has been duly acknowledged and referenced, this dissertation is my own work and no work of this nature has been previously presented before at The Copperbelt University or anywhere else.

Author's signature………………………. Date…30……/…06………/……2016…….

Lackson Ng'andu

DEDICATION

This dissertation is dedicated to my dear wife Mrs. Martha Nankonde Ng'andu and all my lovely children for their patience, support and sacrifice they rendered to me whilst I was pursuing this Master of Science Degree.

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ABSTRACT

The study aimed at investigating the effects of wildfire frequency on two vegetation communities of Busanga Flood Plain. On termitaria woodland the study looked at the effects of wildfire frequency on species composition and structure while on open grassland the study focused on the effects of wildfire frequency on range condition. The study used fire map generated by DNPW GIS head office using fire occurring points accessed from MODIS facilities. In both vegetation, GPS was used to navigate to selected burnt and unburnt sites. The study adopted systematic sampling design to increase area coverage. A total of 18 plots (30m x30m) in termitaria woodland investigated and were tree height, DBH and crown cover were measured while 30 x 1m^2 plots were investigated on open grassland where grass species were identified, counted and classified into their respective ecological status. From termitaria woodland a total of 65 plant species were recorded on both sites. 25 were common while 30 species were absent from burnt sites. The results show significant differences ($P < 0.05$) in species diversity between 2 sites indicating high species diversity in unburnt site than burnt site. Furthermore, the results show high species richness in unburnt site (19.48) than burnt site (7.14). With regard to open grassland a total of 32 grass species were recorded out of which 10 were common in both sites, 14 were absent from unburnt while 8 were absent from burnt site. The results further show 75% of grass species in increaser category II and high density values of *E. inamoana* and sedges in burnt site than in unburnt site.

The study results from both vegetation types provide evidence that wildfire frequency could influence the vegetation changes in species composition, dominance, density and ecological status of Busanga Flood Plain. Therefore, understanding the effects of wildfire frequency on vegetation communities in Busanga Flood Plain will add value to Park Managers and other stake holders to adopt best fire management practices required to conserve and manage vegetation communities of Busanga Flood Plan n Kafue National Park.

Key words. Busanga Flood Plain, Wildfire frequency, termitaria, open flooded grass land

CHAPTER ONE: GENERAL INFORMATION

1.0 BACKGROUND

For many years wildfires have been part of the ecological functions in vegetation communities in the Southern savanna ecosystems (Smith *et al*., 2010). Many researchers have described wildfire as an important management tool in protected areas (Pausas, 2004.) and when it is completely removed for a longer period plant species composition and structure may change from its original status more often by replacing palatable species with undesirable plant species (Omeja *et al.*, 2011). The study by Zolho (2005) in Nhambita community in Mozambique revealed that wildfires help to maintain species richness and spatial distribution of plant species in vegetation communities by breaking their seed dormancy that support regeneration. The scenario improves food and habitat quality of ecosystems and, therefore, wildfire frequency helps to promote good and healthy habitat of an ecosystem on which the distribution and the relative density of wildlife animals depends (Mwima, 2005). Because of its influence on vegetation composition and structure wildfires have been used since in memorial as a mechanism to achieve the desired objectives in savanna ecosystem management. For example the study by Pausas (2004) reported that depending on the desired objective wildfire can be used to maintain woody vegetation by managing low fuel load levels to make fires less frequent and intensity to avoid suppressing young seedling of trees from growing during the burning. The above statement is supported by Ward (2005) who found a positive correlation between low level of fuel load and fire frequency and intensity in woodland vegetation and stated that low fuel load (grass biomass) promote less wildfire frequency and intensity that have no effects on young trees shooting. The findings are similar to two separated studies by Razavi (2012) and Nasi *et al. (*2002) who concluded that low fuel biomass have less wildfire frequency that result in less negative impact to woody species. Trollope (1987) also observed from a study in Zimbabwe that prescribed burning at the period when grass is dormant is important for biomass management in grassland ecosystem rather than burning when species are growing.

Furthermore other studies have revealed that wildfire helps to control bush encroachment. The study by Ward (2005) in Krugar National Park in South Africa concluded that wildfires play an important role to control bush encroachment in grassland vegetation. This is achieved by maintaining high fuel load in high rain fall areas to promote high wildfire frequency to kill young tree seedlings that are recruited during the wet season thereby making grassland vegetation maintained.

However, other studies have revealed that repeated wildfires may have a negative effects on plant species composition and distribution in vegetation communities. Many studies across Africa and beyond have pointed out that vegetation communities have been shaped and changed from their original status by the frequency of wildfires (Bond & Mildgley, 2003; Shackleton & Scholes, 2000). Cauldwell and Zieger (2000) stated that the changes in vegetation types in the landscape of southern savannahs have been caused by negative effects of the frequency of wildfires. For over 25 million years, the frequency of wildfires has negatively influenced the evolution of fire tolerance and fire dependent plant species in ecosystems of protected areas globally (Ibrahim *et al*., 2011; Ward, 2005; Andersen *et al*., 2005). The findings are acknowledged by the study conducted by Ryan (2011) who stated that the change of species composition of large savannah from its original status in Brazil was facilitated by wildfire frequency. In the Russian Federation, wildfire frequency has allegedly been cited to have reduced 60 % plant species diversity during the period of three (3) decades (Shavidenko & Goldammer, 2001).

These wildfires have equally been recorded in Zambia. The research conducted by Hollingsworth *et al.* (2015) estimated that 18.8 million hectares of Zambia's landscape (representing 25 % of total land area) is burnt annually. These occurrences of wildfires in Zambia has influenced vegetation changes in composition and structure in ecological habitat of protected areas including the unique habitats such as Busanga Flood Plan (BFP) in Kafue National Park. Various authors have highlighted wildfire frequency as one of the major driving factor affecting vegetation communities in ecosystems in Zambia (Zimba, 1986; Vinya *et al.*, 2011; Chirwa *et al*., 2015; Syampungani, 2008).

Studies to determine the effects of wildfire frequency on composition and structure including the distribution of vegetation communities have been conducted in Zambia by various researchers (Zimba, 1986; Chidumayo, 2008; Hollingsworth *et al*., 2015; Mwima, 2005: Sileshe & Mafongoya, 2006). However, their main focus has been at general scale with much emphasis on Miombo woodland vegetation, and not on vegetation of Busanga Flood Plain in Kafue National Park. The absence of specific study in Busanga Flood Plain to determine the effects of wildfire frequency of Busanga vegetation communities has posed great challenges to Park management staff and other stakeholders to implement best fire management practices to manage Busanga Flood Plain ecosystem. This study attempt to bridge the existed gap.

1.2 PROBLEM STATEMENT

Busanga Flood Plain (BFP) is part of the habitat affected by wildfire frequency in Kafue National Park. It is one of the unique and specialized habitats on the western part of Kafue National Park and was declared as a RAMSAR site Number 1659 in 1987 (ZAWA, 2010). The habitat has been exposed to wildfires for more than a decade (ZAWA, 2010). Physical observations and ZAWA departmental reports (ZAWA, 2013) revealed that wildfire frequency have become one of the major problem factor in BFP and slowly some plant species in termitaria woodland and open flooded grass land have been noticed declining in abundance suspected to be caused by wildfire frequency resulting into ecosystem degradation. Studies on the effects of wildfire frequency on other vegetation communities other than BFP have been undertaken in Zambia (Zimba, 1986; Mwima, 2005; Hollingsworth *et al.*, 2015) but there has been no deliberate study undertaken to generate data to enhance the understanding of the effects of wildfire frequency on composition and distribution of vegetation communities of Busanga flood plain in Kafue National Park. As such, this study to generate information that will attempts to develop an understanding of the effects of wildfire frequency on composition and distribution of vegetation communities of Busanga Flood Plain with specific emphasis on termitaria and open flooded grass land.

1.3 JUSTIFICATION OF THE STUDY

The habitat of Busanga Flood Plain is described as a jewel of Kafue National Park due to its nine (9) vegetation types that provide habitats to variety of wildlife animals including Lechwe and Statunga which are endemic. Its wildness forest offer scenic beauty making tourist have pleasure adventure and best experience and in 1987 it was declared as an International of ecological importance by declaring it as a RAMSAR site Number 1659. However, the habitat has been subjected to wildfire frequency for over a decade and no specific study was under taken to establish their effects. On this study only two vegetation communities namely termitaria and open flooded grass land were selected to the study. The termitaria vegetation on the southern part was selected as it is the most predominate vegetation believed that act as refuge for a myriad of wildlife animals during periods of floods (Tsvigu, 2013) and it is characterized with termite mounds that consist rich diversity of small and shrub trees that are very sensitive to wildfires (Humphry, 2008). Another vegetation community investigated was open flooded grassland. The open flooded grass land because of its important by providing breeding ground for migratory birds and also it consist of hydrophyte grass species that are very sensitive to wildfires (Tsvigu, 2013).

Figure 1: Termitaria vegetation

Figure 2: Open grass land

Although studies to determine the effects of wildfire frequency on tree species density and diversity have been conducted by various authors (Zimba 1986; Mwima, 2005; Chimayo, 2008 & Hollingsworth *et al.*, 2015) but none of these studies have done on termitaria and grassland particularly in Busanga Flood Plain. This gape motivated author's thoughts to carry out the study to generate the data that will enhance the understanding of the effects of wildfire frequency on composition and distribution of vegetation communities of Busanga Flood Plain and the data will act as a reference point for future research.

1.4.0 GENERAL OBJECTIVE

The overall objective of the study was to determine the effects of wildfire frequency on vegetation communities of Busanga Flood Plain with specific emphasis on termitaria and open grassland in order to build knowledge and enhance understating required to adopt the best fire management practices to conserve and manage the vegetation communities of Busanga Flood Plain in Kafue National Park.

1.4.1. SPECIFIC OBJECTIVES AND RELATED RESEARCH QUESTIONS.

a. To determine the effects of wildfire frequency on species composition and structure of termitaria woody vegetation of Busanga Flood Plain.
    i. What is species composition termitaria vegetation in Busanga Flood plain?
    ii. What effects do wildfire frequency have on tree species diversity, density and dominance across termitaria vegetation?

iii. What is the relationship between wildfire frequency and tree height, DBH and crown cover?

b. To assess the effects of range condition of open grass land of Busanga Flood Plain.

i. What is composition of grass species in open grassland of Busanga Flood Plain?

ii. What effects do wildfire frequency have on grass species richness and ecological status of grass species?

1.5.0. THESIS OUTLINE

The thesis is outlined in five (5) chapters. Chapter one deals with the general information about the theme, problem statement, general objective research questions, specific objectives and study motivations. Chapter two deals with literature review while chapter three deals with the effects of wildfire frequency on woody species diversity and density of termitaria vegetation. Chapter four deals with the effects of wildfire frequency on grass species diversity and density on grassland vegetation type. Chapter five is the last and summaries all the findings from the proceedings and provide practical recommendation that are required to be implemented to control wildfires.

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CHAPTER TWO: LITERATURE REVIEW

Wildfire is considered to be the major critical factor influencing ecological functions on vegetation communities across the world (Cauldwell & Zieger, 2000; Leeuwen *et al*., 2010). Namukonde (2007) described wildfire as uncontrolled fire occurring in the forest that burns either underground and or on the surface of vegetation of grassland or woodland and sometimes burning the canopy of woody vegetation. Wildfire is highly common in many parts of the forests where rainfall is enough to allow vegetation to grow, and also drought period that make the vegetation material to dry and so become flammable. As described by Parr & Andersen (2006) the occurrences of wildfire is dependent on climate which dictates the availability of quality and quantity of fuel load level. The two separate studies conducted by Zolho (2000) and Mapiye *at el.* (2008) indicate that in high rainfall areas, wildfires occur annually as opposed to areas with low rainfall due to lack of enough fuel load to support wildfire occurrences. According to Gialomo (2005) wildfire regimes are highly influenced by fluctuation of rains due to climate change. In the similar development Parr and Andersen (2006) indicated that the fluctuation of rains has an effect on the availability of moisture contents in fuel wood which regulate occurrences of wildfire and greatly influences the wildfire regimes. Nasi *et al*. (2002) also added that wildfires are rare in areas where herbivores are in abundance that result into over grazing grasses, subsequently reducing the biomass (fuel load) that support wildfire to burn.

Studies on the effect of wildfires have been conducted worldwide by various authors, bringing out both negatives and positive impacts depending on the fire regime (Mermoz & Veblen, 2005). The following sections brings out ecological benefits that have been investigated by some researchers across Africa.

Hoffmann *et al.* (2002) and Bowman and Murphy (2010) describe wildfires in their separate studies as part of natural management tool in ecosystem functions for many years and a complete removal can lead to a complete vegetation change and degradation of an ecosystem. Results from studies conducted by Yinghua *et al. (*2012) revealed that wildfire maintains plant species richness, density and facilitates spatial distribution in vegetation communities of an ecosystem. This is achieved by wildfires that occur during the wet season commonly known as early burning fires. Wet season fires have low heat because the burning biomass materials contain moisture that helps to reduce the frequency and heat intensity from burning fire. Low heat fires have no serious negative impact to the woody plants species diversity and density instead it support the ecological processes of savannah vegetation communities (Moreira, 2000).

Bond and Keely (2005) revealed that wildfire is used to control the establishment of woody vegetation and through this process, it facilitates coexistence between trees and grasses. In the same development (Bond, 1997) stated that wildfires play a critical role in facilitating seed dispersal in savanna rangeland by breaking the protective seed structure such as cones, wood capsules and persistence wood inflorescences after being exposed to heat.

The study by Trollope (2002) in South Africa stated that wildfire is used for bush encroachment control in Savannah areas and these findings were similar to the finding by Banda *et al.* (2006) who also concluded that hot wildfires help to open up thickets by killing or suppressing individuals small trees that are recruited during growing season. The killing of individual small trees reduces completion between grasses and small individual tress with resources such as soil nutrients sun light and water and through this mechanism open grass are maintained. The allowing the penetration of light energy increase grass biomass production and subsequently supporting wildlife animals with food and good habitat. It is also argued that opening up of thickets by wildfire makes grazing areas accessible to grazing animals and indirectly promote wildlife distribution in an ecosystem. Bothma (2002) described wildfire as very critical in savannah flooded grassland. The above argument is in line with the findings by Mbatha and Ward (2010) who state that wildfire influence recruitment and growth of grass species that lead to high production of grass plant material required by wild animals and it is further revealed (Bothma, 2002) that perennial grass in wildfire prone areas has higher level of phosphorus and proteins in their foliage stage than those that grow in unburnt area. This argument require further investigations in the area.

However, it is widely documented by many researchers that repeated fires, commonly referred to as wildfire frequency are an ancient form of environmental disturbances which have continued shaping and changing savannah vegetation in Africa and beyond (Mopaure, 2006; Anderson *et al*., 2007). Nasi *et al.* (2002) concluded that for over 25 million years, wildfire frequency has influenced the evolution of vegetation communities globally. For example, a study carried out in Brazil (Trollope & Trollope, 2002) concluded that the largest savannah regions of Cerrado savannah vegetation evolved by wildfire frequencies that resulted into a change in plant species composition from its original status. Similar findings were reported by Shvidenko and Goldammer (2001) from the study in Russian Federation in

Primorsk Kray that the open grass land savannah vegetation reduced to 60% of plant species composition by repeated wildfires during the period of three (3) decades.

Another study by Lecomte (2005) showed that there was absence of regeneration of woody species in areas with higher wildfire frequency than in areas without fire or less fire frequency and (Bond & Mildgley, 2003) linked the absence of regeneration of wood species in fire prone areas due to the presence of wildfire frequency because burning fires affect the nutrition status of the soil over time. This finding were also recorded by Yinghua *et al.* (2012) who carried out a similar study in Yumin Country of Xinjiang west of China. From this study it was recorded that soil nutrients were significantly affected by occurrences of wildfires. Heikkila *et al.* (2010) also observed a similar findings that wildfire frequency jeopardize the nutrient cycling system in an ecosystem by killing both microflora and fauna organisms that play a great role in the function of nutrients in an ecosystem.

The other reason cited could be the way how each individual woody species reacts to wildfire frequency due to physical and chemical properties. The findings from study by Gandiwa (2010) on the Southern African savannah in Zimbabwe explained that certain plant species respond to wildfire differently due to their chemical and physical properties. Plants species with thick and wet barks have high protection from heat of fire as compared to trees with thin and dry barks. For example, the study by Zolho (2005) in Nhambita Miombo woodland community in Mozambique cited *C. molle* as fire tolerant species due to its physical structure that is characterized by thick and succulent bark that protect the plant from heat.

In open grassland savannah, wildfire frequency can influence grassland vegetation structure. The description by Oudtshoon (2014) revealed that over time wildfire frequency in open flooded grassland communities promote grass species that are in increaser II and III categories, leading to rangeland condition of grassland to deteriorate. Grass species in increaser categories II and III increase with the increase on grazing by animals in areas that are affected with wildfire frequency. As described by Botham (2002) the growth of fresh grass species in areas prone to wildfire frequency are palatable resulting rangeland into overgrazing by wild animals which results in recruitment and increase of grass species in increaser II and III categories. Grass species in increaser II and III category disturb the ecological functions of an ecosystem (Cochrane, 1999) due to non-palatability to most of the wild animals. As study by Cochrane (1999) concluded that grass species in increaser category are potential to out compete the grass species that are in decreaser category there by displacing the weaker once.

Two separate studies (Holdo *et al.,* 2007; Prior *et al.,* 2009) reported similar results that repeated wildfire affects many aspects of ecosystem functions from nutrients cycling to grass production and plant species recruitments. Earlier Banda *et al.* (2006) equally observed that wildfires tended to favor herbaceous plants at the expense of woodland vegetation and the consequence is the alteration in species composition of vegetation communities.

The causes of wildfires are normally related to anthropogenic factors caused by human induced activities. Many researchers (Mwima, 2005; Namukonde, 2007; Wilgen, 2000) have cited these anthropogenic factors as land preparation for farming, honey harvesting, poaching, and chasing away dangerous animals for safety. Goldmmer (2013) also added that wildfire can occur as the result of fire escape from fire control burning and penetrate into the forest.

2.2 HISTORY OF WILDFIRE IN ZAMBIA

Effort to document the occurrences and effects of wildfires in Zambia have been done and the findings indicate that wildfires have become one of the major anthropogenic factors that may have potential threats to vegetation communities in Zambia.

Zimba (1986) investigated the effects of fire on *Baikiaea* forest and in his conclusion it was estimated that close to 1,600 ha of *Baikiaea* woodland are destroyed by wildfires annually. Similar findings were reported by Mwima (2000) who stated that Ngoma Forest was 34 km^2 in 1985 in extent but reduced to 18 km^2.Mwima (2000) associated the decline of Ngoma Forest in Kafue National Park to repeated wildfires. The study by Chidumayo (1988) focused on the effects of fires on Miombo regeneration and concluded that fire can reduce species diversity and density in Miombo woodland. Sileshi and Mafongoya (2006) looked at the short impacts of forest fires on micro invertebrates in Miombo and the results revealed that fires can alter vegetation structures by affecting the soil invertebrates that are responsible for manufacturing nutrients. Eriksen (2007) carried out a study focusing on the social economic level with emphasis to assess the effects of wildfire on the rural livelihood and conservation. The conclusion was that wildfire can cause damage to biodiversity if not properly managed. Other authors (Chirwa *et al.,* 2015; Syampungani, 2008; Vinya *et al*., 2011) give general information that repeated wildfire is one of the major contributing factors to forest degradation.

The recent technical report by Hollingsworth *et al*. (2015) estimated that 25% of Zambia's landscape is affected by bush fires annually and it was reported that 18.8 million ha is burnt every year affecting most parts of major protected areas in Zambia including the unique habitat of Busanga Flood Plain. ZAWA (2010) and Physical observations show that wildfire frequency have become one of the major problem in BFP and some plant species seem to be decreasing in abundance. The decrease of the plant species may have caused some changes in composition and distribution of vegetation communities of Busanga Flood Plain in Kafue National Park.

From the information above, there has been no deliberate attempt to understand the effects of wildfire frequency on plant species composition and density in vegetation communities of Busanga Flood Plain. As such this study attempts to develop an understanding of the relationship between wildfire frequency and species diversity in vegetation communities of the Busanga Flood Plain.

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CHAPTER THREE: THE EFFECTS OF WILDFIRE FREQUENCY ON PLANT SPECIES DIVERSITY AND DENSITY OF TERMITARIA VEGETATION COMMUNITY OF BUSANGA FLOOD PLAIN

ABSTRACT

For over a decade Busanga Flood Plain vegetation have been exposed to wildfire frequency and no scientific information is available to understand their effects on species composition and structure. This paper presents the effects of wildfire frequency on termitaria vegetation community by answering two questions. (i) What are the tree species found on termitaria vegetation? (ii) What effects do wildfire frequency have on tree species diversity, density and structure across termitaria vegetation? The study adopted fire map generated by DNPW GIS head office where two sites burnt and unburnt were selected. GPS used to navigate to selected burnt and unburnt sites of the study area. The systematic sampling design was adopted to increase area coverage and a total of 18 of 30m x 30m plots were established and investigated. The variables measured were tree heights, DBH and crown cover.

A total of 65 plants species were recorded with 25 being common in both sites while 30 were absent in burnt site. The results show statistical difference of species diversity between the sites ($P < 0.05$). Unburnt site recorded high species richness (19.47) than burnt site with (7.14). The results show high dominance of *C. adenogonium* in both sites although it recorded high in burnt site. The results show was no deference in tree height, DBH between the two sites but crown cover size was high in burnt site. Therefore, the study provide information that on the effects of wildfire frequency on species composition and structure of vegetation communities of termitaria. The data will add value the use of fire as a management tool to manage termitaria vegetation in Busanga Flood Plain in Kafue National Park.

Key words. Wildfire, Frequency, Busanga, flood plain, Ecosystem, Termitaria

3.0 INTRODUCTION

Wildfire is critical in maintaining ecosystem functions that contribute to the distinctiveness of the vegetation structure required to support variety of fauna diversity (Mapiye *et al.,* 2008). Since time in memorial, wildfire has shaped the natural ecosystem and its removal can lead to a complete vegetation change from its original status (Zolho, 2005; Eriksen, 2007). Additionally, Trapnell (1999) also argued based on his study that the removal of wildfire can lead to complete formation of closed canopy forest in Miombo woodland. Studies carried by various researchers revealed that wildfire play very critical role in plant species composition and structure. For example the study carried by Banda *et al.,* (2006) concluded that wildfire support maintains of species diversity and richness in vegetation communities there by improving range land condition of an ecosystem. Similar findings were recorded from a separate study by Madoffe *et al.* (2012) who stated that wildfire has play very important role by facilitating maintain species diversity and density in the vegetation community in Miombo woodland. Trapnell (1999) also added that wildfire frequency maintain open savanna grasslands and a complete removal can lead to a complete disappearing of grass land by forming closed canopy forest woodland. This is achieved by managing fuel biomass in the vegetation communities. High fuel load (grass biomass) especially in high rain fall and low density grazed areas promote wildfire frequency and intensity that suppress young seedlings and small trees to grow. The killing of young seedlings and small trees by wildfire reduces resource competition between grass species and trees hence open grass land ecosystem are maintained. Ward (2005) reported positive correlation between high fuel level load and wildfire frequency and intensity in woodland vegetation. Vegetation community with low biomass experiences low fire frequency and intensity and subsequently lead to disappearing of open grass land supporting by the young growing plant species leading to close canopy forest community.

Other roles that wildfire play includes breaking seed dormancy in vegetation communities. The study by Andersen *et al.* (2005) in northern part of Australia described wildfire as a factor that facilitates seed germination in vegetation communities by breaking seed dormancy. Through this act, wildfire facilitates plant species regeneration and recruitment in vegetation communities.

The finding by Chirwa *et al.* (2015) also revealed that plant species diversity and dominance is highly influenced by wildfire frequency because plant species respond differently to fire (Shackleton & Scholes, 2000).

However, repeated wildfires have great potential influence on vegetation diversity and species composition. Various studies (Nkomo & Sassi, 2009; Andersen *et al*., 2005; Banda *et al.,* 2006) have shown that wildfire frequency influence vegetation community changes globally. The results from two separate studies by Zolho (2005) and Yinghua *et al*. (2012) state that wildfire has a negative impact on plant diversity and species. The argument has also been supported by other researchers (Syampungani, 2008; Chirwa *et al*., 2015) who revealed that wildfires is one of the major factor that contributes to forest degradation in Zambia.

According to findings by Hollingsworth *et al*. (2015) about 18.8 million hectares, representing 25% of the total landscape of Zambia, is affected by wildfires annually. And these wildfire have affected many protected ecosystems including Busanga Flood Plain in Kafue National Park. Earlier, Mwima (2005) did alluded to that wildfire frequency was one of the major driving factor of vegetation changes in Kafue National Park and recommended vegetation monitoring in special habitats of BFP to ascertain their influence on the vegetation species diversity and density.

Although vegetation surveys have been conducted to determine the effects of wildfire on species diversity and density (Zimba, 1986; Chidumayo, 1988; 2000; Syampungani, 2008) in Zambia, their studies have centered mainly on Miombo woodland vegetation in general and very few or none of these studies have focused on the influence of wildfire frequency on tree species diversity and density in termitaria woodland of BFP. Non availability of information to ascertain how wildfire frequency affects vegetation composition and structure of termitaria woodland pose a great challenge to DNPW staff and other stakeholders to implement effective fire management practices that will enhance protection and management of termitaria vegetation communities of Busanga Flood Plain. As such, this study aims at developing an understanding of how wildfire frequency impacts on species diversity, richness, and dominance and this will influence DPNW staff and other stake holders to adopt effective fire management practices in managing vegetation community of termitaria in Busanga Flood Plain.

3.2 METHODS AND MATERIALS.

3.2.1 STUDY SITE.

Busanga Flood Plain is located in Kasempa District in the north western part of Kafue National Park (Fig. 1). The study area falls under regional 3 of rain pattern whose annual rainfall ranges from 600mm to 1200mm and experiences two dry seasons (cold and hot dry seasons) and one wet season (hot wet season). The mean annual temperature is between 19.4 - 34 ºC in dry season and 5 - 15 ºC in winter (Mwima, 2005). The area gets flooded in the wet season by several small tributaries that run from high grounds and drains into Lufupa stream, which later discharges its water into Kafue River. The flooding become high in March and May in every season.

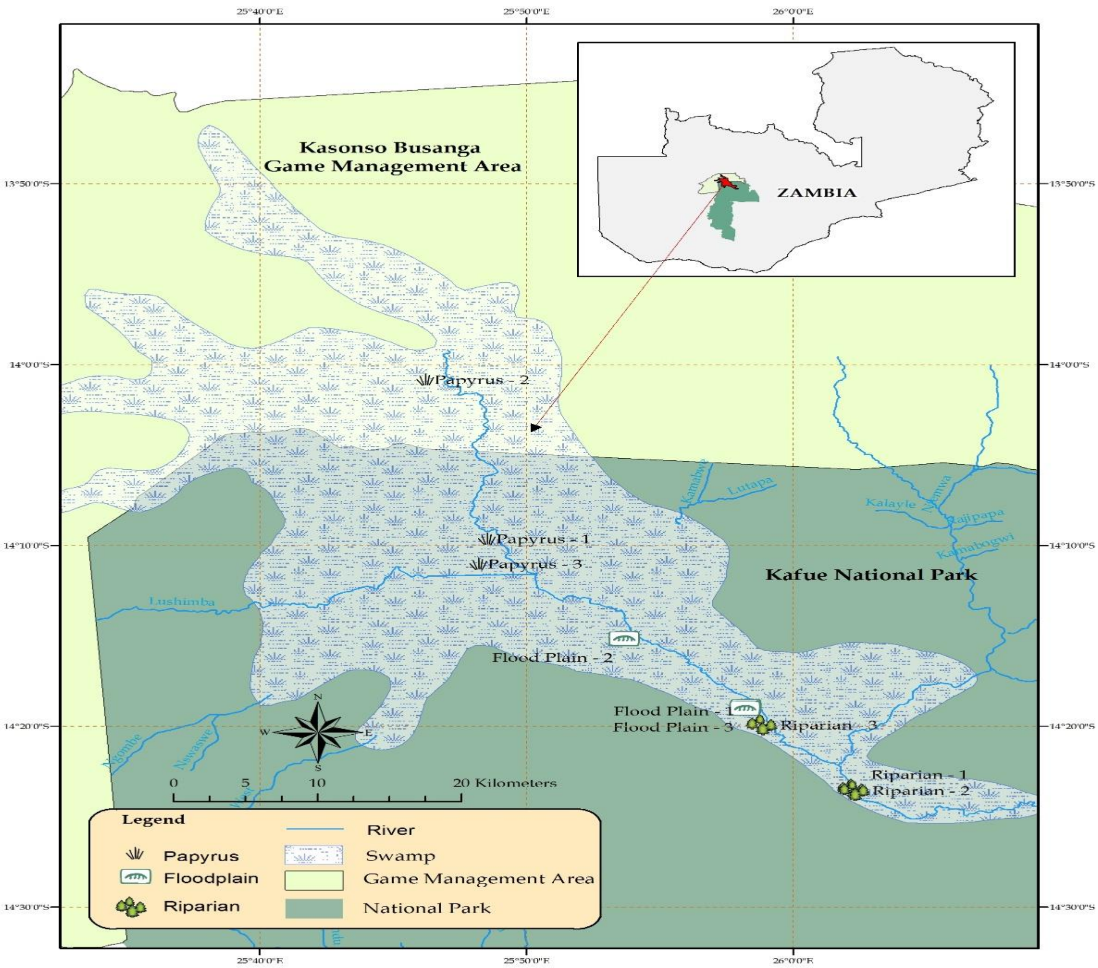

Figure 3: Location of the study area (Source DNPW GIS office)

3.2.2 RESEARCH DESIGN

The study adopted the fire map of study area generated by Department of National Park and Wildlife (DNPW) GIS expert staff fire monitoring team from head office that show wildfire occurrences for the period of 15 year (between 2000 – 2014). Out of nine vegetation types occurring in Busanga Flood Plain (Mwima, 2006), termitaria woodland was selected as it is the most predominate vegetation believed to act as refuge for a myriad of wildlife animals during periods of floods (Tsvigu, 2013) and also consist fire sensitive small trees and shrubs. From the selected vegetation two (2) sites of 100 ha each one in fire prone area (for 15 years) and the other area from fire free were selected. The two sites were next to each other to prevent major variations in environmental factors such as soil fertility, drainage, soil type and altitude (Tsvigu, 2013). GPS unit was used to navigate to the selected sites of the study area and sampling design was assigned based on (Mwima, 2000) description of the vegetation structure of the Busanga Flood Plain.

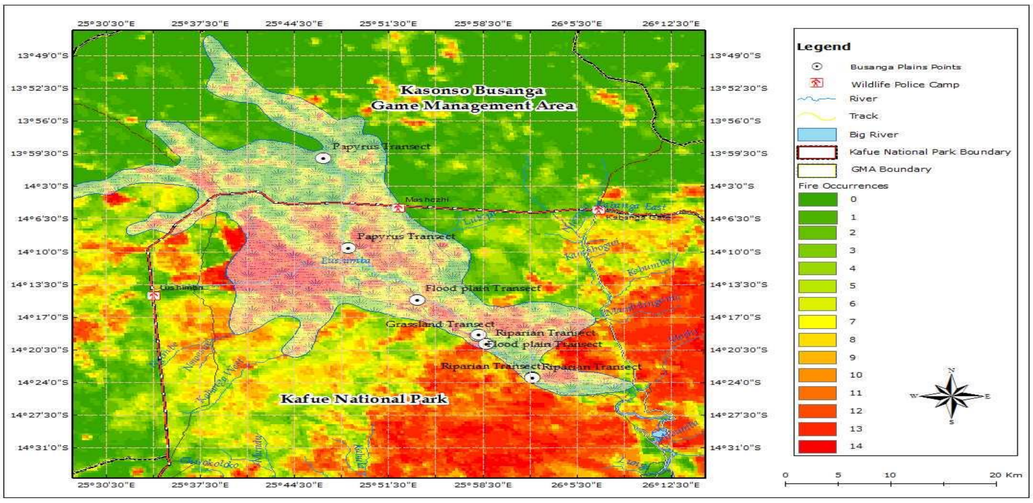

Figure 4: Fire map of Busanga Flood Plain showing wildfire occurrences from 2000 – 2014

The systematic sampling technique was adopted because of its ability to provide wide coverage area (Milne, 1959). On each site 3 transects of 1000m long and 500m apart were established. Using 100m measuring tape, 3 x (30m x 30m) quadrats were systematically established and investigated on each transect at 50m interval. A total of nine (9) quadrats from each site were sampled making a total of 18 for two (2) sites.

In each quadrat, all woody plant species of 1 m and above were identified and counted for the following parameters: tree heights, DBH and Crown cover. The tools used include 7.5m graduated Hastings Fiberglass pole for tree heights, 100m measuring tape for measuring circumference and crown size for trees. Circumference measurements were later converted into diameter by using the formula $D = C / \pi$ (Gandiwa, 2010). Trees with multi-stems emerging from the ground were measured on the bases of getting the average DBH and the height measurement was taken from the tall branch (Mwima, 2005).

3.2.4 DATA ANALYSIS

3.2.4.1 SPECIES DIVERSITY

The Shannon Weiner Index was used to describe species diversity between the two sites. On each site the Shannon Weiner Index for each quadrat was computed and the average were subjected to statistical t test using statistical package of Genstat 13th Edition to determine statistical deference between the burnt and unburnt sites. The formula below was used to compute the Shannon Wiener.

$$H = -\sum(pi\ Inpi)$$

Where pi is the proportion of the observation found in category i to the total number of the species. The Shannon Weiner Index is an index widely used in an ecological study to determine the level of species diversity in different habitats (Mwima, 2005; Tsvigu, 2013). It is merit for wide use by various researchers lay on its simplicity and provision of information on rarity and commonness (abundance and evenness) of species found in the community. According to the Barcbour *et al*. (1987) Shannon Wiener Index value greater than 2 indicate the medium to high species diversity in the a particular community.

3.2.4.2 SPECIES RICHNESS

To determine plant species richness on each site, the following formula was used, once used by Madoffe *et al.* (2012). Species richness was calculated to supplement the results of Shannon Weiner Index.

$$R = \frac{S-1}{In\ N}$$

Where

S = total number of species

N = total number of individuals

3.2.4.3. SPECIES SIMILARITIES

Sorensen's similarity coefficient was computed to compare the similarities of species composition of vegetation composition between the two sites. The SI index values are interpreted as the proportion of species either present or absent of the common species between the sites. The values of SI index value fall between 0 – 1 and the value closer to 1 indicates that species are the same at both sites, whereas an index value closer to 0 indicates no species in common occur between the sites (Odum, 1971). The formula below was used to compute SI (Magurran, 1988).

$$C_S = \frac{2_j}{(a+b)}$$

Where

C_s= similarity index

$_j$ = number of species at both site A and B

a = number of species at site A only

b= number of species at site B only.

3.2.4.4. VEGETATION STRUCTURE

The distribution of species composition vegetation in the study area was determined by calculating Species Importance Values (SIV) using the formula below.

$$S.\ I.V = \frac{(\text{Relative frequency (RF)} + \text{Relative density (RD)} + \text{Relative dominance (RD)})}{3}$$

Where:

$$\text{Relative frequency} = \frac{\text{Number of plots in which species is present}}{\text{Total number of plots recorded}} *100$$

$$\text{Relative density} = \frac{\text{Number of stems recorded for the species}}{\text{Number of stems recorded for all species}} *100$$

$$\text{Relative dominance} = \frac{\text{Sum total of DBH of certain species in all sampled plot} *100}{\text{Sum total of DBH of all tree species in all sample plot}}$$

The formula is widely used due to its ability to incorporate three (3) important factors such as the number of individuals, distribution and size of the plant species (Mwima 2005). As described by Razavi (2012) Species Importance Value (SIV) provide information on dominance and distribution of the plant species that help to make good judgement on ecological condition of a habitats. However, for this present study, SIV was calculated using relative frequency and relative density (SIV = RF + RD /2). This formula have been used by other researchers in vegetation survey before (Razavi, 2012; Rooyen, 1990).

3.2.4.5 AVERAGE TREE HEIGHT, DBH AND CROWN COVER SIZE

Woody vegetation structure is described by the distribution of the tree heights, their diameter and crown cover (Adam & EK, 1974). These parameters play very important role in the function of an ecosystem and very sensitive to anthropogenic factors such as wildfire frequency (Mwima, 2005 & Pyke et al., 2010).

To determine the effects of wildfire frequency, on tree height, DBH and crown size for each plant species, the average of each respective parameter (tree height, DBH and Crown cover) were calculated by the use of Microsoft excel. For each parameter, the total number of each individual species were summed up and divided by the total number of all individual species in each site and the results for 10 common plant species were compared between the two sites as presented in their respective figures.

3.3 RESULTS

A total of 63 different plant species were recorded during the study in both sites, with 25 plant being common to both sites (Appendix 1). However, a total of 30 species were absent in burnt site. With regard to individual trees species, a total of 929 individual tree species were measured and counted out of which 601 trees were in unburnt site while 328 were on burnt site.

3.3.1. SPECIES DIVERSITY, RICHNESS AND SIMILARITIES.

To determine the species diversity Shannon Wiener Index was calculated. The results show Shannon-Wiener index value of 0.6766 for unburnt site while burnt site show Shannon Wiener Index value of 0.4872. To determine the significant difference in species diversity between two sites statistical t-test was computed and the results showed calculated value of 0.03 less $P < 0.05$ value at degree of freedom (n-1) indicating statistical difference in species diversity between the two sites. The Species richness index was computed to supplement the results. This was aimed at getting a better informed evidence of species diversity between the two sites of the study area. The results showed unburnt site with species richness indices value of 19.43 while burnt site show 7.14. This implies that the unburnt site had more species diversity than burnt site. Furthermore the Sorenson Similarity Index was computed determine the species similarities between the two sites and the results indicated 0.51 implying that the species diversity between the two sites had similarities. Table 1 provide details.

Table 1. Indices of species diversity, species richness and Sorenson similarity Index of the study area.

	Burnt site	**Unburnt site**
Shannon Index	0.4872	0.6766
Species richness	7.14	19.47
T – test	P < 0.05	
Sorenson's Similarity	0.51	

3.3.2 VEGETATION STRUCTURE

The Species Importance Value (SIV) was computed to determine the dominance and distribution of the plant species of the study area. To determine the effects of wildfire frequency on species dominance and density, ten (10) common species with relatively high number of species size were selected to represent the comparison between burnt and unburnt sites (Fig. 3 and 4). A comparative analysis indicates mismatch in species dominance and relative density among the common species between the two sites. In both sites, the result shows high values of relative dominance of *C. adenogonium* among the 10 common plant species compared although doubled in burnt site than in unburnt (Fig 3 and 4). The results further showed high value of relative dominance of *D. condylocarpon*, *C. singuana, Z. mucronata, M. obtusifolia* and *T. sericea* in burnt than in unburnt site despite with low values (Fig 3). However, the results indicates high relative dominance of *B. pertersiana* in unburnt site than in burnt site.

With regard to the relative density, the results show high value of *C. adenogonium, D. condylocarpon, C. singuana, C. abbreviata, Z. mucronata,* and *M. obtusifolia* in burnt site than in unburnt. In contrast the results show high relative density value for *B pertersiana* in unburnt site than in burnt site while *K. africana* recorded equal values of relative density on both sites (Figure 4)

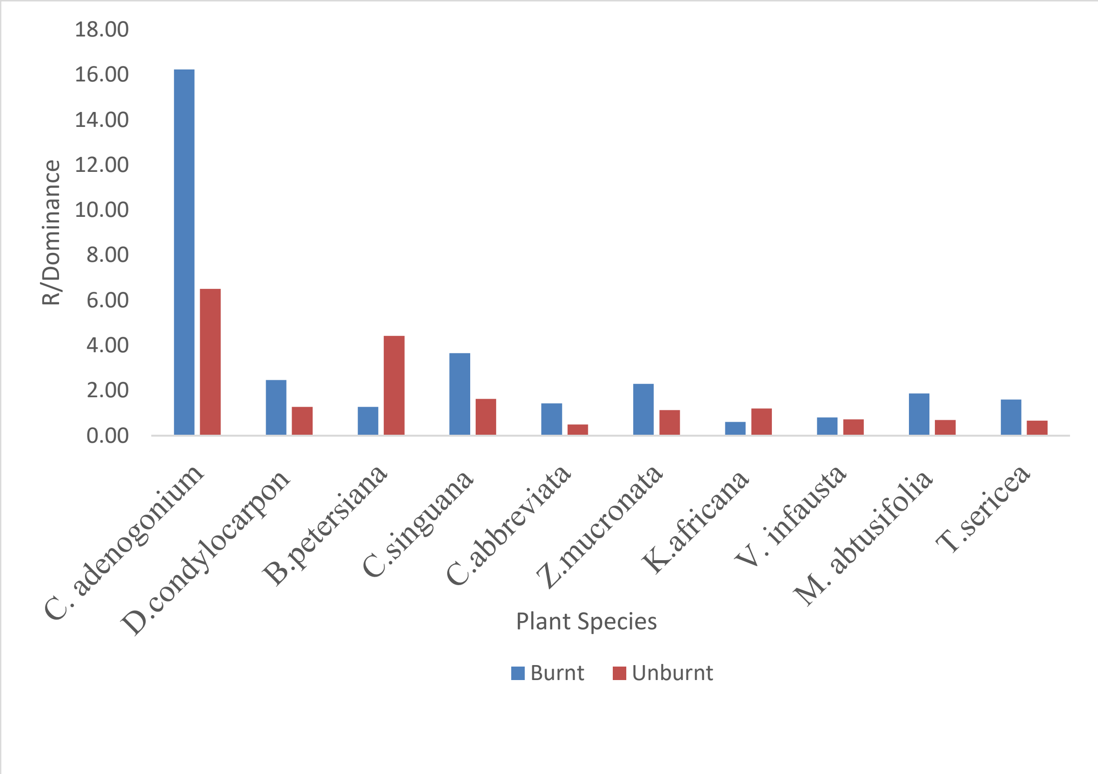

Fig 5: Species Relative dominance of the common plant species of termitaria woodland.

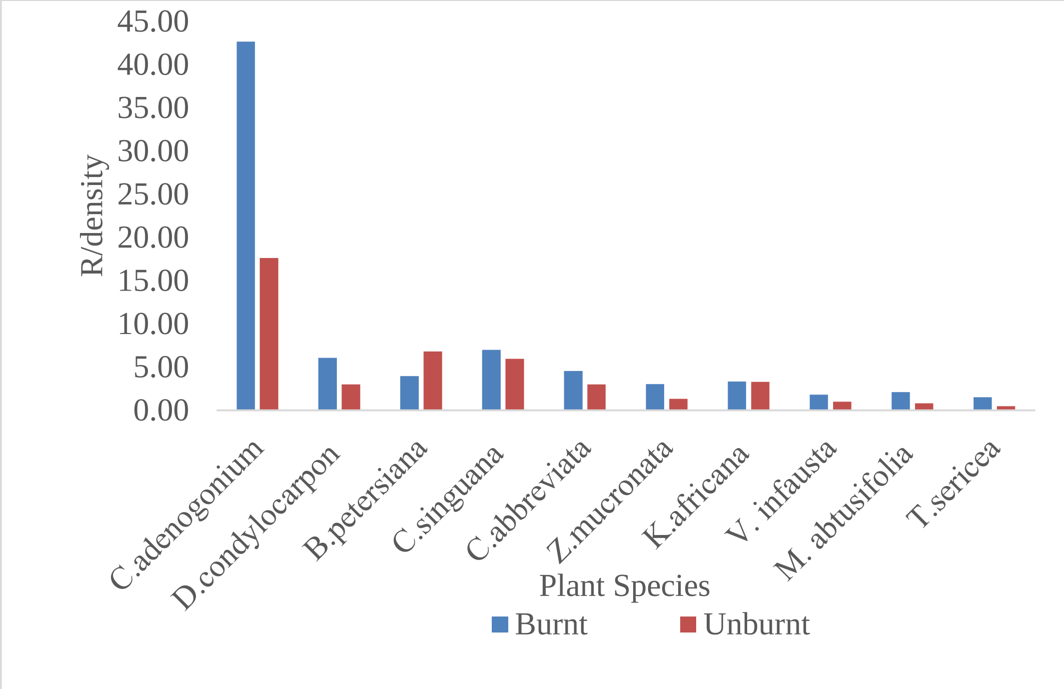

Fig 6: Species Relative density of common species of the termitaria woodland

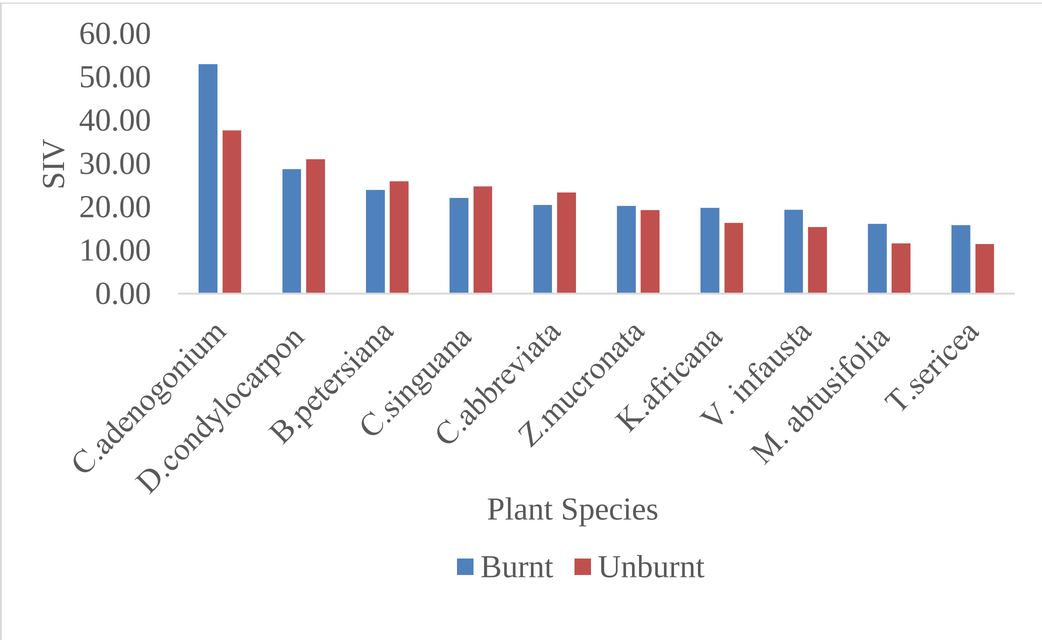

Fig 7: Species Importance Value of the common plant species in the study area

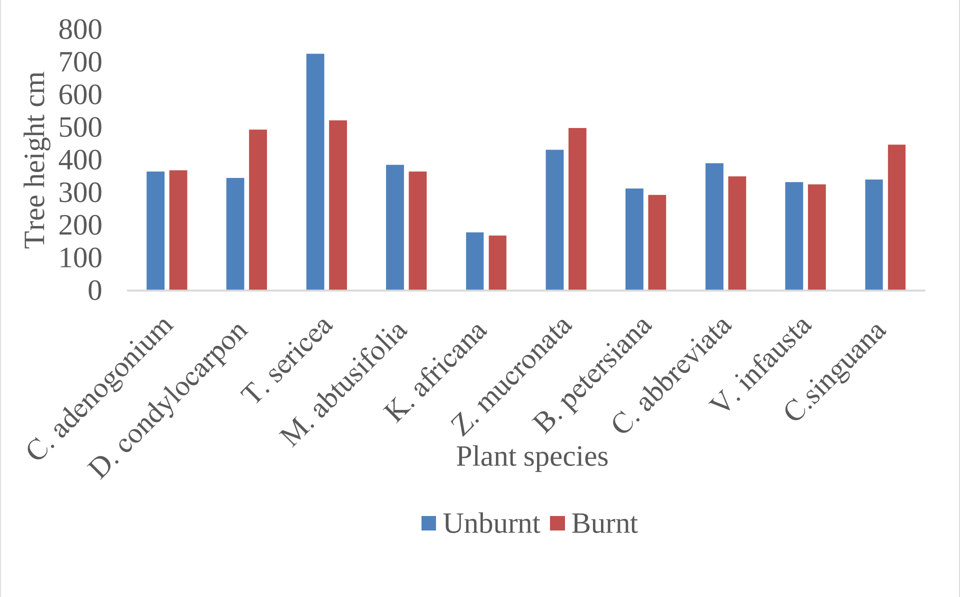

Figure 8: Average tree heights of the ten common tree species of the study area

3.3.3 AVERAGE TREE HEIGHT

The results indicate the average height of all 10 common selected plant species below 10m in both sites except *T sericea* in unburnt site. Generally the results reveal no significant deference in average tree heights between the two sites. However, *C. singuana* recorded slightly high average height in burnt site than unburnt site. *K africana* recorded the lowest average tree height in all sites. The rest of the plant species recoded their average height with the range between 3.5m – 6.5m (Figure 6).

3.3.4. AVERAGE CROWN COVER

The study results show significant difference in average crown cover between two sites. *C. singuana, D. condylocarpon, C. abbreviate and M. abtusifolia* recoded high values of average crown cover in burnt site while *T. sericea*, *K. africana*, and *V. infausta* recorded high values in unburnt site. Among the 10 selected plant species presented in figure 7, *C. condylocarpon*, *Z. mucronata*, and *B. petersiana* recorded the lowest values of average crown cover in all sites. T. sericea recorded the height value among all the species (Figure 7).

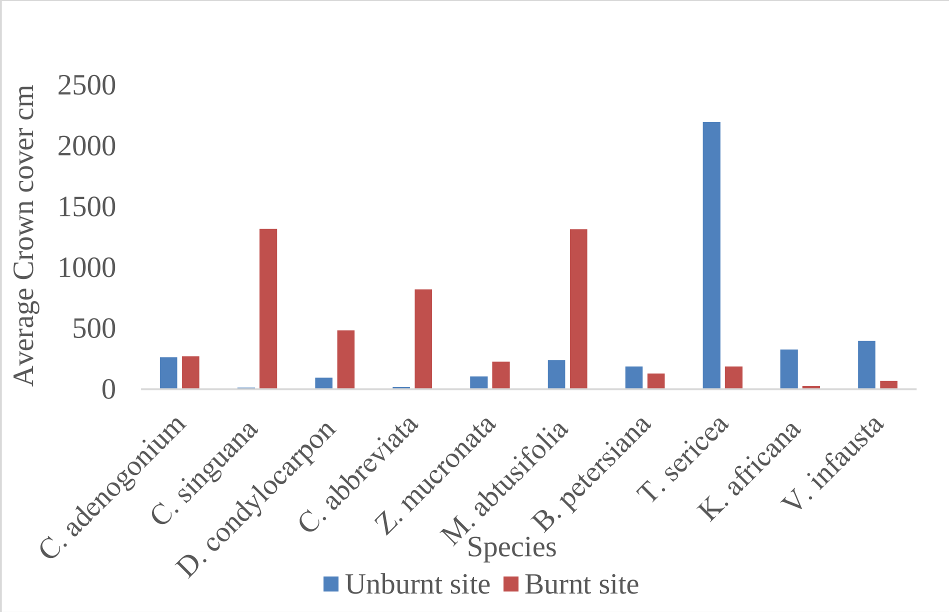

Figure 9: Average crown size for 10 selected plant species

3.3.5. AVERAGE DBH

The results from the study show no significant difference in the average DBH values in both sites with an exception of T sericea whose value were high in unburnt site. K. africana recorded the lowest value of average DBH in both sites while the rest of the species recorded their values ranging from 4.5cm – 14cm. However, some species such as *C- adenogonium, C. singuana, and C. abbreviata* and *Z. obtusifolia* recorded average DBH values above 10 cm.

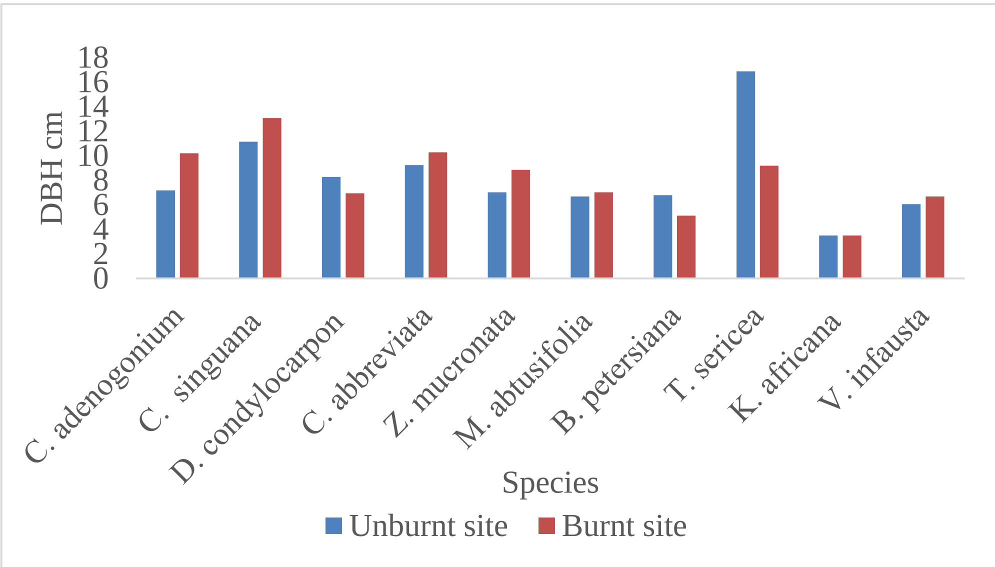

Figure 10: Average DBH for 10 selected plant species of the study area

3.4 DISCUSSION

The study results reveal that at total number of 65 different plant species were recorded in both sites. Out of 65 difference species, 25 were common to both sites. The presence of 25 different species in both sites could have been as the result of similar environmental factors that shared between both sites. As described by Omeja *et al.* (2011) from the study in Kabale National Park in Uganda stated that species composition between two sites become common when two sites share similar environmental factors such as water, soil pH, and temperature soil texture and soil nutrients. However, in this present study a total of 30 different species were absent from burnt site while 11 were absent from unburnt site. The absence of 30 plant species is an indication that wildfire frequency could have an influence on the species composition. This findings match with the finding by other researchers who indicate that certain plant species are very sensitive to wildfire frequency. For example, a studies by Claudius *et al.* (1999) in Tarangire National Park concluded that the increase of wildfire changed vegetation species composition because certain plant species respond to wildfire differently. This was also observed by Syampungani (2009) and Vinya *et al*. (2015) in separate studies that wildfire greatly influence plant species composition in vegetation communities because some plant species are very sensitive to fire. On the other hand the 11 species were absent from unburnt site and this could have been attributed by absence of wildfire that help to break seed dormancy. This augment support the findings by Omeja *et al.* (2011) who stated that the absence of wildfire in vegetation communities disadvantage fire defendant plant species.

In the case of plant species diversity, Shannon Weiner Index was computed for each site and values do not reflect significant differences in species diversity between two sites for this study (unburnt site 0.676 and burnt site 0.487). As described by Bacbour *et al*. (1987) any computed Shannon Index value greater than 2 indicates medium to high species diversity. The low values observed on both sites in this study could have been as a result of low abundance values of species. The Sorenson similarity analysis show no difference in species diversity between the sites. The computed value of SSI (0.51) in this present study indicates partial similarities in species diversity between the two sites. The interpretation of the computed SSI value is guided by Odum (1971) who state that any calculated value of SSI closer to 1 reflect commonality in species composition between the two or more sites while any value closer to 0 indicate no species in common between two sites.. In this study the calculated SSI value could be as a result of 25 plant species which were common in both sites.

However, the significant differences in species diversity between the two sites were observed from the results of statistical t - test ($P < 0.05$) to determine the mean differences of Shannon Index between sites and the results were complemented with species richness calculation. (Unburnt 19.47 and burnt 7.14). These results indicate high significant difference of species diversity between the two sites. Unburnt site recorded 19.47 indicating high species richness while burnt site recorded 7.14. This scenario imply that wildfire frequency can have an influence on species diversity in vegetation communities. The results agree with earlier results from the study by Holdo (2007) in Kalahari woodland west of Zimbabwe who reported that the increase of wildfire frequency could significantly decrease plant species richness. Similar results were also observed by Javadi *et al*. (2013) who recorded a significant reduction of species richness after fire. Various researchers have forwarded reasons to why certain plant species fail to adapt in wildfire prone areas. For example a study by Javadi *et al*. (2013) shows that wildfire frequency may affect the development of plant species richness indirectly by killing micro fauna and flora that are responsible for nutrients cycling in an ecosystem while (Ben-Sharha, 1995) recorded evidence of wildfire frequency killing the growing tips and branches especially among the plant class < 4.5m height hence causing decline in plant species diversity. In this study, the high value of species richness could in unburnt site could the absence of wildfire that is responsible to kill the sprouting young fire sensitive trees.

With regards to Species Importance Value (SIP) the results show *C. adenogonuim* with high dominance in both sites although the values are high in burnt site. Furthermore, other species such as *K .africana, V. infausita, M. obtusifolia and T. sericea* also recorded high dominance values in burnt site than unburnt site indicating fire tolerant species (Fig 5). The high dominance of these species in burnt site may imply that wildfire frequency may have positive influence in their growth by helping breaking seed dormancy and hard seed covers (Syampungani, 2008). A similar conclusion was also drown by Trollope (1987) in the study in Krugar National Park who concluded that wildfire play an important role in an ecosystem by providing maintenance of species dominance and spatial distribution of the vegetation structure. On the other hand this study revealed high dominance and relative density of *B. petersiana* in unburnt site centrally to the findings by other researchers who state that B petersiana is fire tolerant species. For instance the study by Zolho (2005) in Nhambita vegetation community in Mozambique described *B. petersiana* as fire tolerance species. The difference in the results could be due to variances on wildfire frequency in study area which result in heat intensity variation. It is mentioned that wildfire in dry season are extremely detrimental to certain plant species than wildfires that occur in wet season. Dry season fires are the most damaging to plant species in Miombo woodland due to high heat intensity as it affects new growth and survival of young plant species (Vinya *et al*., 2011). This argument agree with those by Chirwa *et al.* (2015) who found that the tree species in open Miombo woodlands responded differently to wildfire fire frequency and intensity. The finding by Ryan and William (2011) also support the argument by stating that some plant species do not survive in regular fire prone areas due to their sensitivity to heat of fire.

With regard to tree height the results of this study reveal that the termitaria vegetation is dominated by small and short trees and shrubs with average tree height ranging between 3.5m – 6.5m and there was no significant difference in average tree height between two sites although *T. sericea* recorded high average height in burnt site. This could be an outlier

The results confirm the statement by Mwima (2005) who stated that termitaria vegetation in Kafue National Park is built up with small and short shrub trees whose height is below 7.5m. A similar argument was observed from the study conducted by Humphrey (2008) in Chizarira National Park in Zimbabwe that reveal that termitaria vegetation harbor a high species richness of tress height ranging from 3m – 6m with few taller than 6m in macrotermes mound. The similarities of the average tree height between burnt and unburnt site in the study area could as a result of the mature of the tree species composition and structure of termitaria woody vegetation. However, this type of vegetation is very whose tree height is below 6m is sensitive to fire. Various studies have confirmed that vegetation structures comprising with small trees and shrubs with < 6m average height are highly influenced by high fire frequency. Higgins *et al.* (2000) recorded high stem mortality for trees with height < 6m from the site that hard high increase of fire intensity than the site that had trees with tall height. Similar findings were reported (Schockleton & Scholes, 2000) stating that fire frequency retard the growth of small trees to grow to big size trees that result the vegetation structures remains with trees and shrubs with average tree height below < 6 m.

The results of the study reveal low average values of DBH of all plant species and show no difference between sites except T sericea in unburnt site implying that wildfire had no effects. This observation is similar to the findings by Humphrey (2008) in the Chizarira National Park in Zimbabwe and by Mwima (2005) in Kafue National Park who both stated that termitaria woodland composed of short small trees and shrubs with DBH ranging between 2 –10cm except in termite mounds. The high average values of DBH in this study could be that the species were recorded from termite mounds. With regard to average crown cover, the results indicate significant difference between the sites. *C. singuana, D. condylocarpon, C. abbreviate* and *M. obtusifolia* show high values of average crown cover in burnt site. The difference could have been caused by presence of fire. The results are similar to the findings by Humphry (2008) in Zimbabwe who recorded high values of crown cover for tree found in fire prone plots. The reason could be that fire create space after killing some small growing trees hence create space for other survival tree species to expand their crown cover (Cook, 2012). The absence of fire in a particular habits create think forest leaving no space for tree to expand their crown size.

3.5 CONCLUSION

The implementation of good fire management practices to manage vegetation communities depend on good knowledge and understanding of the effects of wildfire frequency on plant species variables such as plant species diversity, species richness and structure. The results from this study shows some interesting findings that require to be considered during the adoption on best fire management practices. For example *B petersiana* and *D. condylocarpon* are described as fire tolerance species but the findings from this study indicate contrarily as it was recorded high importance value in terms of relative dominance and density in unburnt site. Furthermore the study revealed that 30 plant species were absent in burnt site while 11 were absent in unburnt sites. The absence of 30 plant species from burnt site indicates negative effects of wildfire frequency on species diversity and species richness while the absence of 11 plants species in unburnt site indicate positive effects of wildfire frequency on species diversity. Similarly, the high dominance of *C. andenogonium,* C. *singuena. Z. mucronata, M. obtusifolia and T. sericea* indicate that wildfire frequency clearly play an important role in species dominance richness and density. Therefore, the results of this study reveal the important information on composition and structure of termitaria vegetation and how it is effected by wildfire frequency. Understanding these issues is of great value at it help park managers and other information in selecting the best fire management practices that will help to enhance management and conservation of Busanga Flood Plain. The data will also act as a baseline data for future research.

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Appendix 1: Plant species recorded in termitaria vegetation – Busanga Flood Plain

Name of the Species		**Abundance**	
		Burnt site	Unburnt site
Combretum adenogonium	*C. adenogonium*	140	106
Friesodielsia obovata	*F. abovata*	0	63
Terminalia sericea	*T. sericea*	5	41
Pterocarpus angolensis	*P. angolensis*	0	38
Markhamia obtusifolia	*M. obtusifolia*	7	36
Terminalia mollis	*T. mollis*	4	26
Baphia massaiensis	*B. massaiensis*	0	23
Bauhinia petersiana	*B. petersiana*	13	20
Pseudolachnostylis maprouneifolia	*P, maprouneifolia*	2	20
Diplorhynchus condylocarpon	*D. codylocarpon*	20	18
Kigelia africana	*K. africana*	12	18
Julbernardia paniculata	*J. Paniculata*	0	14
Antidesma venosum	*A.venosum*	0	13
Brachystegia boehinii	*B. behinii*	0	13
Gymnosporia spp	*Gymnosporia spp*	1	11
Strychnos spinose	*S. spinose*	0	10
Combretum molle	*C. molle*	3	9
Hymenocardia acida	*H. acida*	0	9
Ziziphus mucronata	*Z. mucronata*	10	8
Cordia mkuensis	*C, mkuensis*	0	7
Philenoptera violacea	*P. violacea*	6	7
Lannea discolor	*L. discolour*	4	6
Piliostigima thonningii	*P. thonningii*	4	6
Cassia abbreviate	*C. abbreviate*	15	5
Peltophorum africanum	*p. africanum*	0	5
Syzygium guineense	*S. gueneense*	4	5
Vagueria infausta	*V. infausta*	0	5
Dichrostachy scinerea	*D. cinerea*	0	4
Parinari curatellifolia	*P. curatellifolia*	0	4
Berchemia zeyheri	*B. zeyheri*	0	3
Cassia singuana	*C. singuana*	23	3
Ficus sycomorus	*F. sycomorus*	0	3
Grewia bicolor	*G. bicolor*	2	3
Pericopsis angolensis	*P. angolensis*	3	3
Whritia natalensis	*W. natalensis*	0	3
Ximenia caffra	*X. caffra*	3	3
Acacia polyacantha	*A.polyacantha*	0	2
Albizia amara	*A.amara*	3	2
Combretum hereroense	*C. hereroense*	0	2

Commiphora spp	*Commiphora ssp*	2	2
Dalbergiella nyasae	*D. nyasae*	0	2
Xeroderris stuhlmannii	*X .stuhlmannii*	0	2
Burkea africana	*B. Africana*	0	1
Capparis tomentosa	*C. tomentosa*	0	1
Catunaregum spinose	*C. spinose*	0	1
Combretum imberbe	*C. imberbe*	1	0
Combretum spp	*Combretum spp*	2	1
Dalbergia melanoxylon	*D. melanoxylon*	0	1
Diospirosy kirkii	*D. kirki*	0	1
Diospyros mespiliformis	*D. mespiliformis*	0	1
Erythrophleum africanum	*E. africanum*	0	1
Frorebuda indica (Ntumbulwa)	*F. indica*	0	1
Monotes glaber	*M. glaber*	1	1
Acacia nailotica	*A. nailotica*	4	0
Acacia ssp	*Acacia ssp*	1	0
Bauhinia thonningii	*B. thonningii*	1	0
Combretum elaiagnoides	*C. elaiagnides*	2	0
Combretum paniculatum	*C. paniculatum*	1	0
Eurphobia spp	*Eurphobia spp*	1	0
Grewia elaiagnoides	*G. elaiagnoides*	4	0
Grewia macrohthyrisa	*G. macrohthyrisa*	9	0
Markhamia zanzibarika	*M. zanzibarika*	3	0
Strychonos potaturum	*S. potaturum*	4	0

CHAPTER FOUR: ASSESSING THE EFFECTS OF WILDFIRE FREQUENCY ON RANGE CONDITION OF GRASSLAND OF BUSANGA FLOOD PLAIN

ABSTRACT

Wildfire frequency has been thought to be the major influencing factor on range condition of grassland in BFP for over a decade. However, no effort to conduct a survey has been made to understand its effects on range condition as previous studies have focused on how fire affects tree diversity and density in Miombo woodland. This paper presents the effects of wildfire frequency on grass species density and ecological status resulting range condition of grassland of Busanga Flood Plain in the Kafue National Park. The study adopted fire map generated by DNPW GIS head office using fire occurring points accessed from MODIS facilities. GPS was used to navigate to selected burnt and unburnt sites. The systematic sampling design was used to increase area coverage. Three (3) transects of 100m long and 50m apart were established. Five (5) quadrats (1m²) were laid on each transect at 20m apart and a total of 30 quadrats were surveyed. Microsoft excel was used to compute the data.

The results show high percentage value (75.5%) grass species in increaser II category in burnt site than in unburnt site with 56.53%. The unburnt site show13% of grass species in decreaser category and 28 % in increaser I category higher than burnt site with 7. 14% and 14.28% respectively. The results further show high density values of *sedges* and *E. inamoena* in burnt site implying that wildfire frequency may have an influence on range condition of the wet grassland ecosystem of BFP.

Therefore, the results suggest the need for Park management staff to adopt the best practice of fire management to maintain open flooded grass land vegetation of Busanga flood plain in Kafue National Park.

Key words. Wildfire, Frequency, Range condition, Grassland, Busanga Flood Plain.

4.0 INTRODUCTION

Grasslands are important ecological ecosystems that support a wider range of biodiversity including rare and endangered species (Myers *et al.,* 2004). The variety of vegetation composition support grassland resilience and provide good habitat for different species of wildlife animals that play an important role both economic and ecological development globally (Ludwig & Bastin, 2008).

However, Leeuwen *et al.* (2010) reviewed that there is evidence of declines in wildlife species in grassland ecosystems globally and the major driving factor is alleged to be wildfire frequency. Langevelde *et al.* (2003) report that in North America, unplanned fires are considered to be the major driving factor for poor development of grassland. The range condition of grassland in North America is reported to have deteriorated due to unspecific fire returns intervals (Langevelde *et al*., 2003). In Australia, a similar finding was reported by Andersen *et al.* (2005) that rangeland biodiversity has declined as a result of uncontrolled fires. The results by Steven *et al.* (2000) showed repeated fires have been the main cause of biodiversity decline of both fauna and flora of grassland ecosystems in Serengeti National Park in Tanzania.

In Zambia, the open grassland of Busanga Flood Plan is one of the unique open grassland affected by wildfire frequency in KNP – North. It is estimate that a total of 18.8 million hectares, representing 25% of the total landscape of Zambia, is burnt annually (Hollingsworth *et al.,* 2015) and the open grassland of BFP is part of the area affected. Physical observations and annual reports from DNPW (ZAWA, 2010; ZAWA, 2013) indicate that the range condition of open grassland of BFP is deteriorating and the suspected cause is wildfire frequency. However, these assumptions have not been proved scientifically because, of the few studies undertaken (Chidumayo, 2008; Hollingsworth *et al*., 2015; Eriksen, 2007), none of them has focused on the range condition of grassland of Busanga Flood Plain.

Therefore, this study aimed at determining the effects of wildfire frequency on open grassland of BFP and the result would act as baseline data for fire monitoring programs.

4.1 METHODS AND MATERIALS

4.1.1 STUDY SITE

BFP is located in Kasempa District, in the north western part of KNP- North (Fig. 7). It falls under regional 3 zone whose annual rainfall ranges from 600mm to 1200mm and experiences two dry seasons (cold and hot dry seasons) and one wet season (hot wet season). Its mean annual temperature ranges from 19.4 - 34 ºC in dry season and 5 - 15 ºC in winter (Mwima, 2005; ZAWA, 2010). The area gets flooded in the wet season by several small tributaries that run from high grounds and drain into Lufupa stream, which later discharges its water into the Kafue River. The flooding becomes pronounced in March and May in every season.

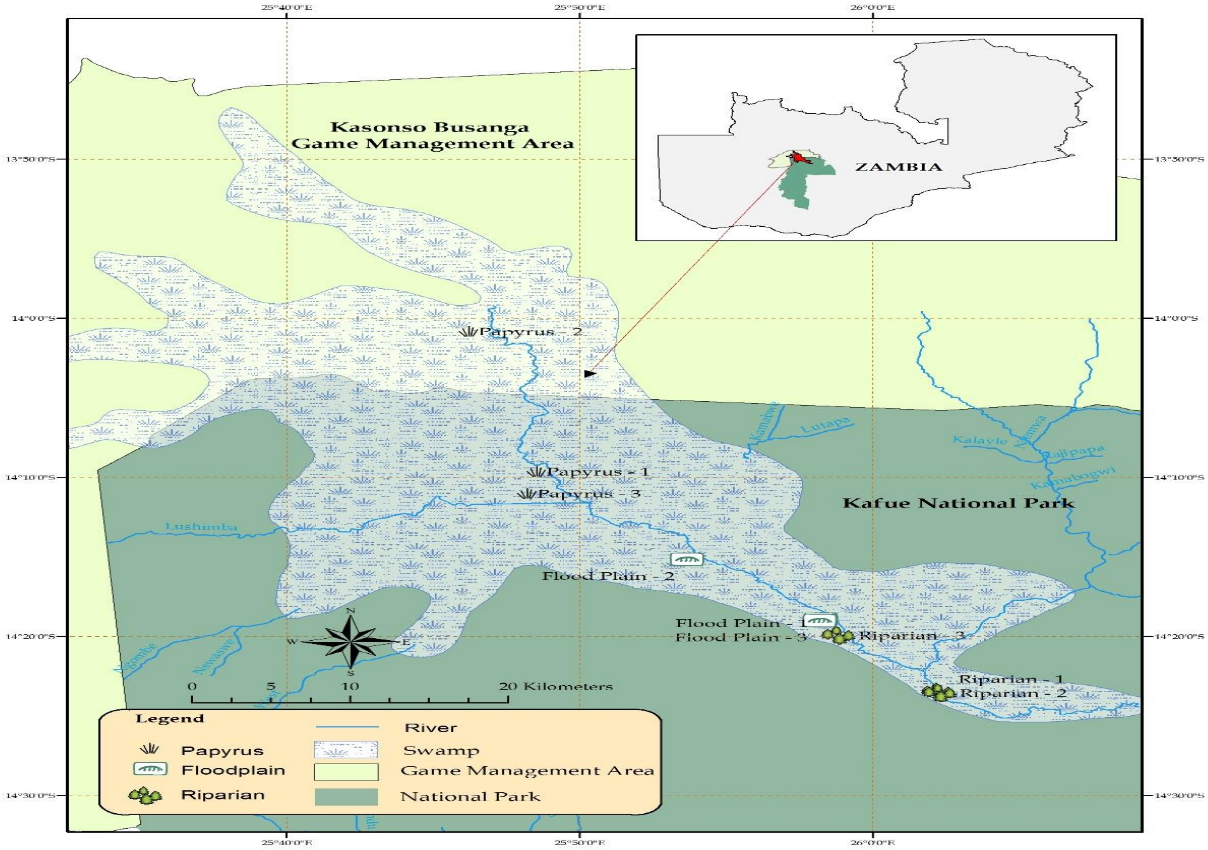

Figure 11: Location of the study area (Source DNPWS GIS)

4.1.2 RESEARCH DESIGN

Sampling sites were assigned based on Mwima (2006) description of the vegetation structure of the BFP, and fire occurrence data was obtained from satellite monitoring facility provided by MODIS Fire Mapper. Zolho (2005) used satellite fire reports to study fire effects on vegetation in Mozambique. Of the nine vegetation types occurring in BFP (Mwima, 2005), open grassland was selected as it is the most predominate vegetation thought to act as good habitat for wildlife after the periods of floods (Mwima, 2005; ZAWA, 2010). Thus, using Arc GIS (ERSI Arc View 3.2), vegetation polygons of open grassland were overlaid onto BFP shape files. Historical fire points (15 years) were overlaid on open grassland shape to determine areas with fire occurrence and those without occurrence (Fig. 5). Two (2) sites, 1.5

ha each, were selected - one in fire prone area and the other in fire absent area (Fig 5). The sites were next to each other to prevent major variations in environmental factors such as soil fertility, drainage, soil type and altitude (Tsvigu, 2013).

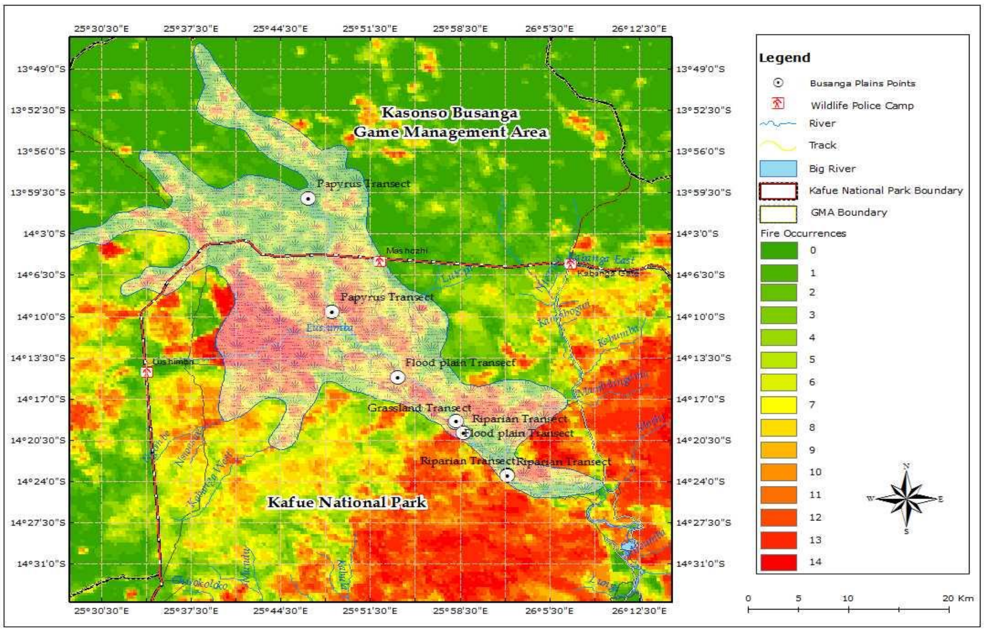

Figure 12: Fire wildfire occurrences from 2000 – 2014 (Source DNPWS GIS)

GPS unit was used to navigate to the study site. Using 100m measuring tape, three (3) transects of 100m long and 50m apart were established on each site, where 5 x 1m² quadrats were established at an interval of 20m apart on each transect. The one meter squared (1m²) was adopted based on minimal species area curve technique widely recommended to provide good estimate of plant species diversity in open grassland (Razavi, 2012). The systematic sampling technique was selected because of its ability to provide wide coverage (Milne, 1959). A total of fifteen (15) quadrats from each site were sampled making a total of 30 for two (2) sites.

4.1.3. DATA COLLECTION

In each quadrat grass species were identified, counted and recorded. The grass materials stemming from a single root system was considered as one plant. In this study, plant materials with a triangular stem or leaves were considered as a sedge. Particular attention was paid to avoid including grass species that did not have their roots in the quadrate. Vast experience of ZAWA workers and safari operators were used to identify grass species.

Field guide books (Oudtshoorn, 2014) supplemented the effort in plant identification. Species that were difficult to identify were taken to Chunga herbarium for further identification. The identified species were grouped into their respective ecological group of categories, namely decreaser, increaser I, II and III categories as described by Oudtshoorn (2013) and the percentage of each ecological grass category was calculated.

4.2. DATA ANALYSIS

To assess the rangeland condition of grassland of BFP, the Microsoft excel was used to calculate density values of each grass species using the formula once used below. The formula has been widely used by others (Mwima, 2005; Teaque & Danckverts, 1989)

$$D = N/A$$

Where:

D = density of the species

N = total number of the species sampled

A = total area sampled

The percentages of ecological status of each site were calculated manually as recommended by Oudtshoorn (2013). The summaries of ecological categories, namely decreaser, increaser I, II and III categories are presented in tables 1 and 2. In order to determine the effects of wildfire on range condition of grassland, 10 common grass species were analyzed for comparison between two sites.

4.2.2 RESULTS

The results show a total of 32 grass species were identified in the study area. Out of 32, 10 grass species were common in both sites. The results also reveal 14 grass species absent from unburnt sites while only 8 were absent from burnt site.

With regard to ecological status of grass species the results show 75.5 % of grass species in increaser category II in burnt site while unburnt site recorded 55.01%. Furthermore, the results indicate high value percentage of grass species in decreaser category by 13.00% followed by increaser I by 28.00% in unburnt sites than in burnt site. However, burnt site recorded no grass species in increaser III category while in unburnt site recorded 04%

representing one grass species that was recorded in increaser category III. Table 2 provides more details.

Table 2: Percentages of ecological status of grass species in both sites of the study area

Ecological status	Unburnt site	Burnt site
Decreaser	13.00%	8.15%
Increaser I	28.00%	16.28%
Increaser II	55.01%	75.57%
Increaser III	04.00%	0

Adopted from Oudtshoorn (2014).

With regard to determine which plant species are have high density values between two sites, the comparisons analysis ten (10) common grass species between burnt and unburnt site was done and the results show *E, inamoena, sedges, I. fasciclatum,* and *H. contortus* with high values of density/ha in burnt site indicating high dominance in the area. In contrast, *C. immense* and *M. caffra* presented high values of density/ha in unburnt site. However, *B. erusciformis* and *S. pyramidal is* presented equal values of density/ha in both sites. Details are on table 3: Although *sedges* and *E inamoena* ranked high in both sites, burnt sites recorded high values of density than unburnt site.

The succession of each grass species are equally shown on table 3 and 4. Results show four (4) grass species in climax succession in unburnt site while 10 grass species were recorded in burnt site. Grass land with high number of grass species in category of succession is described as bad range land condition as it is not preferred by grazers and they do not allow other new grass species to come.

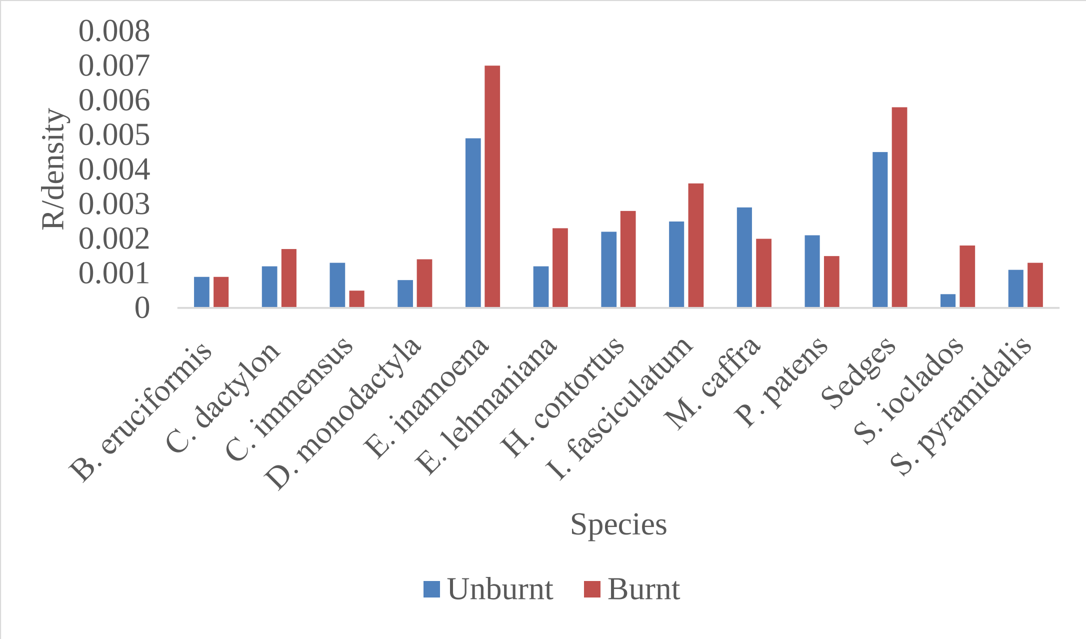

Figure 13: Showing relative density values of common species

Table 3: Ecological and succession status of grass species in unburnt site.

Name of the species	**Ecological status**	**Succession status**
Leersia hexandra	X	x
Ischaemum fasciculatum	Increaser I	Climax
Echinochloa colona	Increaser II	Pioneer
Pennsetum macrourum	Increaser I	Climax
Sedges	X	x
Heteropogon contortus	Increaser II	Subclimax
Microchloa caffra	Increaser II	Pioneer
Eragrostis lehmamania	Increaser II	Climax
Digitaria monodactyla	Increaser II	Subclimax
Perotis patens	Increaser II	Subclimax
Eragrostis inamoena	Increaser II	Subclimax
Cynodon dactylon	Increaser II	Pioneer
Brachiaria eruciformis	Increaser II	Pioneer
Sporobolus pyramidalis	Increaser II	Subclimax
Acroceras macrum	Decreaser	Climax

Cyperu immensus	X	x
Sporobolus ioclados	Increaser II	Subclimax

N.B: x – Value not known

Key note (Adopted from Oudtshoorn (2014).

Decreaser- Grasses that are abundant in good condition but that decrease in number when the grass land or veld is overgrazed or under grazed

Increaser I – Grasses that are abundant in underutilized veld usually unpalatable, robust climax species that can grow without any defoliation.

Increaser II – Grasses that are abundant in overgrazed grass land. They increase due to the disturbed effects of overgrazing and include mostly pioneer and subclimax species.

Increaser III – Grasses species that are commonly found in overgrazed veld. They are usually unpalatable, dense, climax grasses

Table 4: Showing plant species relative density, Ecological and succession status of burnt site of open grassland of BFP

Name of species	**Ecological status**	**Succession status**
Sedges	x	x
Eragrostis inamoena	Increaser II	Subclimax
Hyparrhnia hita	Increaser I	Subclimax
Tristachya spp	Increaser I	Climax
Tristachya leuccothrix	Increaser I	Climax
Digitaria monodactyla	Increaser II	Subclimax
Paspalum scrobicutum	Increaser II	Pioneer
Ischaemum fasciculatum	Increaser I	Climax
Micro chloacaffra	Increaser II	Pioneer
Sporobolus africans	Increaser III	Subclimax
Sporobolus ioclados	Increaser II	Subclimax
Cynodon dactylon	Increaser II	Climax
Digitaria diagonalis	Increaser I	Climax
Eragrostis lehmamania	Increaser II	Climax

Setariasphacelatassp	x	x
Sporobolus pyramidalis	Increaser II	Subclimax
Heteropogon contortus	Increaser II	Subclimax
Brachiaria eruciformis	Increaser II	Pioneer
Hyperthelia dissoluta	Increaser I	Climax
Echinochloa colona	Increaser II	Pioneer
Eragrostis superba	Increaser II	Subclimax
Themeda triandra	Decreaser	Climax
Panicum coloratum	Decreaser	Climax
Anthephora putescens	Decreaser	Climax

N.B: x – Value not known

4.3 DISCUSSION

A total of 32 grass species were identified and counted in the study area. Out of 32, 10 were common in both sites. The results further show that 8 species were absent from burnt site while 14 absent in unburnt site. This means that burnt site had high species richness than unburnt site. The absence and presences of grass species from burnt or unburnt sites could have been affected by wildfire frequency. The findings agree with the findings by Chirwa *et al.* (2015) who found that the plant species in vegetation community responded differently to wildfire frequency. Ryan & William (2011) also recorded a similar observation from his study on the effects of fire frequency in dry Miombo woodland in Gorongosa National Park in Mozambique that some plant species do not survive in regular fire prone areas due to their sensitivity to heat of fire. Tsvigu (2013) equally stated that hydrophyte species have their properties very sensitive to fire and linked the absence of *L. hexandra* in burnt site during his study in Busanga Flood Plain as a result of repeated wildfires.

Wildfires can influence the range condition of grassland ecosystem. From this study, the results show higher values of density/ha for *E. inamoena, sedges, H. contortus* and *S.ioclados* indicating their high abundance in burnt site than in unburnt site (Fig 1). The abundance of these species could have been as a result of wildfire frequency. These species are all in increaser category II of ecological status and subclimax succession. The results are similar to the findings from the study conducted in by (Tsvigu, 2013) who looked at the effect of fire on grass land in Busanga Flood Plain and recorded high density values of sedges. Tsvigu (2013) associated the high density vales of sedges to fire. As described by Oudtshoom (2014) sedges are the least preferred grazing material by wildlife animals and the high values of density/ha of sedges could result into range condition deterioration in open flooded to grass land ecosystem.

Furthermore, the results shown in table 2 indicate burnt site with 75.5% grass species in increaser II category (75.5%) and show low percentage values of grass species in decreaser and in increaser I category. A study by Teaque and Danckverts (1998) that looked at the range condition of grass land in the Eastern Cape of South Africa recoded similar results of high percentage values of grass species in increaser category II in fire prone areas. These results provide a signal that the range condition of open grassland slowly getting deteriorated. Teaque & Danckverts (1989) described any ecosystem with high percentage of grass species in increaser category II and III as deteriorating range condition. The study results also show high value of density/ha of sedge species in burnt site providing a good indicator of range condition of grassland of Busanga Flood Plain deteriorating. Sedge species, despite playing an important role in soil protection, are not highly acceptable to most grazers (Tsvigu, 2013). The dominance of sedge can lead to the disappearing of weak valuable grass species due to competition for resources such as water, light and nutrients. Razavi (2012) stated that dominant species in vegetation community have potential effects to the range condition of an ecosystem because they utilize resources and space.

Furthermore, the results in unburnt site, four (4) high palatable grass species grouped in decreaser category climax succession were recorded. These species (*L. hexandra*, *T. triandra, P. coloratum* and *A. putsescens*) were absent in burnt site (Table 2).The results are the same to the results from the study conducted by Tsvigu (2013) who classified the above grass species as palatable grass species. Grass land with a high number of grass species in decreaser and increaser I categories are regarded as good range condition (Teaque & Danckverts. 1989), On the other hand Teaque and Danckverts (1989 explained that climax and subclimax grass species play an important role in an ecosystem function of flooded grass land as it prevent soil erosion by water, wind and do prevent flooding. For example, Oudtshoorn (2014) described *L. hexandra* as a rice like grass species that grows in semi or permanent water bodies as very important grass species because its coarse leaves and extended rhizome system play an important role in protecting wet places from flooding. Furthermore, Tsvigu (2013) described *L. hexandra* and *P. coloratum* grass species as annual hydrophytes grass that are very sensitive to wildfire and they do not survive in fire prone areas because of dehydration of the environment. The reason is that during the burning of fires in plain ecosystems lower the ground elevations and subsequently, increases water depth. As a result hydrophyte grass species (*P. coloratum* and *L. hexandra)* die. The disappearing of annual hydrophyte grass species caused by wildfires may encourage the establishment and the stabilization of grass species which are in increaser category II and III (Tsvigu, 2013).

4.4 CONCLUSION

The management of vegetation communities on each particular grass land ecosystem depend on the knowledge and deep understanding on the effects of wildfire frequency on grass species variables such as species diversity, species richness and structure. This study provide the findings depicted from the study. The results from this study shows some interesting findings that are unique and require to be considered during the adoption on best fire management practices in range land management. The 28 grass species recorded present in burnt site indicate high species richness than unburnt site that recorded 17 grass species. The difference could be as result of wildfire frequency in the study area. Furthermore, the high density value of *E. inamoena* (0.007/ha) and *sedges* (0.005/ha) in burnt site indicate high dominance of species in fire prone area. The dominance of sedges in an grass land have potential to reduce weak and vulnerable valuable grass species through stiff resource competition cause range condition of an ecosystem to deteriorate. In addition the high percentage values of 75.5% of grass species in increaser II category and 4.7 % of grass species in increaser III category in burnt site indicator that wildfire frequency is a great threat to range condition in rangeland management.

Therefore, the results provide adequate information that is believed to be of great value to protected area Managers and other stakeholders in adopting best fire management practices required to effectively manage range condition of grass land ecosystem. The data is expected to act as baseline for future research.

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CHAPTER 5: GENERAL CONCLUSION AND RECOMMENDATIONS

The study attempted to address the gap that existed by not understanding the effects of wildfire frequency on species composition and structure of vegetation communities of Busanga Flood Plain. Two vegetation communities namely termitaria and open flood grass plain were investigated and the study produce unique results.

5. 1 TERMITARIA WOODLAND

The result of the study show a total of 65 plants species in both burnt and unburnt sites and 25 were common in both sites while 30 were absent in burnt site. The study also show fire sensitive plant species such as *F. abovata, B. massaiensis* and *S. spinosa* which were absent in burnt site. The results show statistical difference of species diversity between the sites ($P < 0.05$). From the study unburnt site recorded high species richness (19.47) than burnt site with (7.14). However, with regard to Species similarity Index, the result show 0.51 depicting the similarities in species composition between the two sites may be as a result of 25 pant species being common. Furthermore the results show dominance of C *adenogonium* in both sites although it recorded high in burnt site. Other species such as *K .Africana, V. infausita, M.obtusifolia and T. sericea.* In contrast *B. petersiana* dominated unburnt site.

5.2 OPEN FLOODED GRASS LAND

The study results on open grass land reveal 32 grass species which identified, counted and recorded in both sites. Out of 32, 10 were common in both sites, 8 were absent from burnt while 14 were absent from unburnt. Furthermore, the results show high percentage value (75.5%) of grass species in increaser II category in burnt site than in unburnt site with 56.53%. The unburnt site show13% of grass species in decreaser category and 28 % in increaser I category higher than burnt site with 7. 14% and 14.28% respectively. The results further show high density values of *sedges* and *E. inamoena* in burnt site implying that wildfire frequency may have an influence on range condition of the wet grassland ecosystem of BFP.

Therefore, the study has generate data / information that will be of great value to enhance the level of understanding on how wildfire frequency affects species composition and structure and as well as range condition of termitaria and open grassland of Busanga Flood Plain respectively. The data will help Park management staff to adopt the best practice of fire management to maintain open flooded grass land vegetation of Busanga flood plain in Kafue National Park.

5. 3 MANAGEMENT IMPLICATIONS

Fire management is one of the key management component in the protection and management of vegetation communities of Busanga Flood Plain. The effective implementation of fire management practices highly depend on the deep understanding of how wildfire frequency affects species composition and structure of vegetation communities in the area. This study provide such information that is believed to be of high value to Park management staff and other stakeholders in adopting best fire management practices during the use of fire as a management tool to manage termitaria and open flooded grass land vegetation of Busanga Flood Plain. The data is also expected to be of a great value in vegetation monitoring and act as baseline data for future research in the same area.

5.4 RECOMMENDATION

The study forward the following recommendations

- ✓ To implement early burning in areas with tree species which are fire sensitive.
- ✓ To implement vegetation monitoring programs to keep track changes on species composition and structure in both vegetation types
- ✓ To understand species composition and structure in order to adopt best fire management practice
- ✓ To undertake a study which will look at the effects of wildfire frequency variations on vegetation species composition and structure of Busanga Flood Plain.