CHAPTER ONE

INTRODUCTION

1. Introduction

Sudan is the third largest country in Africa. It had been the largest until the secession of South Sudan in 2011(UNDP, 2013). According to (UNEP, 2012) the population of Sudan has grown, and continues to grow rapidly from 10.1 million in 1955/56 to 39.2 million in 2008, the average annual growth rate of 2.6 percent. The total population of the country before separation of South Sudan was 28292000 out of which 18636000 (65.9%) live in the rural areas. Forests play an important role in the Sudanese welfare, in conserving the environment and the contribution to the country's national economy. The forests and woodlands covered 17.68% of the total land area of Sudan (FAO, 2000). Forests in the Sudan covered about 10 % of the total area of the country after separation (FNC, 2015). The forests in semi-arid Africa are disappearing at a rapid rate, because of many factors, among which is the need for new agricultural land and, to some extent, also for fuel wood. In general very little has been done with respect to utilization, conservation and the management of the forests for sustained and improved yield (Fries, 1992). The fundamental goal of biodiversity conservation is to support sustainable development by protecting and using biological resources in ways that do not diminish the world's variety of species or destroy important habitats or ecosystems (Reid et al.,1993). Forest management activities strongly affect regeneration success and site preparation clearly improves seedling establishment (Ackzell, 1993).There are large areas of forests that have been destroyed, fragmented and converted to pasture for cattle production, resulting in the loss of plant and animal diversity and the disruption of ecosystem processes (Kaimowitz, 1996 and Houghton, 2003). Natural regeneration is the process by which old trees and shrubs replace themselves without human intervention (Steward , 2004). It usually refers to the process by which native species return to area of land that has been degraded.

The greater Darfur region which was once an independent sultanate underwent a series of divisions and segmentation, as a result of which it is now composed of five states. Central Darfur is one of the recently established state with headquarters at Zalingei town. Anthropogenic factors and natural disasters have collectively impacted the natural resources of the region over the years. The current Darfur conflict had its direct and visible impacts on the natural resources and in particular forests and woodlands of the whole region and Zalingei area in particular. Different people view the status of woody vegetation and natural regeneration in the area differently, some people think that the fleeing of communities to IDPs camps gave chance to the natural regeneration to establish at alarming rate and there are some areas that became closed forest as a result, others think that the long and vast empty areas left chance for wood traders to fell large areas and thus making the environment not conducive for natural regeneration. Having that in mind, it is important systematic research to prove whether or not natural regeneration is happing and to know the trend of woody vegetation growth, diversity and densities at the study area.

1.1. Problem statement and Justification

The vegetation composition of a particular area is the result of interaction of species with varying ecological tolerances and requirements, and any changes in the physical or biotic environment that alter this balance of interactions cause change in vegetation with time (Ikram, 1997). Several parts of the Sudan have been devastated by decades of conflict, which have resulted in the destruction of physical and human resources, and erosion of institutions and social capital. The removal of trees in Sudan has a very negative impact, including increased land and water degradation, and the loss of livelihoods from forest ecosystem services (UNEP 2007). Darfur's environment is particularly resource poor and suffers from very high natural variability and unpredictability (UNEP 2007). Compared to previous studies that have been conducted in the region such as (Smith, 1949), Lebon (1965), (Wickens 1976), (Maydell, 1986), (Badi, *etal* 1989), (El Amin, 1990) and (Adam, 2003**),** it has been noted that there is a change in the tree species composition in Sudan.The various outbreaks of violence, including on going instability in the Darfur region, have forced millions of people to flee their homes and left millions of others facing extreme poverty. The impacts of conflict has been exacerbated by recurrent hazards, including droughts, floods, and outbreaks of animal diseases, which worsen the food security situation throughout the Sudan (FAO, 2010). It has been estimated that deforestation is proceeding at a rate of 30 times greater than reforestation in many sub-Saharan countries (FAO, 1997). It has been a long time ago speculated that by the year 2010, the demand for fuel wood in Africa would exceed 953 million cubic meters a year (FAO, 1986). Comprehensive critical review of the desertification-climate interaction is presented by Williams (1996). The climates of arid and semi-arid lands are highly variable, particularly in rainfall. Low and erratic variation of rainfall is characteristic of dry lands which have no particular rainfall distribution pattern (Loockwood, 1988; Mustafa, 2007). High aridity is an adverse climatic condition that creates fragile ecosystem, which can easily be upset by adverse human activities. The spatial and temporal variation of rain fall determines the density and composition of the vegetation (Hodgkinson, 1992). The Sahelian droughts which have been observed in the late sixties through the seventies, eighties and nineties in addition to the drought episodes which hit the region and Darfur in particular, had caused considerable changes in the plant species composition and structure as well. These natural factors have accelerated and affected human activities and caused a lot of population movement within and outside Darfur. As a result of these major changes, peoples livelihoods have been affected greatly and many of them became more dependent on the natural environment. the current Darfur conflict has also impacted the natural environment greatly however, it is not known if the impact is all negative because some people report on improvement of natural regeneration, while others describe it very negatively. Sudan has never had a truly national forest inventory. In Sudan there is a few Forest wood lands reserves, and the unreserved land are continuously being encroached upon by agriculture and urbanization or otherwise degraded by uncontrolled felling. The forest reservation process which started in 1923 was only able during 70 years to settle and finally gazette 1.3 million ha, equivalent to 0.5% of the total area of the country (FNC, 1996) and Jubara (2009).This is especially important as the experience in many countries such as India indicated that it is increasingly evident that without the commitment and cooperation of forest-dependent communities, the forests of the country will remain in jeopardy (Poffenberger and Mc Gean, 1996 cited in Adam, 2003). As the Forests National Corporation (FNC) is often under-funded to take care of management of species especially in areas that are far and unreserved, local people's participation is imperative (Adam, 2003). Population growth of the rural communities and their search for subsistence income has led to massive deforestation.The natural regeneration of the forests and woodlands resources is affected by the conflict. All these factors mention above threats to natural regeneration of the woody species . The aim of this study is to assess woody vegetation and natural regeneration of woody species at the study area in central Darfur state in general and Zalingei area in particular.

1.2. Objectives of the study

- To determine the condition of the growing stock of woody species and their natural regeneration in Zalingei area.
- To measure the densities of woody species in the Zalingei area.
- To understand the development and nature of natural regeneration of forests species in the study area.

1.3. Hypotheses

- The woody species and natural regeneration of woody species at the study area is considerable and rejoicing.
- The woody species and natural regeneration of woody species at the study area is very poor and not promising at all.
- There is a change in the species composition and structure observed at seedlings stages.
- There is a clear and understandable relationship between natural regeneration densities and mature trees.

CHAPTER TWO

LITERATURE REVIEW

2.Climate

The climate in the Sudan is controlled by the relationships between the dry continental air flow from the North and the moist air flow from the South and southwest, originating from the Atlantic and Indian oceans (Badi et al, 1989). These two air flows control the distribution of the rainfall over the various regions of the country. Accordingly, the fall duration and the length of the rainy season gradually increase from North to the South throughout the country, though the effect of local topography namely Jebel Marra and Imatong mountains can have significant effects. The average rainfall ranges from 4 mm at Wadi Halfa in the north to over 2000 mm at Giloin the Imatong Mountains in the south (Badi et al, 1989). The climate is generally characterized by cold dry winter and hot rainy summers. The beginning of the rainy season is typical of the semi-arid savannah which is marked by great irregularity. The average temperature does not vary significantly between months especially during the rainy seasons, where the relative humidity is high. The potential evapotranspiration is about 170cm/annum, with maximum of 20 cm in May and minimum of 8cm in December and January. The annual mean temperature ranges from 24C^{o}-26C^{o}. The hottest month during the year is May (17C^{o}min-42C^{o}max), while the coldest month is January (7C^{o}min-34C^{o}max). In Zalingei, the temperature in the Wadi bed can be as much as 4C^{o} lower than the recorded screen temperature in the town. Frost can be expected to occur along the coarse of Wadi Azum. Localized hail storms may also be expected **(**Wickens, 1976**).** Table (1) and figure (1),(2) show the rainfall and temperature and relative humidity in the study area.

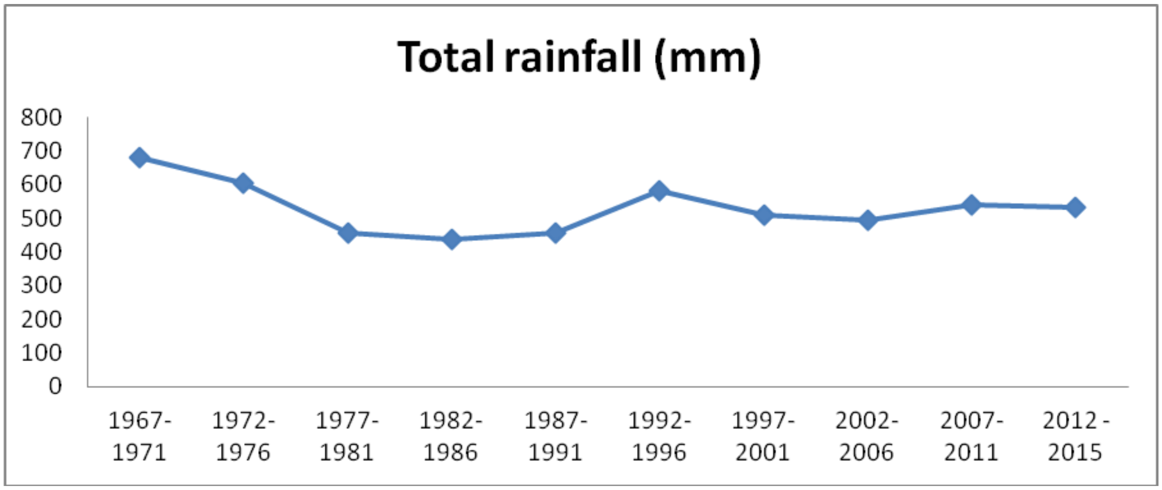

Fig .1. The rainfall (mm) in the study area.

Source: Meteorological station (Zalingei , 2015)

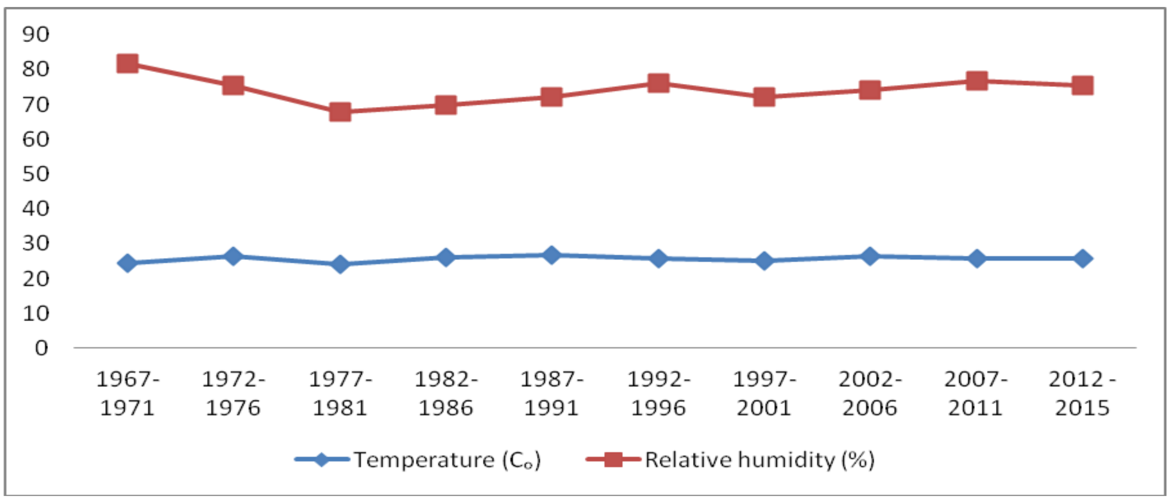

Fig.2. The temperature (C°) and relative humidity (%) in the study area.

Source: Meteorological station (Zalingei , 2015)

2.1. Land use and governance system at the study area

The greater Darfur region has been divided into five States in 2012, with a Governor (Wali) for each State. Central Darfur State which was splitted from the West Darfur state, is composed of eight localities. Zalingei locality is made up of three administrative units namely; Abata , Zalingei and rural traije. The native adminstartion is widely present at the locality down to the administrative units and villages. Generaly the native administration system follows the hierarchy of Sharti(chaiman of local leadership), and in the case of central Darfur State, the Dimangawi who is the highest levels in the system, and is supported by a group of Omdas (chief over sheikhs) who are in turn supported by sheikhs (village heads), the village leaders are entrusted with responsibilities for administrative and judicial function within their own areas. The Omda is the judicial authority for a group of villages. This native administration system of Dimangawi, Shartai, Omda and sheikhs originated early before the 1900s and presently provides support to the localities (Elsiddig, 2007).

Traditional rain fed agriculture is the major land use system at the study area. It is a land rotation cultivation system, like any shifting system of cultivation; the land rotation system is based upon a decline of soil fertility. The major crops at the study area are sorghum and millet. On the Wadi banks and under irrigation system onions, tomatoes, eggplants, okra, sweet potato, and sugar cane are widely produced. Currently, rain fed cultivation and irrigated farming is only practiced in small pockets close to settlements due to insecurity and displacement, in some areas of the study area, some people go camping during the rainy season and return to IDPs camps after harvest a process that is locally called agricultural return or seasonal return, in other settings land owners set local agreements with others who have means of staying in the country side to crop their land and share harvest at agreed percentages (Hadi 2004).

2.2. Vegetation

2.2.1. Definition of forest vegetation

One of the key biophysical indicators for assessing forests and woodlands is the tree canopy cover which allows to characterize the forests and tropical savannas ecosystems, estimate woody biomass production and monitor carbon emission/sequestration balance in the context of global environmental change (Helldén, 1987). The Food and Agriculture Organization of the United Nations (FAO) has been assessing the world's forest resources at regular intervals, its Global Forest Resources Assessments (FRA) are based on data provided by individual countries, using an agreed global definition of forest which includes a minimum threshold for the height of trees at 5 m and at least 10 per cent crown cover (canopy density determined by estimating the area of ground shaded by the crown of the trees) and a minimum forest area size of 0.5 hectares. Urban parks, orchards and other agricultural tree crops are excluded from this definition such as are agroforestry systems used for agriculture. According to this definition there are at present just under 4 billion hectares of forest in the world, covering in all about 30 per cent of the world's land area (FAO 2006). FAO (2006) reached a reliable and acceptable definition of the land cover and the extent of forest and other wooded land of Sudan, which includes five main categories: Forest, other wooded lands, other lands, other lands with tree cover and inland water bodies (Table 1). The crown cover threshold and the land use criteria are, in most cases, the most critical factors defining forests. The 10 per cent threshold of crown cover encompasses both open and closed forests. The term closed forest refers to areas where tree cover exceeds 40 per cent while the term open forest refers to areas where tree cover is between 10 and 40 per cent.

Table 1. Forest Resource Assessment definitions (FRA) for 2005.

Category	**Definitions**
Forest	Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use.
Other wooded land	Land not classified as "Forest", spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds *in situ*; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.
Other land	All land that is not classified as "Forest" or "Other wooded land".
Other land with tree cover (Subordinated to "Other land")	Land classified as "Other land", spanning more than 0.5 hectares with a canopy cover of more than 10 percent of trees able to reach a height of 5 meters at maturity.
Inland water bodies	Inland water bodies generally include major rivers, lakes and water reservoirs.

Source: (FAO, 2006)

In order to assess the state of the world's closed forests, the United Nations Environment Program (UNEP) has recently employed other definition criteria including a minimum crown cover of 40 per cent. It has also used remote sensing to ensure compatibility across countries. Forest is defined as ecosystem with a minimum of 10 per cent crown cover of trees and/or bamboos, generally associated with wild flora, fauna and natural soil conditions and not subject to agricultural practices (Elamin and Ce'sar 1994).Vegetation cover in term of the types, forms, and density depend on the environmental and geomorphologic conditions, the vegetation cover occurring in the form of growth form of trees, shrubs, and herbs. More generally it is referred to as distribution and abundance of vegetation.

Vegetation extent is defined as all plant life in a given area (Thackeray and Lesslie, 2005). Matthews (1982), reported that, terrestrial vegetation is an important factor in the radiation balance of the earth, and in numerous biogeochemical cycles related to climate maintenance and climate change. Forest ecosystems are frequently characterized in terms of their species and genetic composition (Hunter, 1999).

According to Franklin et al., (1988), the forest ecosystem is described by attributes relating to the following aspects:

- Structure: Refers to the spatial arrangement of the various components of the ecosystem, such as the heights of different canopy levels and the spacing.
- Function: Refers to how various ecological processes, such as the production of organic matter, are accomplished and to the rates at which they occur.
- Composition: Refers to the identity and variety of ecosystem components, as characterized by species richness and abundance.

In literature several definitions of vegetation condition are being used for different purposes and at difference scales and this largely depend on the management objectives. In general, as vegetation is subject to modification by natural cycles and trends, and by human activities. A reliable estimate of the past and present status and distribution of vegetation, in a form which is accessible, manageable, and applicable to a variety of trees at study area is necessary.

2.2.2. The vegetation of the world

Worldwide, in 1994 more than 26,100 plant species were threatened (Dallmeier, 1998). The total area covered by forests worldwide is approximately 3869 million ha, almost one-third of the world's land area, of which 95 per cent is natural forest and 5 percent is plantation forest; out of this, 17 % is in Africa, 14% in Asia, 27% in Europe, 14 % in North and Central America and 23% in South America and 5% in Oceania (FAO, 2001a). The five most forest-rich countries (Russian Federation, Brazil, Canada, the United States of America and China) account for more than half of the total forest area. Ten countries or areas have no forest at all and an additional 54 countries have forest on less than 10% of their total land area. In 2010, the estimated total growing stock in the world's forest amounted to about 527 billion m^3, this corresponds to an average of 131 m^3 per hectare. The highest levels of growing stock per hectare were found in central Europe and some tropical areas (FAO, 2010).

2.2.3. Vegetation cover of Sudan

The combination of rainfall and soil texture determines the distribution of vegetation cover in Sudan (Smith 1949; Harrison and Jackson 1958). Sudan forests extend across several agro-ecological zones, which imply the existence of a diversity of fauna and flora species that contribute directly or indirectly to the sustainable livelihood of local communities (El Amin, 2000). Ecologically the Sudan can be classified into five main vegetation zones. The description provided by Harrison and Jackson (1958) has been reviewed and provided in various text (Sahni, 1968 ; Bayoumi *et al*, 1984; Gorashi, 1998; Elsiddig *et al*, 2007). According to Sahni (1968) the principal vegetation divisions are as follow:

i. Desert: vegetation is virtually absent, except along wate rcourses. The average rainfall of this region is less than 75 mm.

ii. Semi-desert: the annual rainfall in this region ranges from 75 mm to about 300 mm. The vegetation in this formation has been divided into subdivisions:

- *Acacia tortilis* subsp. *raddiana – Maerua crassifolia* desert scrub.
- Semi-desert grassland on clay.
- Semi-desert grassland on sand.
- *Acacia mellifera – Commiphora* desert scrub.
- *Acacia glaucophylla – Acacia etbaica s*crub.

iii. Low rainfall woodland savannah: the approximate boundaries of this formation are between 300 mm and 800 mm. This division is divided into two extreme soil types:

- Low rainfall woodland savannah on dark cracking clays in the east.
- Low rainfall woodland savannah on stabilized sand dunes in the west.

iv. Montane vegetation.

v. Riverain vegetation: along the River Nile, the Blue and White Niles and their tributaries.

Forests cover about 29.64 % (74.1 million hectares) of the total area of the country (FNC, 2004). The estimated forest area of the Sudan is approximately 67.6 million hectares out of a land area of 237.6 million hectares representing 28% of that area (FAO, 2005a). Reserved forests amount to 837 forests distributed all over the states of the country, they constitute a great potential for biodiversity conservation (Gorashi, 1998).

AFF (2011) reported that ecological classification of forests and woodlands in the republic of Sudan is illustrated in the table 2 below.

Table 2. Area of vegetation zones and their percentage of total area of Sudan

Desert	Semi-Desert	Low rainfall savannah	High rainfall savannah	Special areas	Mountain vegetation	Flood region	Total
717 (38.6)	486 (26.2)	507 (27.3)	17 (0.9)	119 (6.4)	4 (0.2)	7 (0.4)	1 857 (100)
Arid and semi-arid			Sub-humid			Humid	
92.1			7.5			0.4	100%

Note: All figures in 1000 km² with % of total in brackets

Source: AFF (2011)

It is estimated that there are about 533 tree species in Sudan, 25 species of which are exotics. In addition, there are about 184 shrub species, 33 of which are exotics. There are some important trees species that are under pressure and endangered as a consequence of repeated droughts or over-cutting and felling. Some of these do not have the ability to regenerate such as *Adansonia digitata, Borassus aethiopium, Hyphaene thebaica , Cordia abyssinica , Dalbergia melanoxylon, Grewia tenax , Anogeissus leiocarpus , Lonchocarpus laxiflorus , Ziziphus spina-christi and Khaya senegalensis.* There are many others that are endangered to a less degree (Gorashi, 1998).

2.2.3.1. Degradation of Sudan's vegetation

There is a fast rate of forest resources depletion especially in developing countries. In Sudan and in developing countries forest land is systematically cleared for agriculture, residential settlement and infrastructures associated with development projects. In addition, wars and conflicts together with insufficient reforestation led to decrease of forest cover (FAO, 2006). Many studies curried out in Sudan agreed that agricultural expansion has resulted in forest cover decline. Elsiddig *et al,* (2007), estimates that the deforestation rate continues at an average of 0.455 million hectare per year. The forests cover deterioration is continuous, according to Badi *et al.* (1989) who reported that forests in Sudan in 1981 were estimated to cover 559000 km^2 (55,900,000ha), while the World Bank (1995), reported that it has been reduced to 454000 km^2 (45,400,000ha) at average loss of about 7.5 km^2 (7500ha) per year. Forest Resources Assessments (FRAs) started to cover Sudan forests in more details. The latest assessment work, was released in 2005, is set out in Table (3).

Table 3. Forest Resources Assessments of Sudan.

Categories	Area (1,000 hectares)		
	1990	2000	2005
Forest	76.38	70,491	67,546
Other wooded land	-	54,153	-
Forest and other wooded land	76,381	124,644	67,546
Other land	161,219	112,956	170,056
Total land area	237,600	237,600	237,600
Inland water bodies	12,981	12,981	12,981
Total area of country	250,581	250,581	250,581

(FAO 2005).

According to the **AFF** report **2011**, the total area of Sudan and the area of vegetation cover is reduced after cessation of South Sudan (Table 4).

Table 4. Vegetation cover of Sudan after separation of South Sudan

Percentage of forest cover	**Percentage of vegetation cover**	**Vegetation cover / million km^2**	**Total area / million km^2**
11.6	32%	51.96	187.8
-	68%	109.62	68.2
29.4	100	161.58	256

(**AFF, 2011**).

According to **AFF** report **2011** Sudan forest cover as can be seen in figure 3 below.

Fig .3. Sudan forest cover after separation (AFF , 2011)

2.2.4. Vegetation cover of the study area

According to the modified version of Harrison and Jakson's map by (Wickens, 1976), Zalingei area lies in the thorn Savanna and scrub on clay soils and deciduous savanna wood land on latosols. For the first zone, the average rainfall range from 400 to 800 mm, pure stands of *Acacia mellifera* scrub occur between 400 and 500 mm with *Acacia seyal* and *Balanites aegyptiaca* dominant in the higher rainfall areas. Whereas for the second zone, the average rainfall ranges from 450 to 1300 mm annually. Here, *Combertum glutinsum, Anogeissus leiocarpus ,Terminalia brownii, Albizia amara* subsp. *sericoaphala, Khaya senegalensis* and *Isoberlinia doka* are the major trees (Figure 8). Brief description summary from (Hunting Technical Services ,1968) of the major low land vegetation units is given, followed by a more detailed description for the principal associations of the lowland plain as follows:

- *Acacia mellfera* on hill soils of the basement complex.
- *Acacia senegal- Combretum glutinosum* on Aeolian.
- *Acacia seyal- Balanites aegyptiaca* on clay soils.

HTS maps for the study area (1958 and 1983) explain that the dominant trees species at Zalingei and Teraje as a mosaics are *Anogeissus leiocarpus / Albizia amara* in the area as general , *Balanites aegyptiaca/Ziziphus spina-christi* on the upper terraces and *Faidherbia albida* on the lower terraces . The difference between Zalingei and Teraje is the existence of *Khaya senegalensis* near Wadi Gallabat in Traje, but in Abata area the dominant tree species was a mosaics of *Anogeissus leiocarpus / Acacia seyal* in the area as general , *Balanites aegyptiaca / Ziziphus spina-christi* on the upper terraces and *Faidherbia albida* on the lower terraces (Figure 5 and 6). According to Sudan forest cover produced by FAO (2006). The study area lies in the 100% forest area (figure 4).

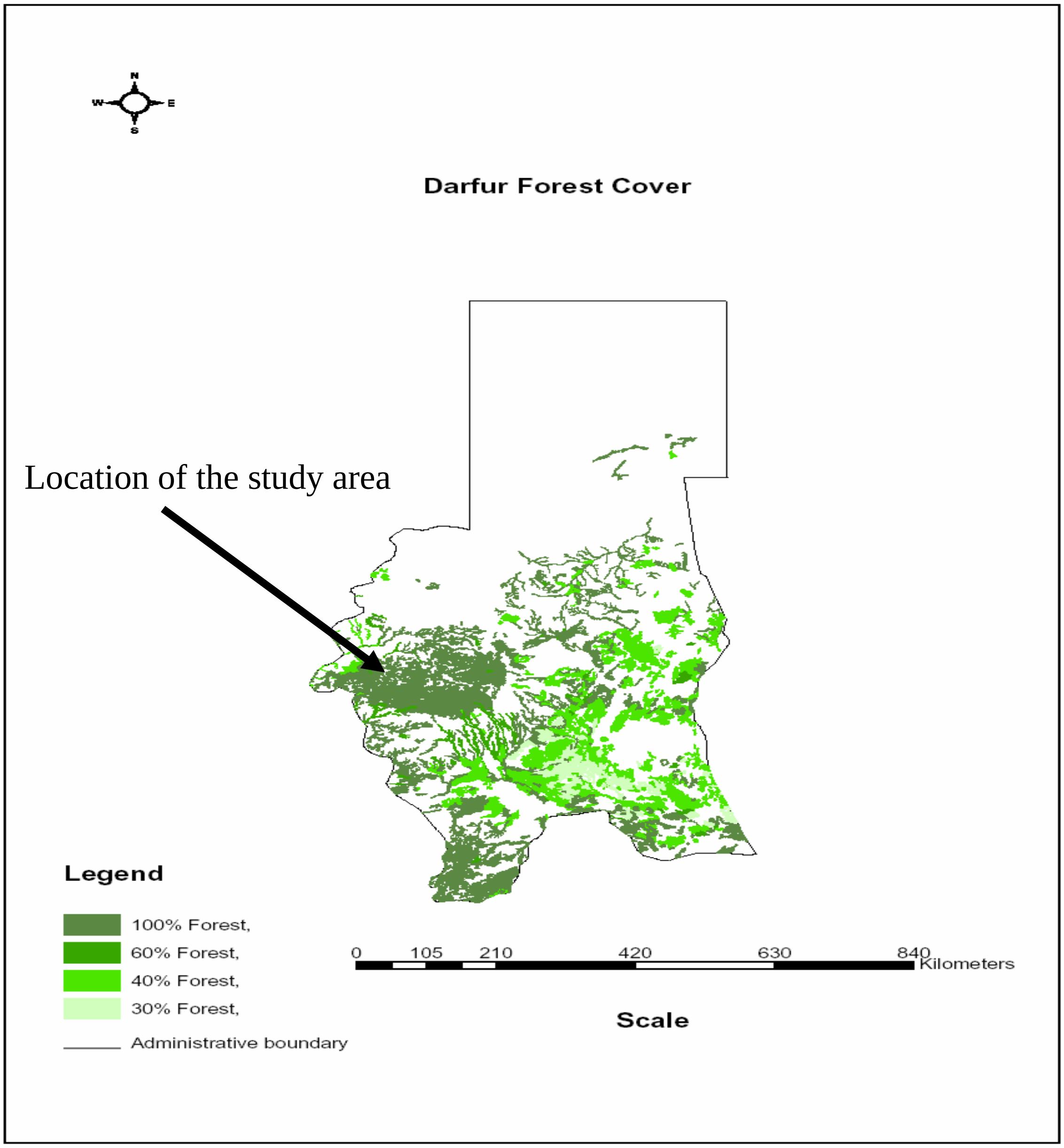

Fig. 4. Darfur forest cover (FAO ,2006).

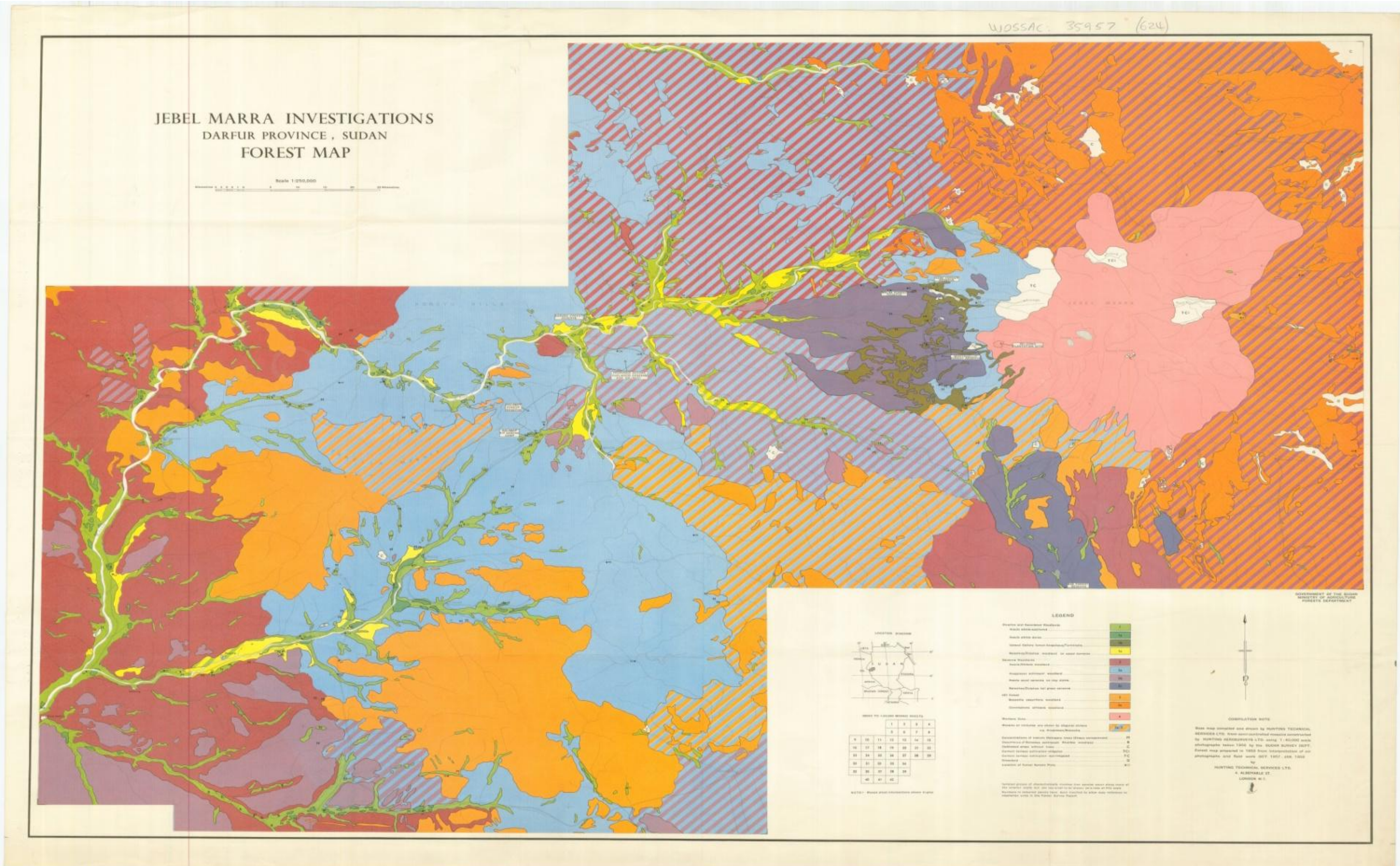

Fig. 5. The vegetation of the study area in the year 1958 (Hunting Technical Services , 1958).

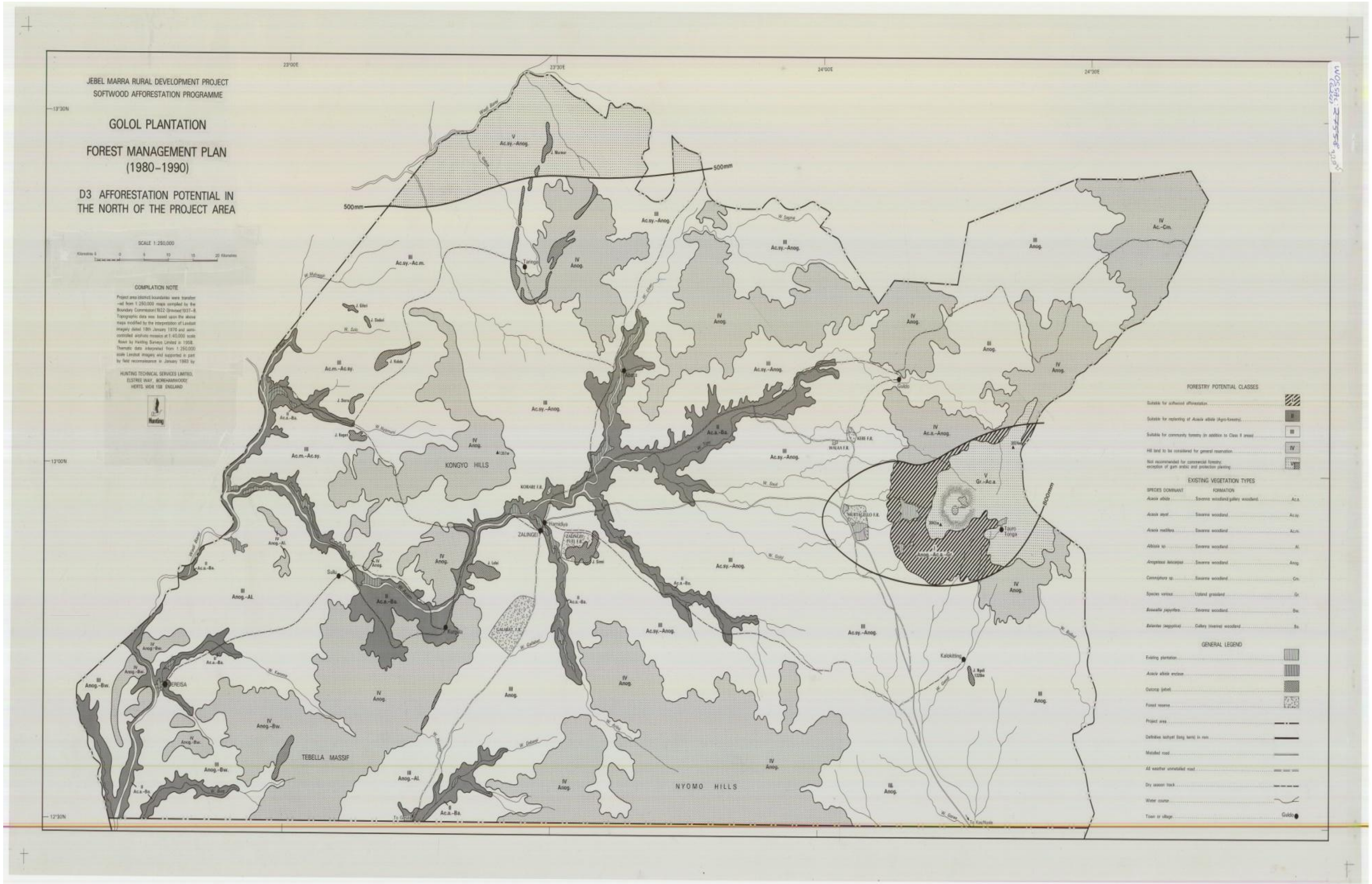

Fig. 6. Soft wood afforestation program implemented by JMRDP (Hunting Technical Services, 1983).

2.2.4. 1.Degradation of vegetation of study area

Darfur has lost more than 30% of its forests since Sudan's independence and rapid deforestation is on going. According to UNEP (2007), Jebel Marra, Western Darfur changed from closed forest to open forest land and burnt areas, Timbisquo, Southern Darfur changed from closed forest and wooded grassland to burnt areas and rain-fed agriculture. Um Chelluta, Southern Darfur the closed forest replaced by burnt areas, pasture and rain-fed agriculture (Table 5 Figures 9).

Table 5. Vegetation degradation of some areas of Darfur

Study area	Original and final forest and woodland cover	Annual linear deforestation rate %+ period loss % in barckets
Jebel Marra, Western Darfur	50.7 to 35.8 from 1973 to 2001	1.04 (29.4)
Timbisquo, Southern Darfur	72.0 to 51.0 from 1973 to 2005	1.33 (29.1)
UmChelluta, Southern Darfur	23.8 to 16.1 from 1973 to 2000	1.20 (32.4)

Source: (UNEP, 2007)

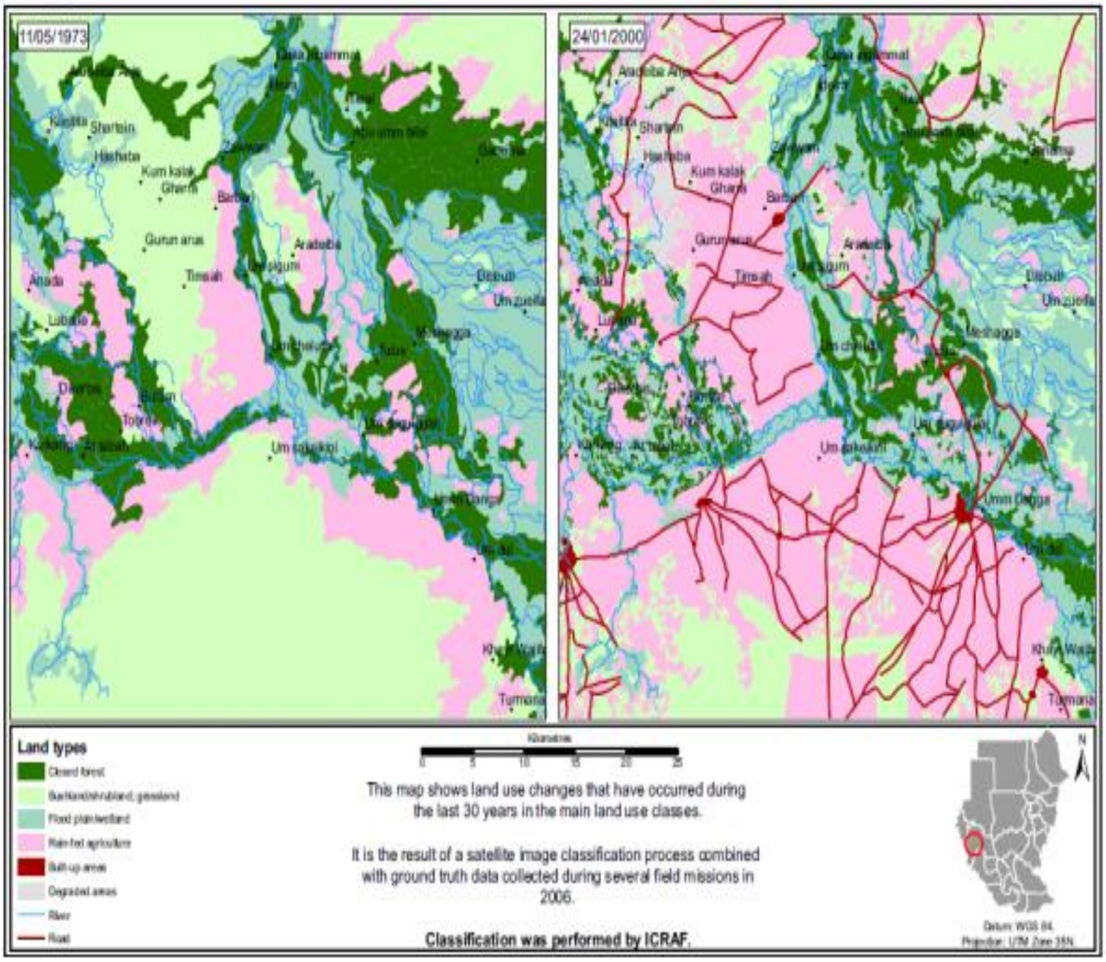

Fig. 7. Vegetation degradation of some areas of Darfur

Source: (UNEP, 2007)

Recently (DRC and U of Z, 2009) reported that there is only twenty trees species at Wadi Salih and Azum locality which reflected low biodiversity, the number of trees per unit area were found to be 42trees/ ha and the natural regeneration was found to be 8598 seedlings/ha, the average wood volume per tree was calculated as 3.4 m^3 while the overall crown coverage was calculated as 5.1%,. The same study revealed that, the dominant tree species are *Albizia amara* and *Balanites aegyptiaca* . Remarkable forest change was reported by (DRC and U of Z, 2009) whose indicated that *Anogeissus leiocarpus*, which was a dominant species at the study area since long time ago is disappearing, and is being replaced by *Albizia amara*. *Faidherbia albida* at Wadies especially at

Wadi Salih area where only 7 and 4 trees per hectare were recorded at Wadi Jiddo and Taringa respectively, but at Zalingei 9 trees/ ha were recorded (DRC and U of Z, 2009). Goda (2005) indicated 11 *Faidherbia albida trees /ha* at Zalingei area. Earlier publications cited by (DRC and U of Z, 2008) and Goda (2005), showed declining trend of *Faidherbia albida* from 72 trees/ha in 1966 to 51 trees/ha in 1968, then to 20 trees/ha in 1977, and lastly 16trees /ha in 1985.

2.2.5. Factors affecting vegetation

The Sudan population is increasing and so is the demand for improved standard of living, both of these trends entail increasing demand for natural resources products, particularly forests and agricultural lands. Protection of these resources becomes more and more important, if there is to be sufficient wood raw material to satisfy the ever increasing demand of the increasing population (Elsiddig 2007). In general vegetation degradation is the quantitative and/or qualitative reduction of the vegetative cover resulting from various factors including human induced activities and severe prolonged droughts under poor land resources management (Mustafa, 2007).

2.2.5.1. Anthropogenic factors

At the arid and semi-arid zones in developing countries, e.g. Sudan, the relatively poor population in the rural areas seeks sustenance from the natural resources of their fragile ecosystem. They cultivate marginal lands growing their stable food. They cut wood for fuel and for building their huts and make enclosures for their animals. Their small herd grazes around the villages and at water points. Thus, the adverse human activities include: over and irrational cultivation of marginal lands overgrazing, wood cutting deforestation , uprooting of shrubs, burning of grasslands, forest and shrub, lowering of the ground water due to excessive water use. These activities cause degradation of the land, which is steadily accelerated due to increasing human and livestock pressures. These inevitable adverse activities prompted by the poverty of the local communities accentuate desertification, poverty, and reliance on the fragile ecosystems; thus completing a poverty vicious circle (Mustafa, 2007). The vegetation of the Sudan was affected by human activities and changes in land uses. Vast areas covered with *Acacias* had disappeared due to cultivation, grazing, felling of trees and natural causes. Desertification, drought and socioeconomic factors have contributed to change in densities and distribution of tree species (El Khalifa et al. 1998). The causes of desertification/land degradation, among other things, could be traced back to the nation's quest of fuel wood (Ayoub 1998). It is reported that the Sudan derives more than 75 % of its energy requirements from fuel wood, estimated at 22 million m^3 per year (WRI 1994). Ayoub (1998) estimated this to be equivalent to about 400 million Acacia trees being cut annually. Another cause of desertification/land degradation in the Sudan is the rangelands cleared for mechanized rain-fed agriculture and shifting cultivation. According to FAO (2001a), during the 1980s and 1990s there was a rapid expansion of rain-fed mechanized cultivation with the aim of attaining self-sufficiency in food production. According to Salih (1987), the land area for mechanized agriculture increased from about 2.0 million ha in 1954 to about 14 million ha in 1994, a rate of 300,000 ha per year. Large scale mechanized farming has been the main factor contributing to deforestation and consequent land degradation (FAO, 2001b). Studies by Ayoub (1998) conclude that overgrazing (47%), improper agricultural practices(22%), deforestation for firewood and urban demand for charcoal (19%), and overexploitation of vegetation for domestic use (13 %) are the major causes of land degradation in the Sudan. Similar findings by the World Bank (1984) confirmed that in Kordofan and Daurfur about 88,000 ha of woodlands are cleared each year for conversion to mechanized agriculture. An estimated 42,000 ha of this land in these regions, after being cropped continuously by sorghum for three to four years, has become degraded, barren and then been abandoned. According to the FAO Global Forest Resources Assessment (FRA) , the total forest cover of Sudan is estimated as 61,630,000 ha and constitutes 26 percent of the country's land area of 237,600,000 ha. The forest cover area in the Sudan decreased from 71,220,000 ha in 1990 to 61,630,000 ha in 2000 (FAO 2001b), a decrease of 959,000 ha/year; 90% of which is for fuel and charcoal making (ADB and FAO 2003). The annual rate of forest cover change in the Sudan is -1.4%, and in concrete terms Sudan recorded an annual loss of 959,000 ha of forest cover from 1990 to 2000. As of 2000, Sudan had 2.1 ha of forested land per capita. In 2000, Sudan registered 60,986,000 ha natural forests and 641,000 ha of forest plantations. The volume of wood was estimated at 9 m^3 ha-1 corresponding to wood biomass of 12 t/ha on average in 2000 (FAO 2001b).

2.2.5.2. Natural factors

The climate of arid and semi-arid lands, are highly variable, particularly in rainfall. Low and erratic variation of rainfall is a characteristic of dry lands, which have no particular rainfall distribution pattern (Loockwood, 1988). Periods of prolonged droughts like the great Sahelian drought 1968-1973 may occur and induce high aridity, which is an adverse climatic condition that creates fragile ecosystems, and can easily be upset by adverse human activities. The spatial and temporal variation of rain fall determines the density and composition of the vegetation (Hodgkinson, 1992).

2.3. Natural regeneration

2.3.1. Definitions of natural regeneration

'Natural regeneration' refers to the natural process by which plants replace or re-establish themselves. Cremer (1990) defines natural regeneration as reproduction from self-sown seeds or by vegetative recovery (sprouting from stumps, lignotubers, rhizomes or roots) after the tops of the plants have been killed by fire, cutting, browsing, etc. Temple and Bungey, (1980) define it as "regrowth which occurs naturally after stress or disturbance. It may be growth from seed of either pioneer or permanent species, or growth from lignotuber (e.g. Eucalyptus spp.), rootstock (e.g. Melaleuca spp.), etc; remaining in the ground". Planting seedlings and direct seeding are alternative methods of reestablishing vegetation (Seydack *etal*, 2000) defined the regeneration individuals as plants between 50 cm and 1.5m. in height. Seedlings were identified as those individuals without any connection with an adult. The natural regeneration is considered the backbone for the continuity and sustainability of the forest. Uneven aged stands have at least three well-represented and well-defined age classes, differing in height, age, and diameter. Often these classes can be broadly defined as: regeneration, pole, and mature. It is necessary to know the different life stages of regeneration for demographic study. Seedling stage is defined as first-year germinant with cotyledons, whose size never exceeds 10 cm according to field measures. However, sterile plants without cotyledons, and taller than 10cm are considered as saplings (Closset-Kopp *et al*., 2007).

2.3.2. Physical conditions of natural regeneration

In forest stands that lack catastrophic disturbances, physical conditions such as climate, light, topography, or the ecological characteristics of trees significantly affect the temporal fluctuation of sapling population size (Connell and Green, 2000; Hall and Harcombe, 2001). Saplings adapt morphologically to light gradients; they tend to sustain vigorous growth, in height, in higher-light environments (King, 1994). Sprouting at the sapling stage maintains individuals by shoot replacement, and enables saplings to stay small until the onset of favorable conditions (Del Tredici, 2001). Seedlings and saplings react against the unfavorable conditions and in contrast they adapt morphologically or physiologically due to changes in the conditions in the surrounding (Eltahir, 2012). Mortality remains one of the least understood components of growth and yield estimation (Hamilton, 1986). The occurrence of regeneration depends on numerous prerequisites such as sufficient volume of viable seeds and appropriate climatic and edaphic conditions for germination and establishment (Lamprecht, 1989).

2.3.3. Advantages of natural regeneration

Kirkpatrick *et al*, (2000) reported that advantages of natural regeneration include good root development by native seedlings, less disturbance to soil ecology and reduced risk of soil erosion, low cost establishment, less labor and equipment and no problem of geographical origin of seeds, also it occurs from plant material that is already present so it will be best suited to the environment and it will help to protect the genetic make- up of the bush on one's property and that it is effective in re-establishing.

2.3.4. Disadvantages of natural regeneration

The disadvantages of natural regeneration are: less control over initial stocking and spacing, generally lower commercial yield, no genetic improvement or the introduction of disease resistant stock, possible delays in regeneration due to drought or inadequate seeds and the possible need for thinning to ensure good growth. Many bush species regenerate primarily from re-sprouting rather than seeds. Increasing of animal specially goat and camel nomads cause adverse damage to the tree seedling. The local cattle breeders also learned from them how to cut this species for their livestock. This loss of the species that inevitably goes hand in hand with the destruction is drastically reducing future possibilities of existence and production as well. It is therefore, necessary to investigate the natural regeneration of the species, its causes and possible options for management of the species with local people's participation (Kirkpatrick *et al* 2000).

2.4. Artificial regeneration of woody plants

Sudan, one of the most seriously affected countries south of the Sahara by desertification and recurrent droughts, is in need for a large afforestation programs to offset the imbalance created by fast forest cover depletion (Hussein, 2006). Afforestation-Reforestation principles are the same all over the world aiming at increasing forest areas and regenerating existing forests for sustainability (Hussein, 2006). Afforestation is establishment of forest plantations on land that, until then, was not classified as forest, while reforestations is establishing a forest in area which carried a forest previously (FAO,2001b). Forest plantations amounted to 186,733,000 ha worldwide given an annual change of -9.391, 000 ha and annual rate of change of - 0.2% the figures for Africa are 8,036,000 ha forest plantations, - 5,262,000 ha annual change and -0.8% annual rate of change; for Sudan, the corresponding figures are 64,000 ha plantations, - 90,000 ha annual change -1.4% annual rate of change (Hussein, 2006). Plantations were first established in Sudan by the Anglo-Egyptian administration. The most significant of these were the teak (*Tectona grandis*) plantations of Southern Sudan. This process was continued by the government forestry administration, and by the mid-1970s, plantations totaled some 16,000 additional hectares of hardwoods and 500 to 600 hectares of softwoods. Today, most of the remaining plantations are found in Central and Eastern Equatoria states, in Southern Sudan. In Sudan, plantations are comprised of river nile *Acacia nilotica* forests, *Acacia senegal* plantations in abandoned mechanized farms, inside forest reserves, in private gum orchards, and in isolated shelter belts planted in Northern Kordofan and other central states, pine and eucalyptus plantations in the Jebel Marra region in Darfur, and eucalyptus in the irrigated agricultural areas (El Taib, 1988). Afforestation usually relies on artificial means, although natural regeneration helped in reforesting forest with minimum costs. Artificial regeneration facilitates control over afforestation programmers. For this, authenticated seeds and well raised seedling are essential. In Sudan, seeds are used mainly for *Acacia* species while seedlings are used for *Euqalyptus* plantation. It is therefore important to study seeds and know nursery practices (Hussein, 2006).

The literature review shows that, there is deterioration in the tree cover in the Sudan in general and at the Zalingei area in particular. Human activities such as over grazing, illegal cutting and agriculture expansion are the factors behind woody vegetation degradation and inadequate natural regeneration that need to be regulated. Natural regeneration is the most important means of renewal and preservation of tree species from extinction, especially the native trees at the study area.

CHAPTER THREE

MATERIAL AND METHODS

3.1. Study area

3.1.1. Location of the study area

Zalingei locality, marked by latitude 12° 30' - 13° 30"N and longitude 30° 23' - 45° 23"E (Hadi, 2004). The study is carried out at Zalingei area which lies between latitude 12° 42' 576" N (South point) and 13° 08' 055" N (North point) and between longitude 23° 39' 761" E (East point) and 23° 25' 835" E (West point), with altitude varies from 890 m to 1121 m above the sea level. The area lies on the semi-arid Savannah zone, which affected by the elevation of Jabel Marra Massif.The study attempted to analyze the woody vegetation and the natural regeneration at the study area.

3.1.2. Soils of the study area

The soils of study area are derived from the gneisses and shists and granites of underlining basement complex. The soils include those of drift alluvial and dry plains. These few sedentary soils and when found are generally truncated (Wickens, 1966). In many cases transported soil material overlies a weathering zone, becoming a part of depositional layering. The predominant top soil is sandy loam, becoming loam or sandy clay **(**Hunting Technical Services, 1958). Other soils range from grey to brown gravely clay of pedi plains to alluvial and colluvial soils (clay loam) in depressions and along the main valley and water courses to volcanic ash and sandy loam pediments plains. The soil of Zalingei area is mostly neutral or slightly acid with little or no lime content. Soil organic matter and the available phosphorous are low, with relatively highly soluble potassium and the Carbon/ Nitrogen ratio is wide (Ali, 2002).

3.1.3. Geology of the study area

The study area is in the surrounding lowlands of Jebel Marra which is a dormant, late tertiary, volcanic massif resting on a base of Archaean rocks at the summit of an up warping between the Chad and Nile basins. The low land of the basement complex have been formed by the more easily weathered schists and gneisses, while the hill lands such as Tebella massif (1413 m) and the Kongyo hills (1359 m), lying to the South East and North of Zalingei respectively, are from the more resistant paraschstis and gneiss, and represent the remnant of higher and older land surface (Wichens 1976). General geology of study area was superficial deposits, alluvial deposits and basement complex rocks (fig1).

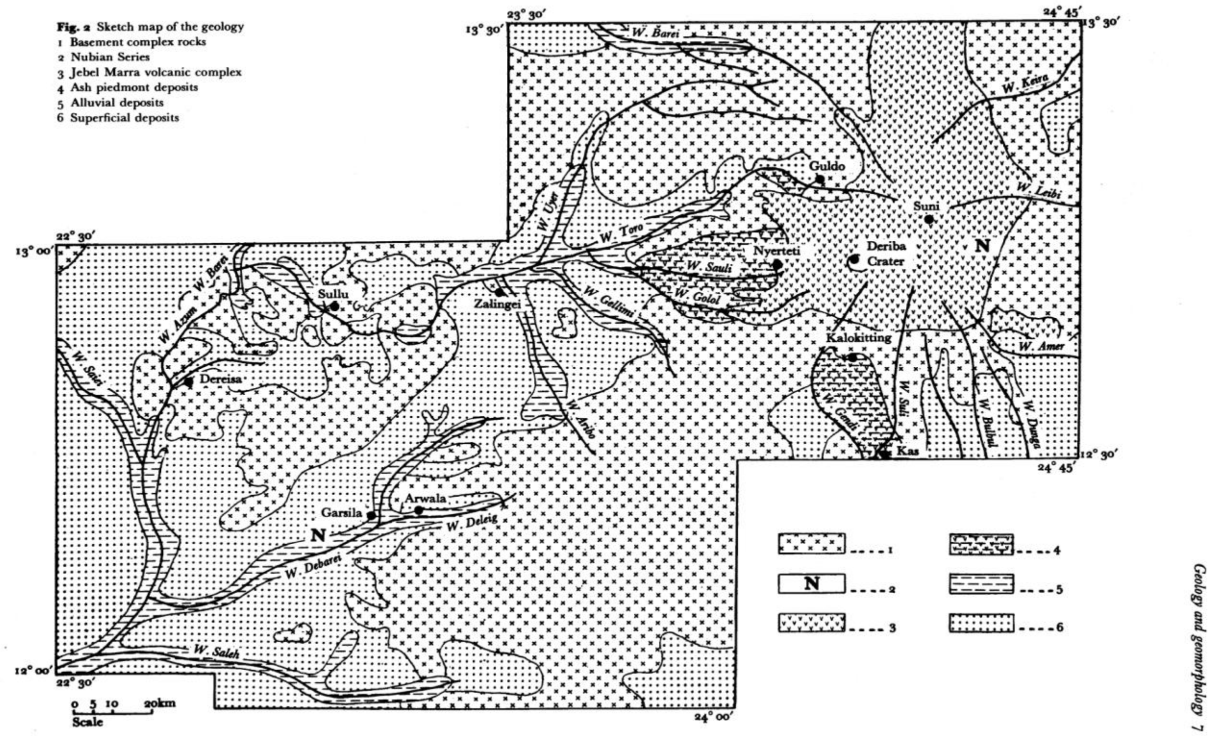

Fig. 8. Geology of Jebel Marra and surrounded areas (Wickens, 1976).

3.1.4. Drainage

The water resources of Jebel Marra can support the settled population, it is a unique region covering the area from the north-west of Darfur and continuing into Chad. Jebel Marra forms a ridge between the Nile Basin and Lake Chad. The drainage to the Nile Basin is mostly through Behar El Arab, while the drainage to Lake Chad is through Wadi Azum and Wadi Kaja (Barsi, 2008). However, due to the aridity, high seepage and evaporation losses, and the runoff from Jebel Marra reaches Behar ElArab only during high rainy seasons. The streams in Darfur are ephemeral, usually running during and shortly after the rainy season. The flow records of most of these Wadis are short, discontinuous and have a poor quality. Numerous Wadis originate from the high lands of Jebel Marra and form eight major Wadis; these Wadis are shown in figure 9.

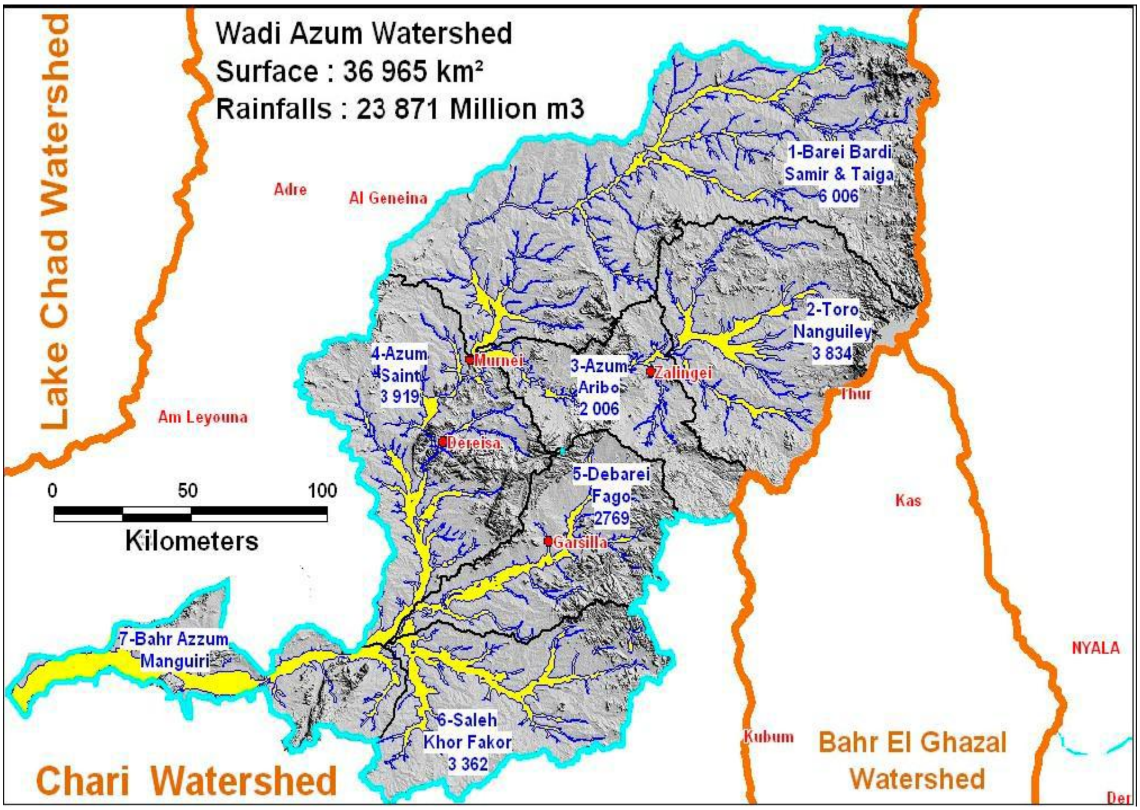

Fig. 9. Drainage and major Wadis of Jebel Marra (Barsi, 2008).

3.2. Reconnaissance survey

A reconnaissance survey was carried out at the study area, during May and July 2013, to assess the general environmental conditions and woody plant community types. The study area was stratified into seven ecological zones according to soil type, slope and distance from Wadi system previously classified and described by (Wickens, 1976). These ecological zones are namely, contemporary flood plains, lower terraces, upper terraces, clay plains, sedentary plains, lower hill slopes and stony hill slopes as shown in Figure10.

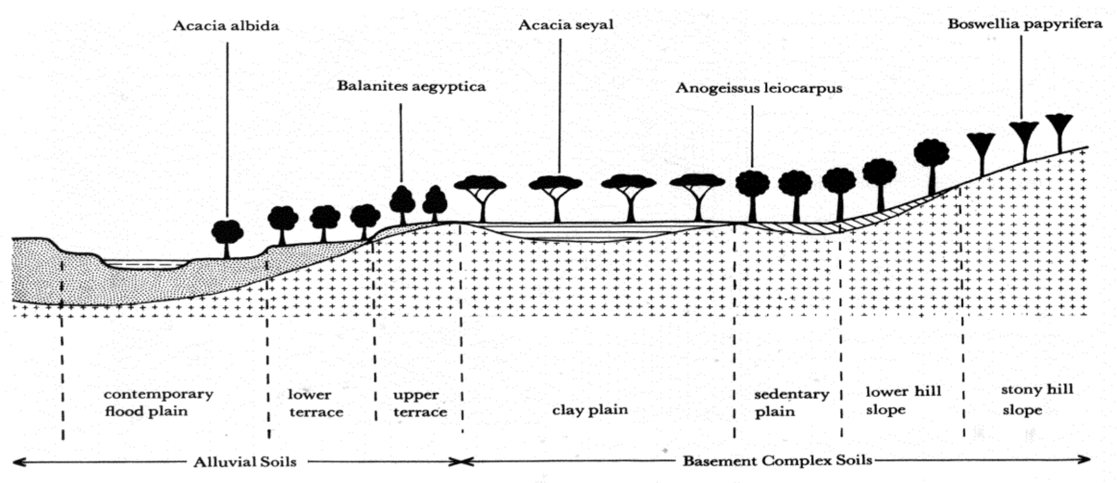

Fig10. Schematic diagram of Zalingei area showing the relationship between geomorphology, soil and vegetation as cited in Wickens (1976).

3. 3 Sites selection for investigations.

According to the reconnaissance survey the selected sites for investigation, represented 278 ha of Zalingei woody vegetation area distributed as follows: 96 ha at Zalingei administrative unit, 108 ha at Abata administrative unit and 74 ha at rural Teraje administrative unit. The total size of sample plots was 13.9 ha representing 5 % of the total survey area.

3.3.1 Selection criteria

Sites selection for investigations was primarily based on its geographical position to the Wadi system, i.e. lying perpendicular to the wadies system, and this included Wadi Gallabat Traje, Wadi Aribo Zalingei, Wadi Dahab sharo Zalingei, Wadi Azum Zalingei and Wadi Uyer Abata, other factors dictated site selection were the existence of woody vegetation, the distribution of trees species in the area, and altitude for the stony hill slope sites (Fig.11)

3.3.2 Description of the sites

Eleven sites were selected for this study. Site 1 is a contemporary flood plain on Wadi Gallabat Teraje with altitude of 999 meter abve see level (m..a.s.l). Sites 2 and 3 represent lower terraces at Wadi Uyer in Abata with altitude of 960 m.a.s.l and Wadi Aribo in Zalingei with altitude of 902 m.a.s.l. Sites 4 and 5 are upper terraces at Wadi Dahab Sharo in Zalingei with altitude 922.2m.a.s.l and Wadi Gallabat Teraje with altitude of 1002 m.a.s.l. Site 6 is clay plain at Wadi Uyer in Abata with of altitude 973 m.a.s.l. Site 7 is sedentary plain at Wadi Uyer Abata with altitude of 980 m.a.s.l. Sites 8 and 9 are lower hill slope at Wadi Uyer in Abata with altitude of 993m.a.s.l and Wadi Gallabat Teraje with altitude of 1016 m.a.s.l. Sites 10 and 11 are Stony hill slope at Wadi Gallabat Teraje with altitude of 1112 m.a.s.l and Wadi Azum in Zalingei with altitude of 944.4 m.a.s.l (Table.6 and App, plate 8,9,10 and 11) for sites description.

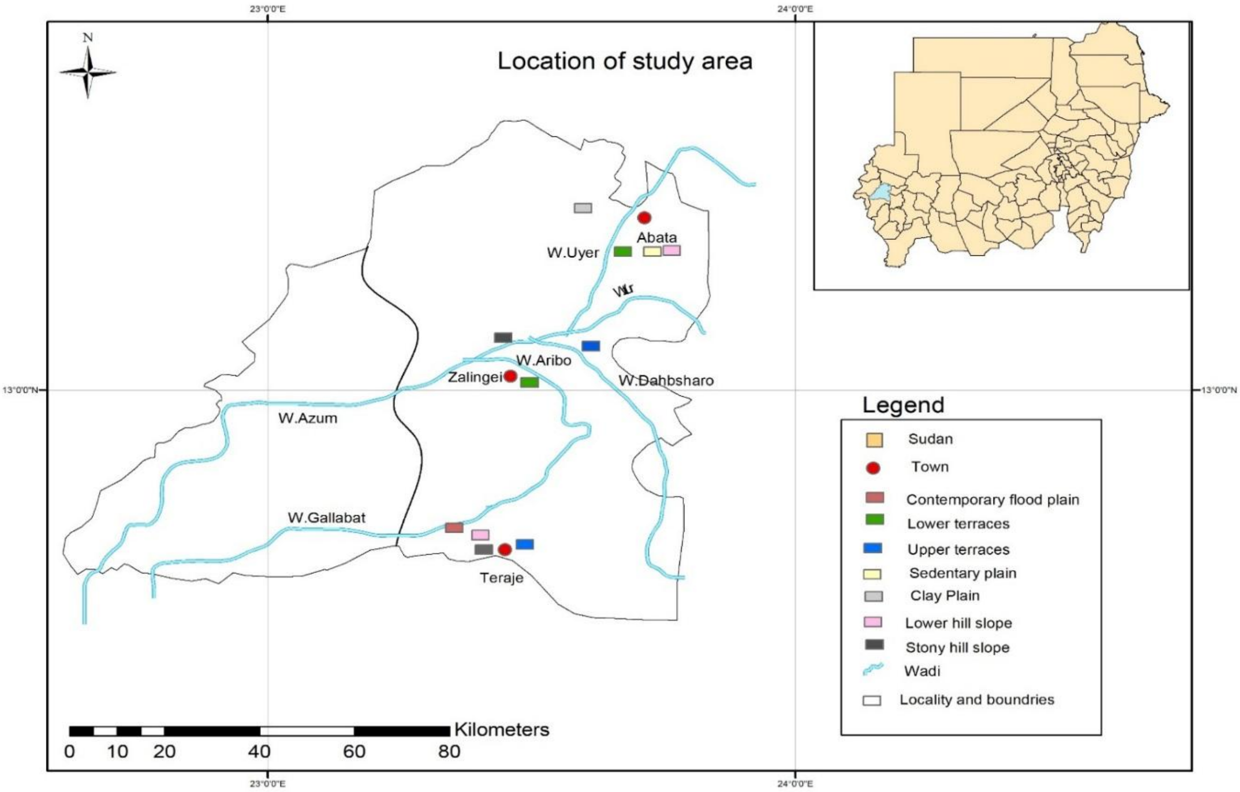

Fig.11. The study sites at Zalingei area modified from Land sat (2015).

Table 6. Description of the area surveyed and direction of the sites relative to Zalingei town.

No	Description	Abbreviation	Total survey area in ha	Sample plot area in ha	Distance and direction from Zalingei Km
1	Contemporary flood plain- Teraje	CFT	10	0.5	26.5 S
2	Lower terraces – Abata	LTA	12	0.6	31 NE
3	Lower terraces – Zalingei	LTZ	12	0.6	1.5 S
4	Upper terraces- Zalingei	UTZ	42	2.1	11.5 E
5	Upper terraces – Teraje	UTT	12	0.6	22 SW
6	Clay plain - Abata	CPA	12	0.6	36 NNE
7	Sedentary plain -Abata	SPA	42	2.1	34 NE
8	Lower hill slope - Abata	LHA	42	2.1	37 NE
9	Lower hill slope – Teraje	LHT	42	2.1	24.5 SSW
10	Stony hill slope- Teraje	SHT	10	0.5	25 SSW
11	Stony hill slope- Zalingei	SHZ	42	2.1	4 .3 N
			278	13.9	

3.4 Types of data collected

Two types of data were collected, primary and secondary data.

3.4.1. Primary data

3.4.1.1. Ecological activities

To achieve the objective the following field surveys were conducted during the period 2013-2014:

- Soil samples collection and analysis.
- Woody vegetation surveys.
- Recurrent natural regeneration surveys.
- The phenology of three dominant trees.
- Social survey (Group discussion).

3.4.1.1.1 Soil samples collection and analysis

According to BLACK *et al.* (1964) random samples are collected in statistically random manner, and the actual depths selected will obviously vary, depending on the soils and crops involved; two possible systems might be employed as follows (depths in cm):

A/ 0-15 cm, 15-30 cm , 30-60 cm , 60-90 cm , 90-120 cm **B**/ 0-10 cm, 40-50 cm, 90-100 cm, 140-150 cm. Hawever, the topsoil is generally subject to variation over short distances, the soil samples were taken and collected from subsurface soils at 15 – 60 cm using an auger. From each site four samples were collected randomly accordingly a total of 44 (4×11) soil samples were taken for analysis. Soil physical and chemical analysis was conducted at the soil department laboratory, faculty of Agriculture University of Khartoum.

3.4.1.1.2 Woody vegetation survey.

The systematic circular line-plot sampling design and systematic strip sampling after Wiley and Sons, (1982) was used for this survey. Using the Global Positioning System (GPS), measuring tape (100 m) , a compass, a caliper, and hypsometer, four inventories were carried out in the two seasons of 2013 and 2014 (Appendix, plate 16 and 17). In the sites described above, sample plots were established as follows: Site 4,7,8,9 and 11 consisted of 42 hectare (600 m × 700 m) with 21 sample plots for each one. The sample plots were circular in shape with a radius of 17.84 m (0.1 ha in area). In addition, the survey lines were drawn with seven sample plots per line. The distance between survey lines is 200 m and the distance between successive sample plots is 100 m. The distance from the outer survey lines to the borderlines is 100 m. each sample plot represents 2.1 hectares. In site 2, 3,5and 6 the area occupied by trees was laid on strip and they were relatively smaller, therefore, strip sample plot were used each of them consisted of 12 hectare (200 m × 600 m) with 2 strip (5m× 600m) along the site and the distance between each strip is 100 m, each strip divided into two sample plots, the size of each sample plot was (5m×300m). Also strip sample plot were used in site 1 and 10, because the areas of trees was laid on narrow strip at site 1 and steep slope at site 10, they were relatively smaller, each of them consists of 10 ha (200 m × 500m) with 2 strip (5m× 500m) along the site and the distance between each strip is 100 m, each strip divided into two sample plots, Size of each sample plot (5m× 250 m).

3.4.1.1.2.1 Parameters measured.

In the eleven sites, the tree species were identified and recorded, and all trees per plot with dbh equal to or greater than seven centimeters were enumerated. The number of trees per ha were calculated. Height, diameter and crown diameter were recorded. Readily available form factors for some species at the study area (Table 7) were used to calculate the wood volume per ha, for the rest of trees estimated form factors were used for volume measurements.

Table 7. The Form Factor for some species at study area

Species	F.F	Species	F.F	Species	F.F
Ziziphus spina-christi	0.62	*Dalbergia melanoxylon*	0.73	*Albizia amara*	0.68
Ziziphus abyssinica	0.73	*Combertum glutinosum*	0.59	*Terminalia mollis*	0.64
Anogeissus leiocarpus	0.47	*Balanites aegyptiaca*	0.47	*Sterculia setgera*	0.46
Dalbergia melanoxylon	0.73	*Acacia sieberana*	0.48	*Acacia seyal*	0.75
Sclerocarya birrea	0.58	*Xeromphis nilotica*	0.75	*Acacia senegal*	0.75
Albizia anthelmintheca	0.68	*Grewia mollis*	0.77	*Acacia girrardii*	0.49
Dichrostachys cinerea	0.79	*Boswellia papyrifera*	0.54	*Lannea fruticosa*	0.64

Source: FNC (1996)

The species composition, the relative dominance, relative abundance, relative frequency and importance value indexes were calculated. woody plant diversity, Similarity between sites and the change in the biomass of woody vegetation between the season 2013 and season 2014 were calculated.

3.4.1.1.2.2 Analysis of woody vegetation data

- species composition

For the analysis of the species composition some definitions were used Abundance (AB) = Stem number of a given species per hectare. Absolute abundance (AAB) = Number of individuals per species. Relative abundance (RAB) = percentage of each species of the total stem number per hectare. Frequency is defined as the probability or chance of finding an individual of a particular species in a given sample area or quadrate. (FR) = occurrence or absence of a given species in a sample plot. Absolute frequency (AFR) = percentage of occurrence (number of plots/all plots). Relative frequency (RFR) = percentage of the total of absolute frequencies. Dominance (BA) = expression of the space that a given species occupies. Absolute dominance (ABA) = the sum of the individual stem basal areas. Relative dominance (RBA) = percentage of a given species of the total stem basal area measured. Importance value index = sum of the relative abundance + relative frequency + relative dominance.The importance value index is a measure of ecological significance of a species in a certain forest type. It also expresses the dominance of a particular species in a stand (Adam, 2003).

- Woody plant diversity

Simpson diversity index was used to measure the woody plant diversity. The value of this index ranges between 0 and 1. Within this index, 0 represents infinite diversity and 1, no diversity. Where: Simpson diversity index

$$D = \sum n(n-1)/N(N-1)$$

Where:

D = Simpson Diversity index.

n = the total number of individuals.

N= the total number of species (Mahmoud, 2009).

- Sites similarity of the area

Similarity coefficient between sites was used to calculate similarity between sites. Sorensen coefficient of similarity can be calculated by the following formula:

$$\boldsymbol{s} = \frac{\boldsymbol{2a}}{\boldsymbol{2a + b + c}}$$

Where:

S= Sorensen coefficient of similarity.

a = number of species common to both quadrates or samples

b= number of species in quadrates/sample (1)

c = number of species in quadrates/ samples (2).

To give a percentage similarity the coefficient is multiplied by 100 (Mahmoud, 2009).

- Change of woody vegetation biomass in season 2013 and season 2014.

The T Distribution (Paired - T-Test) was used to study the change in the biomass of woody vegetation between the season 2013 and season 2014 in all eleven sites. T Distribution (Paired - T-Test) can be calculated by the following formula:

$$T = \frac{D}{SD\sqrt{N}}$$

Where:

T= T Value

N= number of Paired

SD = standard deviation.

D = The difference between the Paired means

The Statistical Analysis System (SAS) was used for data analysis.

3.4.1.1.3 Natural regeneration survey.

The sample plots used for the inventory of the growing stock were simultaneously used as main plots for regeneration sampling. In the center of every main plot fixed with metal pegs was also used as a center of subplot (App plate 15), the radii of these sub plots were 10 m. The number of subplots in site 4,7,8,9 and 11 were 21 subplots per site, size of all sample plot ($10m^2 \times 3.14 \times 21 \times 5$)/10000 = (3.3 ha). In site 2, 3, 5, and 6 the area for natural regeneration sampling was laid on strips, due to the relatively small sizes of these sample plots, these main plots were as well used for natural regeneration. The total area of the plots is 12 hectare (200 m × 600 m) with 2 strip (5m× 600m) along the site and the distance between each strip is 100 m, each strip divided into two sample plots. The size of each sample plot was 5m×300m or 0.15 ha. the same was applied for sites 1 and 10, each of them consists of 10 hectare (200 m × 500 m) with 2 strip (5m× 600m), each strip divided into two sample plots Size of each one (5m× 250 m) (0.125 ha). The total number of samples were 129 with different sizes as follow; 105 sample plots the size of each one is 0.0314 ha, 16 sample plots, the size of each is 0.15 ha and 8 samples the size of each is 0.125 ha. The total sizes of all sample plots was 6.7 ha (3.3ha + 2.4ha + 1ha), accordingly the sampling percentage is 6.7 ha /32.5 ha ((2.1 ha× 5) + 12 ha +10 ha)) = 20.6 % of total survey area for natural regeneration.

3.4.1.1.3.1 Parameters measured.

Regeneration and regeneration type and size of seedlings less than 1m or above 1m and survival rates or percentage of all tree species counting and recording were performed four times recurrently, twice in each season (In August wet season and March dry season in 2013 and 2014).

3.4.1.1.3.2 Analysis of natural regeneration data

-Types of natural regeneration.

To know the main source of seedlings (seeds or coppice or sprouts) the one sample case of the Chi- square Test was used

$$X^2 = \sum_1^k \left[\frac{(O-E)^2}{E} \right]$$

χ^2 = Chi- square O = Observed.

E = Expected. ^{K} = number of individuals.

The Statistical Analysis System (SAS) was used for data analysis.

3.4.1.1.4 The relationship between mature trees and natural regeneration.

Regression analysis was used to find the relationship between mature trees and natural regeneration.The (*by-x*) is calculated according to the formula:

$$by.x = \frac{sp}{ssx}$$

Where:

by-x = Regression coefficient

sp = Total sum of squares of variance

ssx =Total sum of squares of independence variable from its arithmetic mean. The Statistical Analysis System (SAS) was used for data analysis.

3.4.1.1.5 The phenology of three dominant trees.

The woody vegetation composition showed three dominant tree species, namely; *Albizia amara,* at lower hill slope *Balanites aegyptiaca* at upper terraces and *Faidherbia albida* at lower terraces. These three species were selected for their dominance to conduct the phenological study. According to Adam (2003) five trees were selected from each species to this study. Observations were taken weekly during the year 2014, and included the following:

- Time, duration and peak time of flower production
- Time, duration and peak time of fruit production
- Time, duration and peak time of flushing
- Time, duration and peak time of leaf shedding

3.4.1.2. The social survey- group discussion

This technique was applied to collect data through group discussion with twenty villagers recalling the history of woody Vegetation in Zalingei area. A check list was used during group discussion with focus on species diversity, presence and distribution through various sites, besides main factors that cause degradation.

3.4.2. Secondary data

The secondary data includes: FNC archives and reports, metrological data, related studies and scientific papers conducted at the study area.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Soil characteristics

4.1.1. Physical properties

Results in table (8) demonstrate the differences in soil texture in the study area. It is generally sandy loam at Lower terraces, Lower hill slope and Stony hill slope**,** sandy clay loam at Upper terraces and Sedentary plain, loamy sand at Contemporary flood plain and clay at Clay plain**.** This results agreed with Adam (2003) who reported that physical properties of the soils of the 134 ha of Jebel Marra area are generally sandy loam to sandy clay loam. And disagreed with Adam (2003) in two site namely, Contemporary flood plain and Clay plain sites; these sites soil physical properties were loamy sand and clay respectively. This is because, the first site is a contemporary flood plain receiving clay and sand each and every rainy season and the second site is a clay plain whereas, the survey of Adam (2003) was conducted in hill crests in Jebel Marra.

Table 8. Soil texture at the study area in Zalingei

Sites	Clay %	Silt%	Sand %	Texture class
Contemporary flood plain	8.43	7.58	83.99	Loamy sand
Lower terraces	15.31	20.70	63.99	Sandy loam
Upper terraces	35.31	21.95	42.27	Sandy clay loam
Clay plain	54.68	26.33	18.99	Clay
Sedentary plain	25.93	15.08	58.99	Sandy clay loam
Lower hill slope	16.55	11.33	66.62	Sandy loam
Stony hill slope	11.56	32.58	55.86	Sandy loam

4.1.2. Chemical properties

The pH of the soil in the survey sites was found to range from 5.7 at LH to 7.03 at CP. EC ranges from 0.24 at CF to 1.35 at SH. SP ranges from 36.8 to 48 for LH, SH respectively. HO_3 ranging from 3.25 at LH to 7. 5 at CP. In general the differences between sites for the chemical properties such as Na meg/l, Ca+M meg/lg, Ca meg/l, Mg meg/l, K meg/l and Cl meg/l, were shown in (Table 9 and Figure 12). This result agrees with Clift-Hill (1988) who reported that, the soil of Abata (CP, UT, LT and SP) are classified as non- saline non-sodic with pH value of 7.1 to 10.2, these results also agree with Adam (2003) who reported that the soils of Jebel Marra hill crests are acidic with pH ranging from 5.2 – 6.4. The tendency of the soils to alkalinity is due to the increasing soluble cations mg/L such as Na, especially at stony hill slope of Zalingei at kerradito) which is famous by soil salinity. The E.C ranges between 0.24 (at contemporary flood plain indicating low amounts of soluble salts i.e no problems of salinity) to 1.35 at stony hill slope indicating high amounts of soluble salts, or presence of salinity problems.

Table 9. Chemical properties of the soil in the selected sites at zalingei area.

Sites	pH	EC Mmhos/cm	SP ds/m	Na meg/l	Ca+Mg meg/l	Ca meg/l	Mg meg/l	K meg/l	HCO_3 meg/l	Cl meg/l
Contemporary flood plain	6.50	0.242	44.00	0.333	3.00	2.25	0.75	0.138	3.50	5.75
Lower terraces	6.80	0.43	42.7	0.77	3.00	2.25	0.75	1.33	4.25	6.25
Upper terraces	6.45	0.45	44.21	1.49	3.26	2.63	0.63	0.36	4.75	7.75
Clay plain	7.03	0.508	47.36	3.043	3.00	2.25	0.75	0.102	7.50	7.75
Sedentary plain	6.15	0.690	38.95	1.128	4.50	3.75	0.75	0.328	4.00	9.50
Lower hill slope	5.7	0.54	36.8	2.315	3.50	2.75	0.75	0.31	3.25	7.00
Stony hill slope	6.42	1.35	48.00	7.313	11.00	8.25	2.75	0.95	5.00	11.75

Soil analysis was carried out at laboratory of soil department, faculty of agriculture, University of Khartoum,

E.C: Electrical conductivity mmhos /c S P :Saturation percentage

4.2 Distributions of tree species at the study sites

In Contemporary flood plain (Teraje), Lower terraces (Abata) and Lower terraces (Zalingei) the tree with the highest density was *Faidherbia albida with* 4 trees/ha, 5 trees/ha and 6.7 trees/ha, respectively. The density of *Ziziphus spina-christii* and *Ailanthus exclsa* in site 3 was 5 trees/ha and 1.7 trees/ha, respectively. It worth to mention that *Ailanthus exclsa* is an introduced species which is now naturalized and domisticated due to its high seed dispersal and adaptive capacity. Density of *Kigelia africana* and *Balanites aegyptiaca* were 1.7 trees/ha (Table 10).

Table 10. Species composition, abundance (AB), absolute abundance (AAB), relative abundance (RAB), dominance (BA), relative dominance (RBA) at site 1,2 and 3.

Site	Species	AAB	AB	RAB	BA	RBA
Contemporary flood plain (Teraje)	*Faidherbia albida*	2	4	100	3.52	100
	Total	2	4		3.52	
Lower terraces (Abata)	*Faidherbia albida*	3	5	60	1.25	80.8
	Kigelia africana	1	1.7	20	0.15	9.4
	Balanites aegyptiaca	1	1.7	20	0.15	9.8
	Total	5	8.4		1.55	
Lower terraces (Zalingei)	*Faidherbia albida*	4	6.7	50	2	62.5
	Ziziphus abyssinica	3	5	37.3	0.9	28.1
	Ailanthus excelsa	1	1.7	12.7	0.3	9.4
	Total	8	13.4		3.2	

In Upper terraces (Zalingei) and Upper terraces (Teraje) it was found that the highest tree density (trees/ha) was *Acacia seyal* and *Balanites aegyptiaca with* 55.24 trees/ha and 35.24 trees/ha respectively. Also the density of *Balanites aegyptiaca* and *Anogeissus leiocarpus were* 8.33 trees/ha and 3.33 trees/ha, respectively (Table 11). These results are similar to Wickens (1976) who described that *Faidherbia albida* and *Balanites aegyptica* association are dominat on alluvial soils of Wadi Azum system within the contemporary flood plains and lower terraces. Also this results agree with Ali (2012) who found that *Faidherbia albida* at Zalingei area around the Wadies of Azum, Aribo and Uyer, and *Balanites aegyptica* covers the majority of Zalingei area.

Table 11. Species composition, abundance (AB), absolute abundance (AAB), relative abundance (RAB), dominance (BA), relative dominance (RBA) at site 4, 5.

No of sites	Species	AAB	AB	RAB	BA	RBA
Upper terraces (Zalingei)	*Balanites aegyptiaca*	74	35.2	34.7	4.3	60
	Acacia sieberana	1	0.48	0.47	0.04	0.56
	Acacia nilotica	3	1.43	1.41	0.23	3.21
	Acacia senegal	4	1.9	1.87	0.07	1
	Acacia seyal	116	55.24	54.5	2.07	28.9
	Ziziphus abyssinica	15	7.14	7	0.46	6.42
	Total	213	101.9		7.17	
Upper terraces (Teraje)	*Anogeissus leiocarpus*	2	3.33	29	0.2	25
	Balanites aegyptiaca	5	8.33	71	0.6	75
	Total	7	11.66		0.8	

In Clay plain (Abata) the highest tree density was calculated *for Acacia seyal* was 106.7 trees/ha, 31.7 trees/ha, for *Acacia senegal*, 21.7 trees/ha, for *Acacia nilotica* and 10 trees/ha, for *Acacia girrardii*. *Bauhinia rufescens, Balanites aegyptiaca, Ziziphus spina-christi the* density was 8.3 trees per ha for each one. Moreover, the lowest tree density was calculated for *Albizia anthelmintheca* 1.7 trees/ha, (Table 12).

Table 12. Species composition, abundance (AB), absolute abundance (AAB), relative abundance (RAB), dominance (BA), relative dominance (RBA) on site 6.

Species	AAB	AB	RAB	BA	RBA
Acacia seyal	64	106.7	54.2	0.38	46.3
Acacia nilotica	13	21.7	11	0.11	13.41
Balanites aegyptiaca	5	8.3	4.2	0.04	4.9
Acacia senegal	19	31.7	16.1	0.17	20.7
Acacia girrardii	6	10	5.1	0.06	7.3
Bauhinia rufescens	5	8.3	4.2	0.02	2.4
Albizia anthelmintheca	1	1.7	0.5	0.01	1.2
Ziziphus spina-christi	5	8.3	4.2	0.03	3.7
Total	118	196.7		0.82	

This results agree to some extent with Wickens (1976) who said that "*on the clay plain and red-brown drift soils of the upper basin of wadi Azum system the Acacia seyal- Balanites aegyptiaca forms a mosaic with Anogeissus association, with Acacia seyal dominating"* (Fig.10).

In Sedentary plain (Abata) *Albizia amara* scored the highest density 52.4 trees/ha, followed by *Acacia senegal* (29.5) trees/ha, whereas *Balanites aegyptiaca*, *Acacia girrardii*, *Acacia oerfota*, *Acacia nilotica*, *Acacia seyal*, and, *Albizia anthelmintheca*, *Anogeissus leiocarpus*, *Grewia mollis*, *Acacia laeta* , *Acacia mellifera*, *Xeromphis nilotica* showed very low densities (Table 13). These results indicate that *Albizia amara* and *Acacia senegal* are well associated and dominant. This could be marked as a starting point of change in the course of time since Wickens (1976) who described *Anogeissus leiocarpus* as a dominated species on the sedentary plain. Also DRC and U of Z (2008) found that *Anogeissus leiocarpus*, which was a dominant species at the study area since long time ago is disappearing and is being replaced by *Albizia amara* and *Faidherbia albida*.

Table 13. Species composition, abundance (AB), absolute abundance (AAB), relative abundance (RAB), frequency (FR), relative frequency (RFR), dominance (BA), relative dominance (RBA) and importance value index (IVI) on site 7.

Species	AAB	AB	RAB	FR	AFR	RFR	BA	RBA	IVI
Balanites aegyptiaca	7	3.3	3.3	4	19.05	6.67	0.36	7.5	17.47
Albizia amara	110	52.4	51.1	14	66.67	23.36	3.18	66.4	140.8
Albizia anthelmintheca	4	1.9	1.9	1	4.76	1.67	0.12	2.5	6.07
Acacia girrardii	6	2.9	2.8	3	14.29	5.01	0.11	2.3	10.11
Acacia laeta	1	0.48	0.48	1	4.76	1.67	0.05	1.04	3.19
Anogeissus leiocarpus	4	1.9	1.9	3	14.29	5.01	0.28	5.85	12.76
Acacia mellifera	1	0.48	0.48	1	4.76	1.67	0.01	0.21	2.36
Acacia nilotica	5	2.38	2.3	4	19.05	6.67	0.04	0.84	9.81
Acacia oerfota	6	2.9	2.8	5	23.81	8.34	-	-	0
Acacia Senegal	61	29.5	28.5	16	76.19	26.29	0.56	11.7	66.49
Acacia seyal	6	2.9	2.8	5	23.81	8.34	0.08	1.7	12.84
Grewia mollis	2	0.95	0.9	2	9.52	3.34	-	-	0
Xeromphis nilotica	1	0.48	0.48	1	4.76	1.67	-	-	0
Total	214	102.5			285.7		4.79		

There are only two dominant species in Lower hill slope (Abata) namely *Albizia amara* with adensity of 69.05 trees/ha, and *Acacia senegal* (30.84 trees/ha). In Lower hill slope (Teraje) the highest tree density (tree/ha) was *Balanites aegyptiaca*, 20 trees/ha, followed by *Acacia seyal* 12.4 trees/ha, Anogeissus *leiocarpus* 6.2 trees/ha, *Albizia amara* 5.24 trees/ha and *Acacia nilotica* 2.9 trees/ha (Table 14).

Table 14. Species composition, abundance (AB), absolute abundance (AAB), relative abundance (RAB), frequency (FR), relative frequency (RFR), dominance (BA), relative dominance (RBA) and importance value index (IVI) on site 8 and 9.

N	Species	AAB	AB	RAB	FR	AFR	RFR	BA	RBA	IVI
Lower hill slope (Abata)	*Albizia amara*	145	69.05	63.3	16	76	34.1	3.2	74	171.4
	Acacia senegal	64	30.48	27.9	16	76	34.1	0.7	16	78
	Acacia girrardii	1	0.48	0.43	1	4.7	2.1	0.05	1.2	3.73
	Bauhinia rufescens	3	1.43	1.31	1	4.7	2.1	0.03	0.6	4.01
	Acacia nilotica	5	3.38	2.18	3	14.2	6.37	0.07	1.5	10.05
	Balanites aegyptiaca	1	0.48	0.43	1	4.7	2.1	0.01	0.14	2.67
	Acacia seyal	3	1.43	1.31	3	14.2	6.37	0.2	4.9	12.58
	Dalbergia melanoxylon	2	0.95	0.87	2	9.5	4.26	0.03	0.6	5.73
	Dichrostachys cinerea	3	1.43	1.31	2	9.5	4.26	0.02	0.39	5.96
	Acacia oerfota	1	0.48	0.43	1	4.7	2.1	-	-	0
	Acacia tortilis	1	0.48	0.43	1	4.7	2.1	0.03	0.58	3.11
	Total	229	110.7			223		4.32		0
Lower hill slope Teraje	*Ziziphus spina-christi*	4	1.9	3.28	4	19.1	7.6	0.04	0.8	11.68
	Acacia senegal	2	0.95	1.64	2	9.5	3.8	0.01	0.2	5.64
	Balanites aegyptiaca	42	20	34.43	8	38.1	15.1	1.58	31.4	80.93
	Acacia seyal	26	12.4	21.31	9	42.9	17	0.45	8.95	47.26
	Dalbergia melanoxylon	1	0.48	0.82	1	4.8	2	0.34	6.8	9.62
	Anogeissus leiocarpus	13	6.2	10.66	6	28.6	11.3	1.13	22.5	44.46
	Albizia amara	11	5.24	9.01	6	28.6	11.3	0.69	13.7	34.01
	Faidherbia albida	1	0.48	0.82	1	4.8	2	0.01	0.2	3.02
	Dichrostachys cinerea	4	1.9	3.28	2	9.5	3.8	0.02	0.4	7.48
	Acacia girrardii	5	2.38	4.1	3	14.3	5.7	0.07	1.39	11.19
	Acacia nilotica	6	2.9	4.92	4	19.1	7.6	0.16	3.18	15.7
	Lannea fruticosa	1	0.48	0.82	1	4.8	2	0.05	1	3.82
	Sclerocarya birrea	5	2.38	4.1	5	23.8	9.4	0.38	7.55	21.05
	Sterculia setigera	1	0.48	0.82	1	4.8	2	0.1	2	4.82
	Total	122	58.2			253		5.03		

This results differ from Lebon (1965) who mentioned that sites on slopes of low hills of Zalingei are covered with more diversified tree cover including, *Sclerocarya birrea*, *Acacia senegal*, *Albizia sericocephala*, *Dalbergia melanoxylon*, *Lanea fruticosa* ,*Lanea schimperi* and *Azanza garckeana*, these species have probably disappeared due to adverse human activities and climatic changes.

There is only one dominant tree species in Stony hill slope (Teraje) namely *Boswellia papyrifera* with density of 52 trees/ha, followed by *Lannea fruticosa* (18 trees/ha), *Dichrostachys cinerea* (12 trees/ha) and *Acacia girrardii* (8 trees/ha). The dominant tree species in Stony hill slope (Zalingei) was *Albizia amara* (45.25 trees/ha) followed by *Balanites aegyptiaca* (7.62 trees/ha) and *Acacia senegal* (6.19 trees/ha) as in Table 15. This result is in line with Wickens (1976) who described *Boswellia papyrifera* is dominated on the stony hill slopes and *Albizia amara* is dominated on the lower hill slope respectively..

Table 15. Species composition, abundance (AB), absolute abundance (AAB), relative abundance (RAB), dominance (BA), relative dominance (RBA) on site 4 and 10 and 11.

Site	Species	**AAB**	**AB**	**RAB**	**BA**	**RBA**
Stony hill slope (Teraje)	*Boswellia papyrifera*	26	52	54.2	1.37	76.1
	Lannea fruticosa	9	18	18.8	0.17	9.4
	Acacia senegal	1	2	2.01	0.004	0.022
	Acacia seyal	1	2	2.01	0.23	12.8
	Dichrostachys cinerea	6	12	12.5	0.024	1.3
	Dalbergia melanoxylon	1	2	2.01	0.018	1
	Acacia girrardii	4	8	8.3	0.027	1.5
	Total	48	96		1.8	
Stony hill slope (Zalingei)	*Albizia amara*	95	45.24	73.6	2.44	47.4
	Balanites aegyptiaca	16	7.62	12.4	2.34	45.4
	Dalbergia melanoxylon	1	0.48	0.78	0.05	1
	Combertum glutinosum	3	1.43	2.33	0.06	1.2
	Terminalia mollis	1	0.48	0.78	0.07	1.4
	Acacia senegal	13	6.19	10.1	0.19	3.7
	Total	129	61.44		5.15	

4.3 Woody plants diversity

The value of diversity index is between 0.19 and 1. The highest diversity was for site Lower hill slope Traje with diversity index value of 0.19 followed by site Lower terraces Zalingei (0.30), Lower terraces Abata (0.32), Clay plain Abata (0.34), Stony hill slope Traje (0.34), Sedentary plain Abata (0.35), Upper terraces Zalingei (0.42), Lower hill slope Abata (0.48), Upper terraces Traje (0.52) Stony hill slope Zalingei (0.56) and there is no diversity in Contemporary flood plain Traje (Table 16), this is considered as a high diversity index in Lower hill slope Traje (0.19) and there is no diversity in Contemporary flood plain Traje (1) because, the area of contemporary flood plain is a sandy soil with a lot of water and mostly dominated by *Faidherbia albida*.

Table 16. Simpson diversity index for the eleven study sites at Zalingei.

No	Site	N	N(n-1)	$\sum n(n-1)$	Simpson's index
1	Contemporary flood plain -Traje	2	2	2	1
2	Lower terraces – Zalingei	8	56	18	0.32
3	Lower terraces –Abata	5	20	6	0.30
4	Upper terraces- Zalingei	213	45156	18970	0.42
5	Upper terraces –Traje	7	42	22	0.52
6	Clay plain –Abata	118	13806	4620	0.34
7	Sedentary plain- Abata	214	45582	15828	0.35
8	Lower hill slope –Abata	229	52212	24952	0.48
9	Lower hill slope –Traje	122	14762	2734	0.19
10	Stony hill slope Traje	48	2256	764	0.34
11	Stony hill slope- Zalingei	129	16512	9332	0.56

The diversity index for the terraces ranged between 0.15 - 1. The highest diversity for the terraces was for the lower terraces 0.15 followed by lower hill slope 0.26, stony hill slope 0.33, clay plain 0.34 , sedentary plain 0.35,upper terraces 0.41 and contemporary flood plain 1 (Table 17). The diversity index for the terraces which ranges between 0.15 – 1, the lower terraces have the highest diversity index of (0.15) due to availability of water and good soil conditions.

Table 17. Simpson diversity index for the terraces at Zalingei in Darfur State.

Site	N	N(n-1)	$\sum n(n-1)$	Simpson's index
Lower terraces	13	156	24	0.15
Clay plain	118	13806	4620	0.34
Sedentary plain	214	45582	15828	0.35
Lower hill slope	351	122850	31470	0.26
Upper terraces	220	48180	19732	0.41
Stony hill slope	177	31152	10124	0.33
Contemporary flood plain	2	2	2	1

4.4 Sites similarity of the area

Similarity coefficient between sites: upper terraces Zalingei and upper terraces Traje was 20%, lower terraces Abata and lower terraces Zalingei was 25% , lower hill slope Traje and lower hill slope Abata was 39% and stony hill slope Traje and stony hill slope Zalingei was 23.5% for woody plant species are presented in table 18.

The similarity coefficient is low between sites which indicate that the vegetation differs from site to site and this might be due to the topography and soil types, and rainfall as was explained by (Smith 1949; Harrison and Jackson 1958) whose reported that the combination of rainfall and soil texture determines the distribution of vegetation cover in Sudan.

Table 18. The similarity between sites at Zalingei in Darfur State.

Family / species		Sites										
Family	**Latin name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Rhamnaceae	***Ziziphus spina-christi***				+				+			
Rhamnaceae	***Ziziphus abyssinica***					+	+					
Anacardiaceae	***Anogeissus leiocarpus***			+					+	+		
Apocyanaceae	***Lannea fruticosa***								+			+
Anacardiaceae	***Sclerocarya birrea***								+			
Fabaceae	***Albizia anthelmintheca***			+	+							
Fabaceae	***Albizia amara***		+	+				+	+			
Fabaceae	***Dichrostachys cinerea***		+						+			+
Fabaceae	***Faidherbia albida***	+				+			+		+	
Fabaceae	***Dalbergia melanoxylon***		+					+	+			+
Fabaceae	***Bauhinia rufescens***		+		+							
Fabaceae	***Acacia seyal***		+	+	+		+		+			+
Fabaceae	***Acacia senegal***		+	+	+		+	+	+			+
Fabaceae	***Acacia girrardii***		+	+	+				+			+
Fabaceae	***Acacia laeta***			+								
Fabaceae	***Acacia mellifera***			+	+							
Fabaceae	***Acacia nilotica***		+	+	+		+		+			
Fabaceae	***Acacia oerfota***		+	+								
Fabaceae	***Acacia tortilis***		+									
Fabacea	***Acacia sieberana***						+					
Rubiaceae	***Xeromphis nilotica***			+								
Tiliaceae	***Grewia mollis***			+								
Combretaceae	***Combertum glutinosum***							+				
Combretaceae	***Terminalia mollis***							+				
Sterculiaceae	***Sterculia setgera***								+			
Balanitaceae	***Balanites aegyptiaca***	+	+	+			+	+	+	+		
Burseraceae	***Boswellia papyrifera***											+
Simaroubaceae	***Ailanthus exclsa***					+						
Bignoniaceae	***Kigelia africana***	+										

Were site:

1= Lower terraces –Abata 2= Lower hill slope –Abata 3= Sedentary plain- Abata
4= Clay plain –Abata 5= Lower terraces – Zalingei 6= Upper terraces- Zalingei
7= Stony hill slope- Zalingei 8= Lower hill slope –Traje 9= Upper terraces –Traje
10- Contemporary flood plain–Traje 11= Stony hill slope Traje

4.5. Distributions of tree species in the study area.

The results showed that *Faidherbia albida* was dominant in the contemporary flood plains and lower terraces. However *Balanites aegyptiaca*, *Acacia seyal* were dominant in the upper terraces. On the other hand, *Acacia seyal* dominated the Clay plains. The results indicated that *Albizia amara*, *Acacia senegal* are dominant on the sedentary plain. at the lower hill slopes, *Albizia amara*, *Acacia senegal and Balanites aegyptiaca* were dominant. On the other hand, *Boswellia papyrifera*, *Albizia amara* dominated the stony hill crests and slopes (Fig. 12).

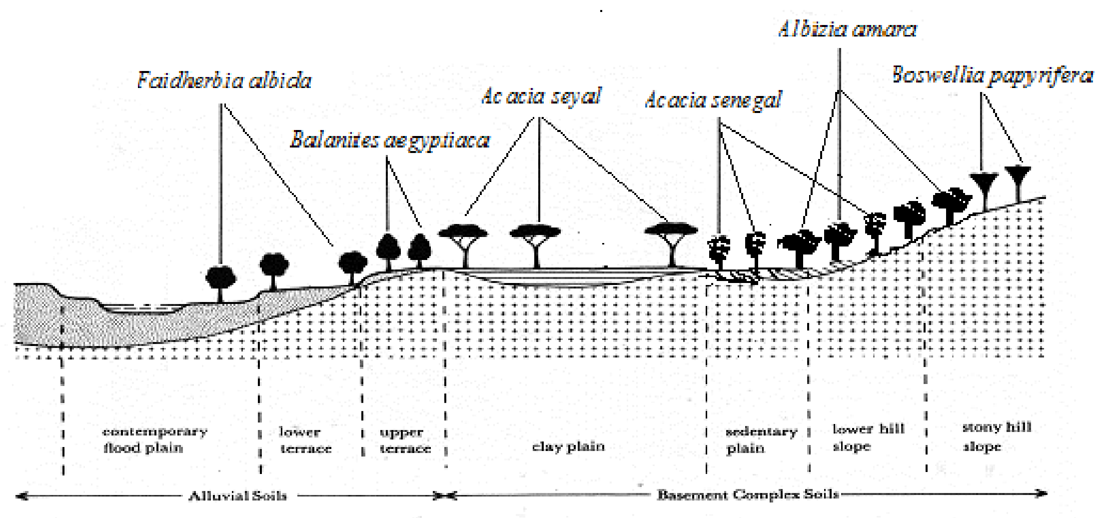

Fig.12. Schematic diagram of tree cover across the Wadi system to the stony hill slopes at Zalingei area.

The results showed that the highest tree density in all sites for *Albizia amara* was (24.1trees/ha), *Acacia seyal* (14.33 trees/ha), *Acacia senegal* (10.36 trees/ha) and *Balanites aegyptiaca* (9.33 trees/ha), followed by *Acacia nilotica* (1.38 trees/ha), *Boswellia papyrifera* (1.69 trees/ha), *Ziziphus spina-christi* (1.1 trees/ha), *and Acacia girrardii* (1.1 trees/ha) and *Anogeissus leiocarpus* (1.1 trees/ha). All other species were less than one tree/ha. The results also showed that the survival rate declined by 6% in the second year compared to the first year from 95% to 89%. The average tree/ha for Zalingei area was 70.27 as follow: 78.99 during the first survey in the rainy seasons of the year 2013, 74.68 during the second survey in the dry seasons of the year 2013, 67.34 at the first survey in the rainy seasons of the year 2014 and 60.07 at the second survey in the dry seasons of the year 2014 (Table 19).

These results are in line with Hunting Technical Services maps (1958,1983) who reported that the study area is dominated by a mosaic of *Anogeissus leiocarpus/ Albizia amara* in the area as general , *Balanites aegyptiaca/ Ziziphus spina-christi* on the upper terraces and *Faidherbia albida* on the lower terraces . The difference between Zalingei and Teraje exists in the presence of *Khaya senegalensis* near Wadi Gallabat Traje, but at Abata area the dominant tree species was a mosaics of *Anogeissus leiocarpus/ Acacia seyal* in general *, Balanites aegyptiaca/ Ziziphus spina-christi on* the upper terraces and *Faidherbia albida* on the lower terraces (Fig 5 and 6). Presently, there have a few number of trees of *Khaya senegalensis* and *Anogeissus leiocarpus.*

The results in (Table 19 and Figure 12) are more or less similar with Ali (2012), who reported that *Albizia amara* widely, covers the area, wile *Balanites aegyptiaca* and *Acacia seyal* cover all the area, *Acacia senegal* and *Acacia nilotica* are found in the west and north Abata and Traje , *Boswellia papyrifera* in south Zalingei around the mountains, *Acacia girrardii* is in Zalingei and traje and *Anogeissus leiocarpus* and *Ziziphus spina-christi* are thinly scattered in the area.

The number of tree species in the study area was reported as 29 trees reflecting a good biodiversity and is almost equal to that of DRC and U of Z, (2009) whose reported 31 tree species.

The overall tree density was calculated as 70.27 trees/ ha at the study area, a figure which is low compared to other similar areas such as Nuba mountains, where Daldoum (2012) recorded a density of 120 trees/ ha, however, the study of the Nuba mountain was conducted in an area that inaccessible to human and animal for a long time due to security reasons that prevailed, and that consequently led to better protection of the area.

The present tree density (70.27 trees/ha) in the study area is high as compared to other studies, (Ali, 2006) who recorded that the density of 20 trees/ ha in an open degraded area at Umrimita, White Nile State.

DRC and U of Z (2009) reported that 42 trees /ha at Wadi Salih and Azum locality, this variation is due to the fact the present study was conducted in areas where trees exist and excluded the farming areas and thus contrasting of DRC and U of Z (2009) which included farming areas.

Tree species survival rate was found to be decreasing between the wet and dry seasons from 0.95 between the two surveys in the first year to 0.89 between the two surveys in the second year. This result is due to the over exploitation of the tree vegetation of the area especially at Upper terraces and this agreed with Mustafa (2007) who reported that vegetation degradation is the quantitative and/or qualitative reduction of the vegetative cover resulting from various factors including human induced activities and severs prolonged droughts under poor land resources management (Appendix plates 17,18 and 19).

Table 19. Density of tree species during and after rainy season in Zalingei area

Latin name	Y1W	Y1D	**S R**	Y2W	Y2D	**S R**	**Mean**	**Tree/ ha**
Ziziphus spina-christi	19	17	0.89	14	11	0.79	15.25	1.10
Ziziphus abyssinica	8	7	0.88	7	6	0.86	7	0.50
Anogeissus leiocarpus	19	18	0.95	13	11	0.85	15.25	1.10
Lannea fruticosa	9	8	0.89	7	7	1.00	7.75	0.56
Sclerocarya birrea	5	5	1.00	3	2	0.67	3.75	0.27
Albizia anthelmintheca	5	3	0.60	3	3	1.00	3.5	0.25
Albizia amara	361	347	0.96	331	301	0.91	335	24.10
Dichrostachys cinerea	13	14	1.08	11	8	0.73	11.5	0.83
Faidherbia albida	10	10	1.00	10	10	1.00	10	0.72
Dalbergia melanoxylon	5	4	0.80	3	3	1.00	3.75	0.27
Bauhinia rufescens	8	6	0.75	5	4	0.80	5.75	0.41
Acacia seyal	216	211	0.98	197	173	0.88	199.25	14.33
Acacia senegal	164	151	0.92	134	127	0.95	144	10.36
Acacia girrardii	22	18	0.82	11	8	0.73	14.75	1.06
Acacia laeta	1	1	1.00	1	1	1.00	1	0.07
Acacia mellifera	6	4	0.67	4	3	0.75	4.25	0.31
Acacia nilotica	32	31	0.97	21	18	0.86	25.5	1.83
Acacia oerfota	6	6	1.00	6	7	1.17	6.25	0.45
Acacia tortilis	1	1	1.00	0	0	0.00	0.5	0.04
Acacia sieberana	1	0	0.00	0	0	0.00	0.25	0.02
Xeromphis nilotica	1	0	0.00	0	0	0.00	0.25	0.02
Grewia mollis	2	2	1.00	2	2	1.00	2	0.14
Combertum glutinosum	3	2	0.67	2	2	1.00	2.25	0.16
Terminalia mollis	1	1	1.00	2	2	1.00	1.5	0.11
Sterculia setgera	1	1	1.00	2	1	0.50	1.25	0.09
Balanites aegyptiaca	151	144	0.95	122	102	0.84	129.75	9.33
Boswellia papyrifera	26	24	0.92	23	21	0.91	23.5	1.69
Ailanthus exclsa	1	1	1.00	1	1	1.00	1	0.07
Kigelia africana	1	1	1.00	1	1	1.00	1	0.07
Total	1098	1038	0.95	936	835	0.89	976.75	70.27
Total/ha	78.99	74.68	0.95	67.34	60.07	0.89	70.27	-

Were:

Y1W = survey in the rainy seasons of first year
Y2W = survey in the rainy seasons of second year
Y1D = survey in the dry seasons of first year
Y2D = survey in the dry seasons of second year
SR = survival rate

4.6.Effects of soil physical properties on the distribution of trees .

Faidherbia albida is the dominant tree species in contemporary flood plain and lower terraces where the soil texture is loamy sand and sandy loam, respectively. *Balanites aegyptiaca* was dominant on the sandy clay loam of upper terraces. At sedentary plains and lower hill slopes where the soil texture was sandy clay loam and sandy loam, respectively the dominant species are *Albizia amara* and *Acacia senegal*. On the other hand *Acacia seyal* and *Acacia senegal* are dominant on the clay plain in clay soil textured. *Boswellia papyrifera, Albizia amara* dominant on the sandy loam of stony hill slope.

Results of Simpson diversity index show that the most diverse site is the lower terraces (0.15) were the soil texture was sandy loam followed by sandy loam of lower hill slope (0.26) and stony hill slope (0.33), followed by clay plain (0.34), sandy clay loam of sedentary plain (0.35) and upper terraces (0.41) and no diversity at loamy sand of contemporary flood plain (Table 20).

4. 7. Effects of soil chemical properties on the distribution of trees .

Faidherbia albida is the dominant tree species in contemporary flood plain and lower terraces where the soil pH ranges from 6.5 - 6.8, EC Mmhos/cm ranges from 0.24 – 0.43, SP ds/m ranges from 42.7 – 44, Na meg/l ranges from 0.33- 0.77, Ca+Mg meg/l is 0.30, K meg/l ranges from 0.14 – 1.33, HCO_3 meg/l ranges from 3.5 – 4.25 and Cl meg/l ranges from 5.75 – 6.25. *Balanites aegyptiaca* dominant at the sandy clay loam of upper terraces . *Albizia amara* dominant at sedentary plain, lower hill slope and stony hill slope where the soil pH ranges from 5.7 - 6.42, EC mmhos/cm ranges from 0.54 –1.35, SP ds/m ranges from 36.8 – 48, Na meg/l ranges from 1.13-7.31, Ca+Mg meg/l ranges from 3.50 - 11, K meg/l ranges from 0.31 – 0.95, Hco_3 meg/l ranges from 3.25 – 5 and Cl meg/l ranges from 7 – 11.8. *Acacia senegal* is dominant at Sedentary plain, lower hill slope and Clay plain where the soil pH ranges from 5.7 - 7.03, EC mmhos/cm ranges from 0.54 – 0.69, SP ds/m ranges from 36.8 – 47.4, Na meg/l ranges from 1.13- 3.04, Ca+Mg meg/l ranges from 3.00 – 4.5, K meg/l ranges from 0. 1 – 0.33, HCO_3 meg/l ranges from 3.25 – 7.50 and Cl meg/l ranges from 7 – 9.5.

Acacia seyal dominant at the clay plain. *Boswellia papyrifera* dominant on Sandy loam of Stony hill slope (Table 20). Generally, there is no diversity at contemporary flood plain due to the low value of important chemical properties such as NPK and the site receiving clay and sand every rainy season and expose to the gully erosion. The lower terraces have the highest diversity index of (0.15) due to availability of water and good soil conditions especially K meg/l (1.33) (Table 20).

Table 20. The effects of soil physical and chemical properties on the distribution of trees at Zalingei areas

sites	Chemical properties								Soil texture	D value	Dominant tree species
	Ph	ECe Mmhos/cm	SP ds/m	Na meg/l	Ca+Mg meg/l	K meg/l	Hco_3 meg/l	Cl meg/l			
CF	6.50	0.24	44.0	0.33	3.00	0.14	3.50	5.75	Loamy sand	1	*Faidherbia albida*
LT	6.80	0.43	42.7	0.77	3.00	1.33	4.25	6.25	Sandy loam	0.15	*Faidherbia albida*
UT	6.45	0.45	44.2	1.49	3.26	0.36	4.75	7.75	Sandy clay loam	0.41	*Balanites aegyptiaca*
CP	7.03	0.51	47.4	3.04	3.00	0.10	7.50	7.75	Clay	0.34	*Acacia seyal* , *Acacia senegal*
SP	6.15	0.69	39	1.13	4.50	0.33	4.00	9.50	Sandy clay loam	0.35	*Albizia amara* , *Acacia senegal*
LH	5.7	0.54	36.8	2.32	3.50	0.31	3.25	7.00	Sandy loam	0.26	*Albizia amara* , *Acacia senegal*
SH	6.42	1.35	48.0	7.31	11.00	0.95	5.00	11.8	Sandy loam	0.33	*Boswellia papyrifera*, *Albizia amara*

Were site:
CF= Contemporary flood plain **LT** = Lower terraces **UT** = Upper terraces **SP=** Sedentary plain **CP** = Clay plain **LH** = Lower hill slope
SH = Stony hill slope **D value** = Simpson Diversity index

4.8. Results of Growing stock volume

The results show that there is a great variation in woody vegetation stock at different locations. The greatest vegetation stock was recorded for lower terraces in Zalingei (38.9 m^3/ha), contemporary flood plain Teraje (35.68 m^3/ha) and lower terraces Abata (20.28 m^3/ha). The lowest was for clay plain in Abata (3.64 m^3/ha), upper terraces Teraje (7.17 m^3/ha) and lower hill slope Abata (7.23 m^3/ha). The mean valume is 14.87m^3/ha in the area with 1.9 m^3/h annual loss as shown in Table 21.

This results slightly differs with (FAO 2001b) who reported wood volume for Sudan at 9 m^3/ha,this variation is attributed to the fact that, FAO study was for all the country but the result of this study are only for Zalingei (Figure 6). Also differs with (DRC and U of Z, 2008) whose reported wood volume for Zalingei area at 17.9 m^3/ha.This variation is attributed to adverse human activities such as over cutting, overgrazing and agricultural expansions. The vegetation stock volume is below the average of the world wich is equal to about 131 m3/ha (FAO, 2010). This is obviously because Sudan is mostly covered with dessert.

The total vegetation stock volume m^3/ha was found to be decreasing from 16.2 m^3/ha to 14.9 m^3/ha in the first year and from 14.1 m^3/ha to 13.2 m^3/ha in the second year between the seasons. This degradation of vegetation in the area results from dependency of people livelihoods on forest resources. The most affected sites by human activities are upper terraces at Zalingei and lower terraces at Abata, for the first one, it is considered as the main area of charcoal making for Zalingei Town (plate 2- 3), where as for the second site is overgrazing by camel breeders whose fell down all the branches of the dominant *Faidherbia albida species* during summer period (Appendix plate 19).

Table 21. Woody vegetation stock in the different sites.

Site	Y1W	Y1D	Y2W	Y2D	Annual loss m^3/ h	Volume m^3/ha
Contemporary flood plain- Teraje	17.84	17.84	17.84	17.84	0.0	35.68
Lower terraces – Abata	15.94	10.46	10.57	11.7	-2.1	20.28
Lower terraces – Zalingei	23.34	23.34	23.34	23.34	0.0	38.9
Upper terraces- Zalingei	26.2	20.41	16.53	11.94	-9.1	8.94
Upper terraces – Teraje	4.3	4.3	4.3	4.3	0.0	7.17
Clay plain - Abata	2.74	2.37	1.97	1.65	-0.7	3.64
Sedentary plain -Abata	22.97	22.56	21.05	18.86	-2.8	10.17
Lower hill slope - Abata	16.74	15.59	14.98	13.43	-2.0	7.23
Lower hill slope – Teraje	19.8	19.34	17.16	16.09	-2.9	8.62
Stony hill slope- Teraje	6.61	6.48	6.39	6.23	-0.2	12.86
Stony hill slope- Zalingei	22.18	21.62	20.96	20.02	-1.4	10.1
average	16.2	14.9	14.1	13.2	-1.9	14.87
Total	178.66	164.31	155.09	145.4	-23.1	163.59

Were:

Y1W = survey in the rainy seasons of first year

Y1D = survey in the dry seasons of first year

Y2W = survey in the rainy seasons of second year

Y2D = survey in the dry seasons of second year

4.8.2. Crown cover.

The results showed that there is variation in the vegetation crown cover at different sites. The highest percentage of crown cover was the stony hill slope in Teraje (31.02%) followed by clay plain in Abata (28.72%), lower hill slope Abata (23.57%) and upper terraces in Zalingei (22.01%). The lowest was for the lower terraces in Abata (3.38%), upper terraces in Teraje (4.31%) and contemporary flood plain in Teraje (4.9%).The percentage of the vegetation cover of the area was17.96% (Table 22).

This results showed that there were variation in the vegetation cover at different sites. And the percentage of the vegetation covers of the study area is less than that of (FAO, 2006), that worldwide vegetation cover was estimated at 21.4 % of the total land area. Half of this area was located in Russia, Canada and Brazil.

FNC,(2004) reported that Forests cover of Sudan was 29.64 %. FAO, (2000) reported that the forests and woodlands covered 17.68% of the Sudan. FAO (2005a) reported that the estimated forest cover was 28% of that study area, UNEP (2007) report that the vegetation degradation of Jebel Marra, Western Darfur shifted from 50.7% in the year 1973 to 35.8% in the year 2001. AFF, (2011) ,reported that the total area of Sudan and the area of vegetation cover of Sudan is reduced after separation of the two countries to 11.6%, which shows that most of the forest went with the Southern Sudan.

Table 22. Crown cover and percentage of woody vegetation at different Sites.

Site	**Y1W**	**Y1D**	**Y2W**	**Y2D**	Average /ha	Sample plot / ha	Crown cover %
Contemporary flood plain- Teraje	245	245	245	245	0.025	0.5	4.9 %
Lower terraces – Abata	258.7	177.02	181	194.4	0.020	0.6	3.38%
Lower terraces – Zalingei	583.4	583.4	583.4	583.4	0.058	0.6	9.72%
Upper terraces- Zalingei	6811.3	5010.7	3669.7	2993.1	0.462	2.1	22.01%
Upper terraces – Teraje	258.7	258.7	258.7	258.7	0.026	0.6	4.31%
Clay plain - Abata	2048.6	1810.6	1618.9	1414.1	0.172	0.6	28.72%
Sedentary plain -Abata	4797.1	4469.3	4005.8	3641.4	0.423	2.1	20.14%
Lower hill slope - Abata	5523.1	5246.1	4723.7	4306.2	0.495	2.1	23.57%
Lower hill slope – Teraje	3770.8	3605.2	3173.5	3021.6	0.339	2.1	16.16%
Stony hill slope- Teraje	1594.5	1561.5	1540.5	1507.9	0.155	0.5	31.02%
Stony hill slope- Zalingei	3363.2	3209.4	3155.6	3136.2	0.322	2.1	15.31%
Total	29254.4	26176.9	23155.8	21302	2.497	13.9	17.96%

Were:

Y1W = survey in the rainy seasons of first year

Y1D = survey in the dry seasons of first year

Y2W = survey in the rainy seasons of second year

Y2D = survey in the dry seasons of second year

4.9.1. Trends in growing stock volume (m^3).

Results of statistical analysis showed that there is a great deterioration in the woody vegetation stock through the seasons namely; survey in the rainy seasons of first year (Y1W), survey in the rainy seasons of second year (Y2W), survey in the dry seasons of first year (Y1D) and survey in the dry seasons of second year (Y2D). Also there is a great deterioration in the woody vegetation stock in the sites studied especially at upper terraces Zalingei and lower hill slope Abata. and there was little change in the clay plain of Abata , stony hill slope of Zalingei and lower hill slope of Teraje but there was no change at the other sites (Table 23 and plate1,2 and 3) and (Appendix plate 18,19 and 20).

Results in table 23 and 24 showed that the vegetation stock has changed completely with the seasons especially in upper terraces of Zalingei and lower hill slope Abata in due to adverse human activities such as charcoal making and wood cutting at these sites (plates 1,2 and 3) and this confirmed the result by (FAO, 2001b) who reported that a decrease of 959,000 ha/year; 90% of which is for fuel and charcoal making (ADB and FAO, 2003). And this result agreed with (UNEP, 2007) who reported that the annual linear deforestation rate (period loss) in Jebel Marra and Western Darfur are 1.04 % and 29.4 % respectively. Similar findings by FAO (2001b) estimate the total forest cover of Sudan is 61,630,000 ha and constitutes 26 percent of the country's land area of 237,600,000 ha. The forest cover area in the Sudan decreased from 71,220,000 ha in 1990 to 61,630,000 ha in 2000.

Table 23. Woody vegetation stock volume (m^3) during different seasons.

Site	Comparison	T – value	Std Error	P	Level of significant
Lower terraces – Abata	Y1W **vs** Y2D	1.51	0.704	0.2292	**NS**
Upper terraces- Zalingei	Y1W **vs** Y2D	7.57	0.0897	0.000001	*****
	Y1W **vs** Y1D	4.98	0.0554	0.0001	*****
	Y2W **vs** Y2D	3.08	0.0709	0.0059	****
	Y1D **vs** Y2W	4.06	0.0455	0.0006	*****
Clay plain - Abata	Y1W **vs** Y2D	3.35	0.0813	0.044	***
	Y1W **vs** Y2D	0.83	0.1115	0.4677	**NS**
	Y2W **vs** Y2D	4.62	0.0173	0.0191	***
	Y1D **vs** Y2W	1.39	0.0719	0.2584	**NS**
Sedentary plain -Abata	Y1W **vs** Y2D	2.10	0.0931	0.0483	***
	Y1W **vs** Y2D	1.96	0.0099	0.0636	**NS**
	Y2W **vs** Y2D	1.42	0.0735	0.1713	**NS**
	Y1D **vs** Y2W	2.90	0.0248	0.0089	****
Lower hill slope - Abata	Y1W **vs** Y2D	4.40	0.0358	0.0003	****
	Y1W **vs** Y2D	1.58	0.0346	0.1289	**NS**
	Y2W **vs** Y2D	2.40	0.0308	0.0264	***
	Y1D **vs** Y2W	2.08	0.0139	0.050	***
Lower hill slope – Teraje	Y1W **vs** Y2D	2.52	0.0701	0.0203	***
	Y1W **vs** Y2D	1.56	0.0141	0.1356	**NS**
	Y2W **vs** Y2D	1.68	0.0303	0.1077	**NS**
	Y1D **vs** Y2W	1.65	0.0630	0.1151	**NS**
Stony hill slope- Teraje	Y1W **vs** Y2D	1.38	0.0689	0.2616	**NS**
Stony hill slope- Zalingei	Y1W **vs** Y2D	3.11	0.0331	0.0056	****
	Y1W **vs** Y2D	1.62	0.0164	0.1201	**NS**
	Y2W **vs** Y2D	1.70	0.0264	0.1049	**NS**
	Y1D **vs** Y2W	**1.81**	**0.0174**	**0.0856**	**NS**

Were:
NS= Not Significant * = Significant at 0.05 ** = Significant at 0.01 *** = Significant at 0.001
Y1W = survey in the rainy seasons of first year Y2W = survey in the rainy seasons of second year
Y1D = survey in the dry seasons of first year Y2D = survey in the dry seasons of second year

4.9.1.1. Trends in crown cover (m^2)

The results showed that there was variation in the crown vegetation cover between seasons namely; survey in the rainy seasons of first year (Y1W), survey in the rainy seasons of second year (Y2W), survey in the dry seasons of first year (Y1D) and survey in the dry seasons of second year (Y2D). Also there is a great decrease in crown vegetation cover in the different sites especially upper terraces Zalingei, lower hill slope Abata and sedentary plain Abata. There was a little change at the clay plain Abata , sedentary plain Abata and stony hill slope Zalingei, but there was no change in the rest of the sites (Table 24 plates 1,2 and 3) and (Appendicx, plates 18,19 and 20).

Table 24. Crown vegetation cover (m^2) in the wet and dry seasons

Site	Comparison	T – value	Std Error	P	Level of significant
Lower terraces – Abata	Y1W **vs** Y2D	1.64	9.7789	0.1988	**NS**
Upper terraces- Zalingei	Y1W **vs** Y2D	5.66	32.135	0.00001	***
	Y1W **vs** Y1D	3.16	27.148	0.0049	**
	Y2W **vs** Y2D	2.40	13.417	0.0262	*
	Y1D **vs** Y2W	4.18	15.270	0.0005	***
Clay plain - Abata	Y1W **vs** Y2D	5.64	28.106	0.0110	*
	Y1W **vs** Y2D	9.79	6.0765	0.0023	**
	Y2W **vs** Y2D	2.26	22.646	0.1088	**NS**
	Y1D **vs** Y2W	1.44	33.250	0.2451	**NS**
Sedentary plain -Abata	Y1W **vs** Y2D	4.39	12.542	0.0003	***
	Y1W **vs** Y2D	2.86	5.4538	0.0096	**
	Y2W **vs** Y2D	2.60	6.6848	0.0173	*
	Y1D **vs** Y2W	3.37	6.5401	0.003	**
Lower hill slope - Abata	Y1W **vs** Y2D	4.31	13.429	0.0003	***
	Y1W **vs** Y2D	2.38	5.5442	0.0274	*
	Y2W **vs** Y2D	2.79	7.1336	0.0114	*
	Y1D **vs** Y2W	3.69	6.7489	0.0015	**
Lower hill slope – Teraje	Y1W **vs** Y2D	3.15	11.340	0.0051	**
	Y1W **vs** Y2D	1.85	4.2550	0.0787	**NS**
	Y2W **vs** Y2D	1.92	3.7766	0.0699	**NS**
	Y1D **vs** Y2W	2.4	8.5831	0.0256	*
Stony hill slope- Teraje	Y1W **vs** Y2D	2.68	8.0782	0.0750	**NS**
Stony hill slope- Zalingei	Y1W **vs** Y2D	2.53	4.2789	0.0201	*
	Y1W **vs** Y2D	2.02	3.6301	0.0573	**NS**
	Y2W **vs** Y2D	0.1214	0.5710	0.1214	**NS**
	Y1D vs Y2W	**0.0677**	**1.3265**	**0.0677**	**NS**

Were:
NS= Not Significant   * = Significant at 0.05 ** = Significant at 0.01   *** = Significant at 0.001
Y1W = survey in the rainy seasons of first year   Y2W = survey in the rainy seasons of second year
Y1D = survey in the dry seasons of first year   Y2D = survey in the dry seasons of second year

Plate 1. Cuttings of *Balanites aegyptiaca* at stony hill slope in Zalingei area

Plate 2. Some felled *Balanites aegyptiaca* trees on the upper terraces of Zalingei site.

Plate 3. Some felled *Acacia seyal* trees on the upper terraces of Zalingei site (left) and charcoal making on the upper terraces Zalingei (right).

4.10. Source of natural regeneration and density by species.

The results indicated that the highest density of seedlings was 75.58/ha for *Acacia seyal*, 75.31/ha for *Albizia amara*, 68.63/ha for *Balanites aegyptiaca*, 58.78/ha for *Acacia senegal* and 41.66/ha for *Dichrostachys cinerea*. However 22.19/ha for *Acacia nilotica*, 19.03/ha for *Ziziphus spina-christi*, 9.64/ha for *Ziziphus abyssinica*, 7.84/ha for *Acacia girrardii*, 4.18/ha for *Acacia mellifera* and 6.46/ha for *Faidherbia albida* with moderate seedlings density. Other species gave very lowe densities (Table 27). Also the results showed that all species have more than one source of natural regeneration, such as *Albizia amara*, *Balanites aegyptiaca*, *Dichrostachys cinerea* which are renewed by seeds, coppice and sprouts (plate 4,5 and 6). Other species have two sources of regenerations; namely seeds and coppice (Table 25 and Appendix Table 32). On the other hand coppice and sprouts are more tolerant to drought and have high survival rate compared to seeds due to the good root system. The number of seedlings/ha (388.77) is less than that of Adam (2003) who reported 14607 seedlings/ha. This variation is due to the changes that have occurred in the area during this time lapse in addition, the study of Adam (2003) was conducted in the foot of Jebel Marra area while this study wasn conducted in Zalingei area.

Table 25. Source of natural regeneration and density by species in Zalingei.

Species	Seedlings more than one m in height			Seedlings less than one m in height			Seedlings /ha
	Seed	Coppice	Sprout	Seed	Coppice	Sprout	
Albizia amara	143	61.3	113.3	81.5	68.5	37	75.31
Acacia senegal	104.5	95.3	0	119.3	74.7	0	58.78
Faidherbia albida	20	14	0	4.5	4.8	0	6.46
Albizia anthelmintheca	0.5	0	0	1	0.25	0	0.26
Acacia girrardii	13	5	0	24	10.5	0	7.84
Acacia seyal	142.5	40.3	0	237.8	85.8	0	75.58
Acacia sieberana	1	0.8	0	2.3	0.5	0	0.69
Acacia nilotica	41.7	12.5	0	70.5	24	0	22.19
Acacia mellifera	15.5	5	0	15	6.3	0	6.24
Acacia tortilis	0	0	0	0.3	0	0	0.04
Acacia oerfota	4	1	0	4.5	1	0	1.57
Acacia polycantha	0.3	0	0	0.3	0	0	0.09
Ziziphus spina-christi	24	9.3	0	20	11.3	0	9.64
Anogeissus leiocarpus	1.25	0	0	0.25	0	0	0.22
Sclerocarya birrea	0.25	0	0	1.5	0	0	0.26
Dichrostachys cinerea	69.3	25.5	25.3	111.5	25.5	22	41.66
Dalbergia melanoxylon	1.8	5	0	4.5	0.5	0	1.76
Bauhinia rufescens	11.75	4.75	0	13.25	3.35	0	4.94
Xeromphis nilotica	6.5	3.75	0	9.5	5	0	3.7
Balanites aegyptiaca	118.25	75.25	55.75	125.3	37.5	47.75	68.63
Boswellia papyrifera	0.75	2.5	0	2	4.75	0	1.49
Azanza garckeana	1. 5	1	0	0.75	0.5	0	0.34
Combertum glutinosum	0.25	0	0	1. 5	0	0	0.04
Terminalia mollis	2.25	0	0	4.75	0	0	1.04
Average	722.35	362.25	194.35	854.3	364.75	106.75	388.77

Plate 4. Sprout of *Albizia amara* on lower hill slope Abata

Plate 5. *Faidherbia albida* seedlings on upper terraces Teraje (left)

Ziziphus abyssinica seedlings at lower terraces in Zalingei (right)**.**

Plate 6. *Balanites aegyptiaca* coppice at stony hill slope Zalingei (left) and *Albizia amara* coppice at lower hill slope Abata (right)

4.11. Effect of sites on natural regeneration of trees pecies.

The results indicated that the contemporary flood plain site have less seedlings compared to other sites. *Albizia anthelmintheca*, *Combertum glutinosum, Sclerocarya birrea, Anogeissus leiocarpus Acacia tortilis acacia polycantha, Faidherbia albida* have less survival rate (Table 26 and Appendix, Table 33). However *Albizia amara, Balanites aegyptiaca, Acacia senegal*, *Dichrostachys cinerea, Acacia nilotica, Ziziphus spina-christi* have highly survival rate. The results also show that seedlings with more than one meter length have better survival rate than those with less than one meter height. It was observed that over grazing, drought and termites have strongly affected the trees seedlings at the summer seasons (plate, 7) and (Appendix, plate 17).

Table (26) indicated that the contemporary flood plain site have less seedlings compared to other sites because the area of contemporary flood plain is a sandy soil and often there is only one species *Faidherbia albida*.

The results also show that *Albizia anthelmintheca*, *Combertum glutinosum, Sclerocarya birrea, Anogeissus leiocarpus Acacia tortilis Acacia polycantha, Faidherbia albida* have less survival rate and this result agree with Ali (2012) who mentioned that in Zalingei area there is no natural regeneration of some species such as *Faidherbia albida, Boswellia paprifera, Cordia Africana, Tamarintus indica and Khaya senegalensis.*

On the other hand *Albizia amara, Balanites aegyptiaca, Acacia senegal*, *Dichrostachys cinerea, Acacia nilotica*, *Ziziphus spina-christi* have good survival rate and more tolerant to drought and termites. Seedlings of more than one meter hight were found have better survival rate compared to seedlings that are less than one meter in hight.

Plate 7. Impact of over grazing and termites on the tree seedlings.

Table 26. Natural regeneration of trees in the different site of Zalingei area

Species	Seasons	CF		LT		UT		SP		CP		LH		SH		Total	S R
		≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1		
Albizia amara	Y1	**0**	**0**	0	0	10	2	14	13	0	0	93	105	84	204	**523**	**84.8**
	Y2	0	0	0	0	6	3.5	11	19	0	0	58	106	85	200	**487**	**89.5**
Acacia Senegal	Y1	0	0	0	0	2	0	33	30	6	4	127	79	48	75	**403**	**82.5**
	Y2	0	0	0	0	5	1	73	38	8	5	55	86	34	82	**400**	**77.4**
Faidherbia albida	Y1	9	1	29	6	8	1	1	0	0	0	0	0	0	0	**56**	**24.2**
	Y2	0	1	19	5	2	2	0	1	0	0	0	0	0	0	**30**	**31.1**
Albizia anthelmintheca	Y1	0	0	0	0	0	0	2	1	0	0	0	0	0	0	**3**	**20**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Acacia girrardii	Y1	0	0	0	0	3	3	6	2	4	2	20	3	9	5	**55**	**52**
	Y2	0	0	0	0	5	0	8	1	10	3	5	6	5	4	**49**	**58.1**
Acacia seyal	Y1	0	0	0	0	172	41	4	6	171	90	73	33	11	19	**677**	**48.7**
	Y2	0	0	0	0	128	57	13	2	61	88	22	18	15	11	**464**	**47.9**
Acacia sieberana	Y1	0	0	1	0	0	0	0	1	0	0	2	3	1	0	**7**	**36.4**
	Y2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	**2**	**50**
Acacia nilotica	Y1	0	0	28	8	5	10	6	5	4	6	38	17	19	16	**162**	**75.1**
	Y2	0	0	26	11	11	7	8	7	8	5	22	3	14	13	**134**	**65.4**
Acacia mellifera	Y1	0	0	0	0	2	0	5	2	10	19	5	0	0	0	**44**	**60**
	Y2	0	0	0	0	1	0	1	3	16	15	0	2	0	0	**40**	**54.9**
Acacia tortilis	Y1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**0**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Acacia polycantha	Y1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	**2**	**0**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**

Continue table 26

Species	Seasons	CF		LT		UT		SP		CP		LH		SH		Total	S R
		≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1		
Acacia oerfota	Y1	0	0	0	0	0	0	7	3	0	0	0	0	0	0	14	**57.1**
	Y2	0	0	0	0	0	0	5	6	0	0	0	0	0	0	11	**69.2**
Ziziphus spina-christi	Y1	0	0	13	2	9	17	4	1	19	13	35	23	1	2	140	**65.3**
	Y2	0	0	12	5	10	14	1	4	13	12	8	29	3	4	115	**73.5**
Ziziphus abyssinica	Y1	3	0	9	4	12	28	0	0	2	5	0	0	0	0	64	**60**
	Y2	1	0	11	4	14	21	0	0	10	4	0	0	0	0	65	**49.4**
Anogeissus leiocarpus	Y1	0	0	0	0	0	0	0	0	2	1	0	0	0	0	2	**33.3**
	Y2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	**0**
Sclerocarya birrea	Y1	0	0	0	1	2	0	0	0	0	0	2	1	0	0	5	**40**
	Y2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	**0**
Dichrostachys cinerea	Y1	0	0	43	42	102	17	20	5	5	7	2	3	27	33	307	**74.4**
	Y2	0	0	40	47	36	29	13	10	12	6	0	0	16	40	250	**73**
Dalbergia melanoxylon	Y1	0	0	0	0	0	0	0	1	0	0	0	1	2	0	4	**50**
	Y2	0	0	0	0	0	0	1	0	0	0	4	1	2	1	9	**41.7**
Bauhinia rufescens	Y1	0	0	1	0	0	0	1	1	4	7	5	4	1	0	25	**72.4**
	Y2	0	0	2	0	0	0	3	0	7	5	7	5	0	1	30	**53.8**
Xeromphis nilotica	Y1	0	1	0	0	0	0	0	0	0	0	3	0	7	13	24	**77.8**
	Y2	0	0	0	0	0	0	0	0	0	0	0	2	7	16	26	**59.4**
Balanites aegyptiaca	Y1	0	0	13	16	149	157	2	4	1	1	34	20	21	37	455	**79.1**
	Y2	0	0	16	14	117	162	10	3	15	1	14	41	23	42	450	**83.8**
Boswellia papyrifera	Y1	0	0	0	0	0	0	0	0	0	0	2	0	8	5	15	**30.4**
	Y2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	5	**25**

Continue table 26

Species	Seasons	CF		LT		UT		SP		CP		LH		SH		Total	S R
		≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1		
Albizia amara	Y1	**0**	0	1	2	0	0	0	0	0	0	0	0	0	0	**3**	**50**
	Y2	0	0	0	4	0	0	0	0	0	0	0	0	0	0	**4**	**80**
Combertum glutinosum	Y1	0	0	0	0	0	0	0	0	0	0	2	1	0	0	**2**	**20**
	Y2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**	**0**
Terminalia mollis	Y1	0	0	0	0	0	0	0	0	0	0	0	0	2	5	**7**	**44.4**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	7	0	**7**	**36.4**

Were:

Y1W = survey in the rainy seasons of first year

Y1D = survey in the dry seasons of first year

CF =Contemporary flood plain

UT = Upper terrace

CP =Clay plain

SH = Stony hill slope

Y2W = survey in the rainy seasons of second year

Y2D = survey in the dry seasons of second year

LT = Lower terraces

SP =Sedentary plain

LH =Lower hill slope

S R = Survival rate

4.12. Difference in the source of natural regeneration using X^2 test.

Statistical analysis showed that there is highly significant difference between the three sources of seedlings (seeds, coppices and sprouts) for *Albizia amara*, *Balanites aegyptiaca* and *Dichrostachys cinerea*. *Albizia amara*, *Balanites aegyptiaca* were the main source of seeds followed by coppice and then sprouts, but *Dichrostachys cinerea* was the main source of seeds followed by coppice and sprouts as shown in (Table 27).

The seeds of *Albizia amara, Balanites aegyptiaca* and *Dichrostachys cinerea* were available with high viability compared to coppices and sprouts happened when the trees are exposed to over cutting and over grazing.

Table 27. Difference in the source of natural regeneration using X^2 test

Species	* Seeds	* Coppices	* Sprouts	X^2 calculated	X^2 Tabulated	L. S
Albizia amara	214	114	132	105.4	13.82	***
Balanites aegyptiaca	238	101	80	61.63	13.82	***
Dichrostachys cinerea	125	45	43	37.06	13.82	***

*= average of four seasons L.S = level of significantce.

4.13. Relationship between mature trees (T) and natural regeneration (S).

In general there was strongly positive and highly significant differences between mature trees and seedlings at $P \leq 0.001$ and $P \leq 0.01$ and there is significant differences between mature trees and seedlings at $P \leq 0.05$ far all trees in various sites except *Faidherbia albida* at lower terraces in Abata , *Ziziphus abyssinica* at lower terraces in Zalingei and *Acacia girrardii* at clay plain Abata.This is because, the adjusted R^2 for the species in these sites are low compared to the other sites, the adjusted R^2 of *Faidherbia albida* at lower terraces Abata , *Ziziphus abyssinica* at lower terraces Zalingei and *Acacia girrardii* on clay plain at Abata were low and this could be attributed to a few number of seedlings for the species in those sites which may indicates a possible change on trees species compositions (Table 28).

Table (28): Regression analysis for the relationship between mature trees (T) and natural regeneration per seedlings (S) in Zalingei area.

species	Site	F – value	Model	Adj R^2	L S
Albizia anthelmintheca	**SPA**	297.19	S = 0.05+0.987 T	0.9367	***
Balanites aegyptiaca	**LTA**	64	S = 1.667 + 5.33T	0.95	*
	UTZ	21.57	S = 3.41 + 1.86 T	0.5070	***
	UTT	20.22	S = 14.84 + 29.53 T	0.865	*
	SPA	253.94	S = -0.0086 + 0.74 T	0.9267	***
	LHA	41.87	S = 0.25+4.75 T	0.6715	***
	LHT	8.17	S = 1.37 + 0.405 T	0.2638	*
	SHZ	63.23	S 1.358 + 2.03 T	0.7568	***
Albizia amara	**SPA**	52.42	S = 0.643+ 0.132 T	0.52.42	***
	LHA	79.13	S = 2.694+0.531 T	0.7962	***
	LHT	60	S = 1.6+ 4.574 T	0.7468	***
	SHZ	181.27	S = 2.24+ 2.7442 T	0.9001	***
Faidherbia albida	**CFT**	289	S = 0 + 8.5 T	0.98	**
	LTA	0.75	S = 0+ 1 T	-0.091	**N.S**
	LTZ	52.48	S = 1.316 + 6.95 T	0.94	*
Acacia nilotica	**UTZ**	36.29	S = 0.1+0.6333 T	0.6383	***
	CPA	25	S =- 2.33+1.667 T	0.888	*
	SPA	63.91	S = 0.29+1.68 T	0.7588	***
	LHA	48.09	S = 0.636+1.53 T	0.7019	***
	LHT	31.18	S = 1.77+2.138 T	0.6014	***
Ziziphus abyssinica	**LTZ**	11.84	S = 0.58 + 1.74 T	0.783	**N.S**
	UTZ	11.62	S 0.65+0.66 T	0.347	**
Acacia seyal	**UTZ**	20.76	S 5.99 +1.1 T	0.4970	***
	CPA	18.39	S -15.3+7.257 T	0.8529	*
	SPA	55.51	S = - 0.066+1.769 T	0.8065	***
	LHA	5.26	S = 0.7222+0.944 T	0.1758	*
	LHT	56.79	S = 3.199+1.955 T	0.7361	***
	SHT	196	S = 7.66 +9.33 T	0.98	**
Acacia oerfota	**SPA**	55.51	S = - 0.061+0.55 T	0.7316	***
Bauhinia rufescens	**LHA**	36.29	S= 0.1+0.633 T	0.6383	***
	CPA	54.32	S= - 0.136+2.053 T	0.9467	*
Dalbergia melanoxylon	**LHT**	17.19	S= 0.05+0.95 T	0.4474	***
	SHZ	8.14	S= 0.1+0.9 T	0.2632	*
Ziziphus spina-christi	**CPA**	109.8	S= 2.84+6.53 T	0.973	**
	LHT	9.84	S= 2.65+6.6 T	0.3065	**
Acacia mellifera	**SPA**	52.98	S = 0.35+3.65 T	0.7222	***
Boswellia papyrifera	**SHT**	320	S = 0.65+0.696 T	0.9907	**
Acacia senegal	**UTZ**	15.38	S = 0+ 0.5 T	0.4183	***
	CPA	32.09	S = - 0.90+ 0.73 T	0.91	*
	SPA	17.02	S = 1.53+ 0.53 T	0.4448	***
	LHA	22.04	S = 5.547+ 0.774 T	0.5127	***
	LHT	11.41	S = 3.053+ 3.95 T	0.3423	**
	SHT	386.29	S = 4.33+ 34.667 T	0.993	**
	SHZ	30.35	S = 1.842+ 3.023 T	0.5947	***
Dichrostachys cinerea	**LHA**	10.47	S = 0.0417+ 0.375 T	0.3213	**
	LHT	173.06	S = 0.105+ 1.697 T	0.8959	***
	SHT	97	S = -0.9+ 12.6 T	0.97	**

Acacia girrardii	**CPA**	1.67	S = 1+0.5 S	0.182	**NS**
	SPA	533.32	S = 0.62+1.616 T	0.9638	***
	LHA	9.47	S = 0.26+2.35 T	0.2976	**
	LHT	48.93	S = 0.323+2.043 T	0.7056	***
	SHT	117.6	S = 75+3.5 T	0.974	**

LS = Level of significance * Significant at 0.05 ** Significant at 0.01

*** Significant at 0.001 NS = not Significant

4.14. Phenology of dominant tree species at the study area.

Table (29) and figure (13,14 and 15) represents the time, duration and peak days of flowering, fruit production, leafing and leaf shedding of the *Albizia amara*, *Faidherbia albida* and *Balanites aegyptiaca.* Flowers of *Albizia amara* start to emerge at the beginning of September and continues until the end of November, while fruiting starts to emerge at the end of October and continues until the beginning of April. These result agreed with Sahni (1968) who reported that the flowering of *Albizia amara* occurs during the rainy season and the period of fruiting is from November to April. However the results of the this study, disagree with Ali (2012) who mentioned that the flowering of *Albizia amara* takes place from May to June and the period of fruiting is from October to November.

Flowers of *Faidherbia albida* starts to emerge at the end of October and continues until the beginning of January, while fruiting starts to emerge at the end of November and continues until the beginning of April. This results is similar to Sahni (1968), Elkhalifa (1996). It also in line with Ali (2012) for the fruiting period because he found that the period of fruiting of *Faidherbia albida* is from December to January.

Flowers of *Balanites aegyptiaca* starts to emerge at the beginning of November and continues until the end of December, while the fruiting starts at the beginning of December and continues until the end of March. These results disagree with Sahni (1968), Elkhalifa (1996) and Ali (2012). Elkhalifa 1996 reported that flowers of *Balanites aegyptiaca* starts in November and continues until April, while the fruiting starts in December and continues until January. Ali (2012) reported that Flowers of *Balanites aegyptiaca* starts at May and continues until September, while the fruiting starts in September and continues until October. This variation is due to the bioannual flowering and fruiting of some trees.

Flushing of *Albizia amara* starts at the end of May and continues until the beginning of November, while the leaf shedding starts in the end of October and continues until the end of May. *Faidherbia albida* flushes at the beginning of October and continue until the end of May, while the leaf shedding starts in the beginning June and continues until the end of October. These results agreed with Sahni (1968), Elkhalifa (1996) and Ali (2012).

Tree that evergreen state is *Balanites aegyptiaca*, starts in the end of April and continues until the beginning of December. However the tree starts shedding it is leaves from the end of November to the end of February. This results also similar to Sahni (1968), Elkhalifa (1996) and Ali (2012).

4.15. Results of group discussion.

4.15.1. Vegetation in the area.

According to the results of group discussion there are shrubs 42 trees and 14 shrubs which belong to 21 families (Table 30). The identified species which were mentioned in group discussion were listed according to their occurrence in the different ecological zone.

The results of group discussion showed that the *Balanites aegyptiaca*, *Albizia amara* ,*Acacia seyal*, *Anogeissus leiocarpus, Acacia senegal*, *Dichrostachys cinerea*, *Ziziphus spina-christi* and *Acacia nilotica* have wide spread in the study area followed by *Faidherbia albida, Acacia girrardii*, *Xeromphis nilotica*, *Grewia tenax, Boscia senegalensis* and

Acacia mellifera which has less spread. The rest of the species are either not present or rarely or very rarely found.

Result of the group discussion were in line with the results of field survey especially in the distribution of trees in the different ecological zone. But there is variation in the number of trees where the results of the field survey showed 29 tree species only. This variation coud be due to the fact that more than half of these species were rare. Also the results of the group discussion agree with DRC and U of Z (2009) who recorded that some tree species rare, namely *Boswellia papyrifera, Steropermum kunthianum, Cordia Africana* and *Khaya senegalensis* are rare in Wadi Salih and Azum localities. Gorashi (1998) reported some of the important trees species that are under pressure and /or endangered as a consequence of repeated droughts or over-cutting and felling. Some of trees do not have the ability to regenerate such as *Adansonia digitata, Borassus aethiopium, Hyphaene thebaica,, Cordia abyssinica, Dalbergia melanoxylon, Grewia tenax, Anogeissus leiocarpus, Lonchocarpus laxiflorus, Ziziphus spina-christi and Khaya senegalensis.*

4.15.2. Factors causing degradation of vegetation.

Results of group discussion showed that the vegetation decreased in the last four decades. The main factors causing degradation is the adverse human activities such as illicit cutting, overgrazing, insecurity and agriculture expansion. Climatic change namely drought have negative affect the area in 1985 and 1986. FAO (2010) who reported that the various outbreaks of violence and the ongoing instability in Darfur region, have forced millions of people to flee their homes and millions of others are facing extreme poverty. The impact of conflict has been exacerbated by recurrent hazards such as drought, insecurity and poverty will have negative impact vegetation especially the trees. FAO (1997) estimated that deforestation is proceeding at a rate of at least that is 30 times greater than reforestation in many sub-Saharan countries.

Hodgkinson (1992) also reported high aridity as an adverse climatic condition that creates fragile ecosystem, which can easily be upset by adverse human activities. The spatial and temporal variation of rainfall determines the density and composition of the vegetation. Loockwood (1988) and Mustafa (2007) reported that the climates of arid and semi-arid lands are highly variable, particularly to rainfall. Low and erratic variation of rainfall is characteristic of dry lands, which have no particular rainfall distribution pattern.

Table 29. Phenology of dominant tree species at Zalingei area.

Species	Tree No	Flower production		Fruit production		Tree in leaves		Leafless period	
		Time	D	Time	D	Time	D	Time	D
Albizia amara	1	13/9- 2/11 (31)	49	30/10- 7/4 (112)	159	1/6- 3/11 (123)	155	4/11-31/5	210
	2	30/9- 8/11 (29)	38	1/11- 28/3 (98)	117	22/5- 31/10 (142)	162	1/11-21/5	203
	3	3/9-17/11 (41)	74	4/11-5/4 (113)	152	26/5-13/10 (121)	140	14/10-25/5	225
	4	22/9- 21/11 (38)	60	29/10- 19/4 (116)	172	11/6- 20/10 (118)	131	21/10-10/6	234
	5	7/9-9/11 (43)	62	21/10-31/3 (102)	130	17/5-13/ 10 (128)	146	12/10-16/5	219
Average		(36.4)	56.6	(108.2)	146	(126.4)	146.8	-	218.2
Faidherbia albida	1	13/11- 26/12 (30)	44	30/11- 9/4 (91)	130	9/10-11/6 (237)	245	12/6- 8/10	120
	2	19/11- 24/12 (23)	36	11/12- 11/4 (79)	121	28/10-1/6 (198)	209	2/6- 27/10	147
	3	29/10- 2/1 (41)	65	13/12- 26/3 (76)	103	29/9-26/5 (231)	241	27/5-28/9	124
	4	31/10- 7/1 (52)	69	16/12- 19/4 (89)	124	16/10-7/6 (224)	236	8/6- 15/10	129
	5	4/11- 8/1 (46)	66	4/12- 23/ 3 (72)	109	19/10-3/6 (217)	229	4/6-18/ 10	136
Average		(48)	56	(81.4)	117.4	(221.4)	232	-	131.2
Balanites aegyptiaca		**Flower production**		**Fruit production**		**Tree in leaves without Shedding**		**Sheds leaves period**	
		Time	D	Time	D	Time	D	Time	D
	1	13/11- 26/12 (31)	43	15/12-19/3 (76)	95	30/4-7/12 (220) 14/2-29/4 (74)	294	8/12- 13/2	71
	2	1/11- 17/12 (29)	47	3/12-6/4 (98)	123	30/4-1/12 (218) 28/2-29/4 (61)	279	30/11-27/2	86
	3	16/11- 16/12 (21)	31	13/12- 26/3 (91)	103	30/4-26/11 (209) 1/3-29/4 (58)	267	25/11-28/2	98
	4	7/11- 19/12 (33)	42	12/12-4/4 (86)	112	30/4-5/12 (217) 21/2 – 29/4 (67)	284	8/12-20/2	81
	5	30/11- 7/1 (22)	38	29/12- 30/3 (74)	93	30/4-16/11 (199) 4/3- 29/4 (56)	255	17/11-3/3	110
Average		(25.8)	36.9	(85)	(105.2)		275.8	-	89.2

*D = Duration * Figure between two bracket are peak time.

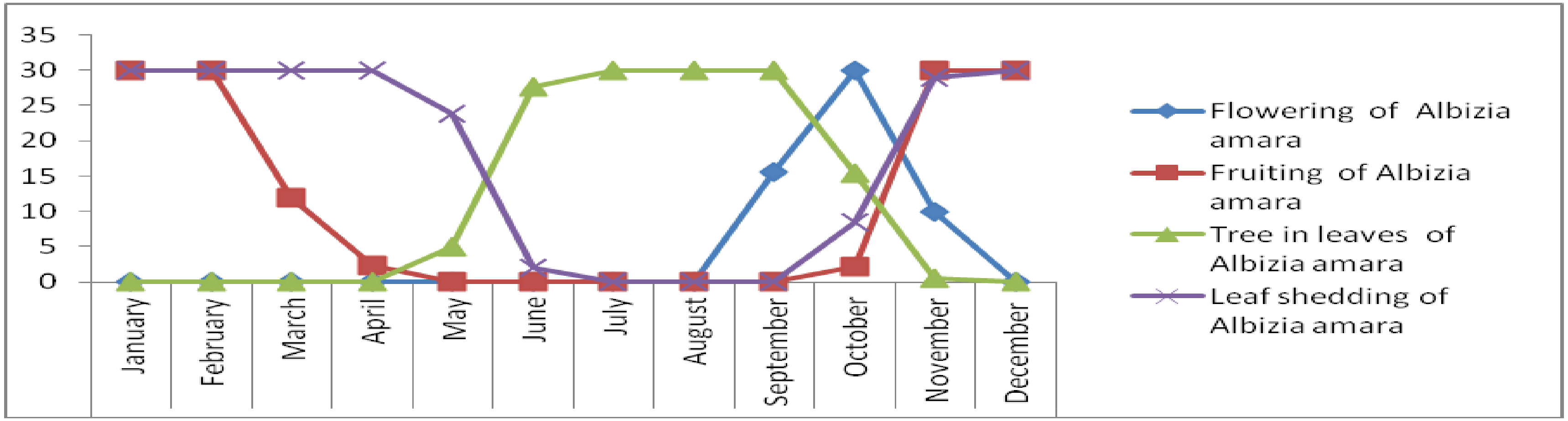

Fig. 13. Phenology of *Albizia amara* at Zalingei area.

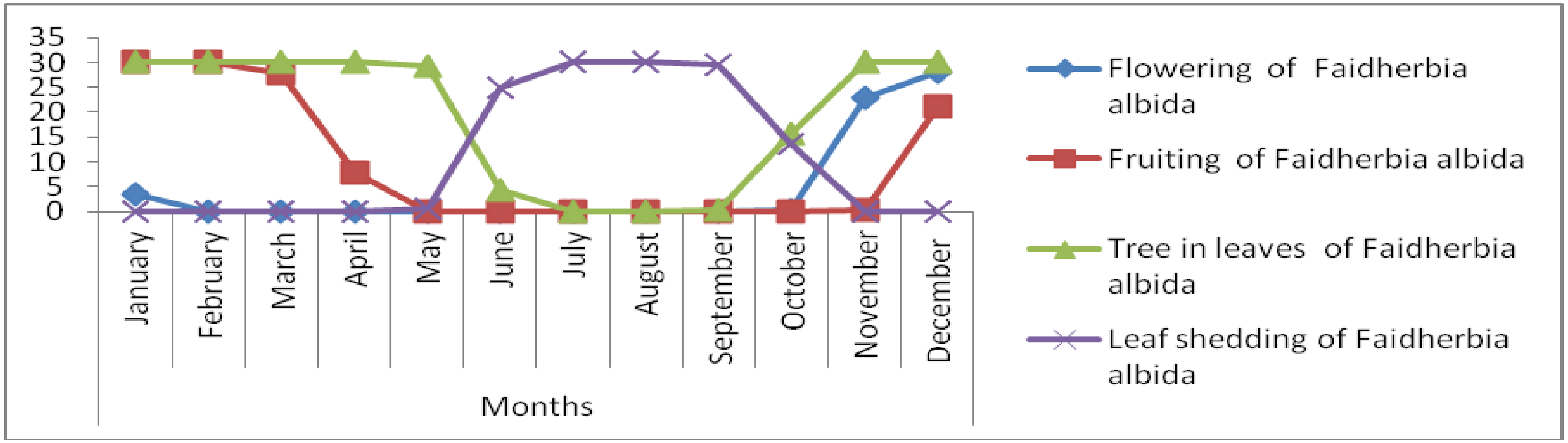

Fig. 14. Phenology of *Faidherbia albida* at Zalingei area.

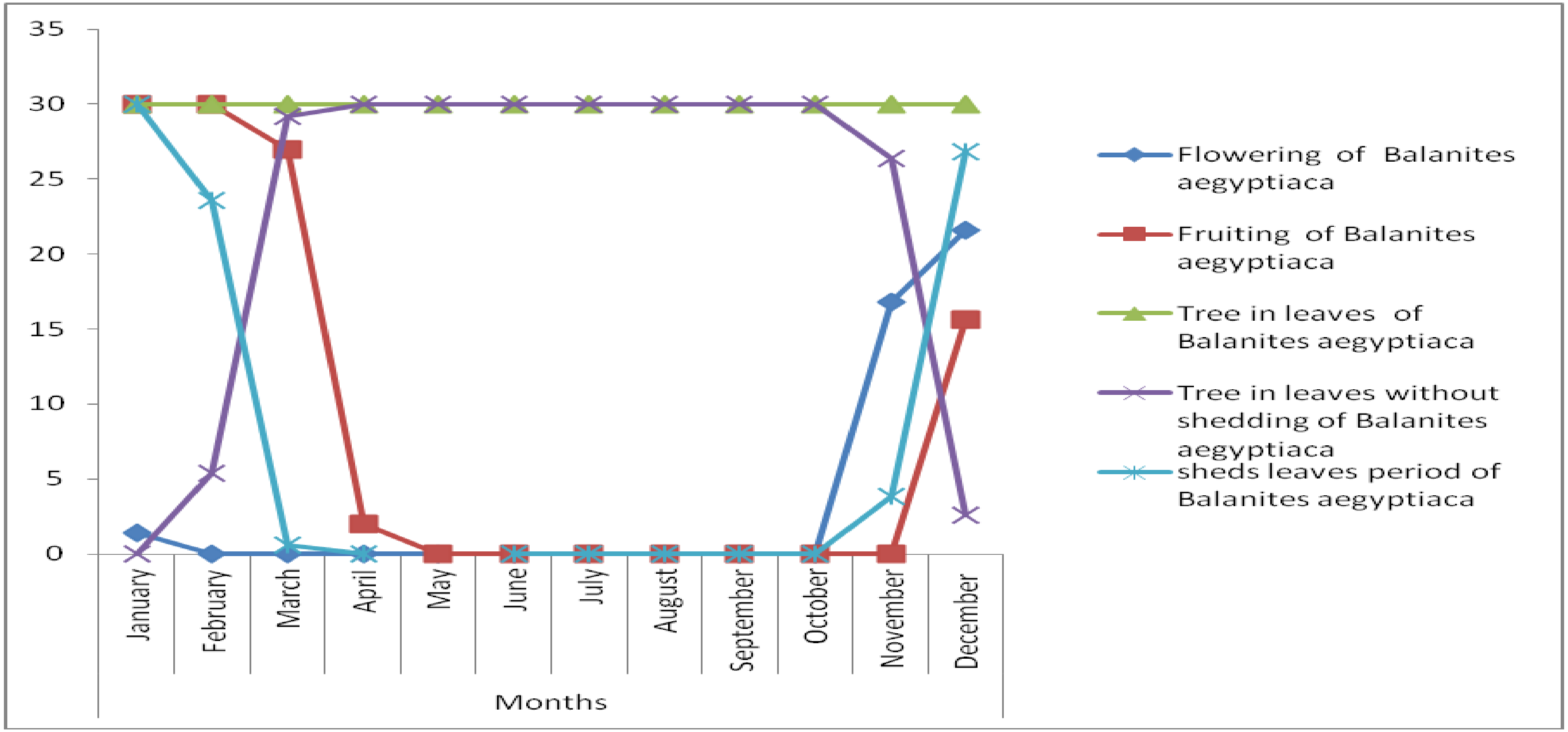

Fig. 15. Phenology of Balanites aegyptiaca at Zalingei area.

Table 30. Results of the group discussion about the vegetation in Zalingei area.

Family	Scientific Name	Local Name	Distribution							Existence	Habitat
			1	2	3	4	5	6	7		
Fabaceae	*Albizia anthelmintheca*	Grfeldod				+				VR	Tree
Fabaceae	*Albizia amara*	Ared				+		+	+	WS	Tree
Fabaceae	*Dichrostachys cinerea*	Kadad			+	+	+	+	+	WS	Shrub
Fabaceae	*Faidherbia albida*	Haraz	+	+	+					MS	Tree
Fabaceae	*Dalbergia melanoxylon*	Abnos						+	+	Ns	Tree
Fabaceae	*Bauhinia rufescens*	Kulkul				+		+		Ns	Tree
Fabaceae	*Acacia seyal*	Talih			+	+	+	+	+	WS	Tree
Fabaceae	*Acacia senegal*	Hashab			+	+	+	+	+	WS	Tree
Fabaceae	*Acacia girrardii*	Selgim				+		+	+	Ns	Tree
Fabaceae	*Acacia laeta*	Shubahi						+		VR	Tree
Fabaceae	*Acacia mellifera*	Kitir				+		+		Ns	Tree
Fabaceae	*Acacia nilotica*	Sunt		+	+	+	+	+		WS	Tree
Fabaceae	*Acacia oerfota*	Laut				+				RF	Shrub
Fabaceae	*Acacia tortilis*	Seyal						+		VR	Tree
Fabacea	*Acacia sieberana*	Kouk		+	+					VR	Tree
Fabaceae	*Acacia polycantha*	Kakamoot		+	+					VR	Tree
Fabaceae	*Tamarindus indica*	Aradaib		+						VR	Tree
Fabaceae	*Parkinsonia acula*	Sesban			+	+				VR	Tree
Fabaceae	*Piliostigma reticulatum*	Kharub		+						VR	Shrub
Rhamnaceae	*Ziziphus spina-christi*	Nabag		+	+	+	+	+		WS	Tree
Rhamnaceae	*Ziziphus abyssinica*	Karno		+	+					Ns	Tree
Umbelliferae	*Stegano taenia*	Abusibha			+	+				VR	Tree
Palmae	*Hyphaene thebaica*	Dom		+						VR	Tree
Palmae	*Borassum aethiopum*	Delap		+						VR	Tree
Palmae	*Phoenix reclinata*	Nakhil		+						VR	Tree
Malvaceae	*Azanza garckeara*	Jakhjakh		+						RF	Tree
Balanitaceae	*Balanites aegyptiaca*	Hegleeg		+	+	+	+	+	+	WS	Tree
Apocyanaceae	*Ozoroa insignis*	Keldus			+					VR	Shrub
Apocyanaceae	*Lannea fruticosa*	Melas							+	RF	Tree
Combretaceae	*Terminalia laxiflora*	Subagh								VR	Tree
Combretaceae	*Combertum glutinosum*	Habeel							+	RF	Shrub
Combretaceae	*Combretum molle*	Habeel							+	VR	Tree
Combretaceae	*Guiera senegalensis*	Gebash							+	VR	Tree
Anacardiaceae	*Anogeissus leiocarpus*	Sahab		+	+	+	+	+		WS	Tree
Anacardiaceae	*Sclerocarya birrea*	Himad			+			+		Ns	Tree
Bombacaceae	*Adansonia digitata*	Tabaldi			+					VR	Tree
Asclepiadaceae	*Calotropis procera*	Usher			+					VR	Shrub
Capparidaceae	*Cadaba rotundifolia*	Kurmut				+		+		Ns	Shrub

WS= Wide spread **MS**=moderate spread **Ns**= Not spread **VR**=Very rarely found
RF= rarely found **1**=Contemporary flood plain **2**= Lower terraces **3**= Upper terrace
4=Sedentary plain **5**=Clay plain **6**=Lower hill slope **7**= Stony hill slope

Continue table 30

Capparidaceae	***Capparis decidua***	**Tundub**						**+**		**Ns**	**Shrub**
Capparidaceae	*Cadaba glandulosa*	Serah				+				VR	Shrub
Capparidaceae	*Crateva adansonii*	Dabker			+	+				RF	Tree
Capparidaceae	*Boscia senegalensis*	Mukkheit			+	+		+		MS	Shrub
Tliaceae	*Grewia mollis*	Basham			+	+				RF	Shrub
Tiliaceae	*Grewia tenax*	Guddeim		+	+	+				MS	Shrub
Tiliaceae	*Grewia villosa*	Tico		+						RF	Shrub
Boraginaceae	*Cordia african*	Gembeel		+	+					RF	Tree
Boraginaceae	*Cordia rothii*	Andrab			+	+				Ns	Shrub
Burseraceae	*Commiphora Africana*	Gafal						+	+	Ns	Tree
Burseraceae	*Boswellia papyrifera*	Targtarg							+	RF	Tree
Meliaceae	*Khaya senegalensis*	Mahogani		+						VR	Tree
Moraceae	*Ficus sycomorus*	Gimeez		+						Ns	Tree
Rubiaceae	*Gardenia lutea*	Abu Gawi				+				VR	Tree
Rubiaceae	*Xeromphis nilotica*	**-**						+	+	MS	Shrub
Simaroubaceae	*Ailanthus exclsa*	Kibreet		+						VR	Tree
Bignoniaceae	*Kigelia africana*	Umshtor		+						VR	Tree
Sterculiaceae	*Sterculia setigera*	Tartar			+					VR	Tree

WS= Wide spread **MS**=moderate spread **Ns**= Not spread **VR**=Very rarely found
RF= rarely found **1**=Contemporary flood plain **2**= Lower terraces **3**= Upper terrace
4=Sedentary plain **5**=Clay plain **6**=Lower hill slope **7**= Stony hill slope

CHPATER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The present research attempted to study the status of woody plant and natural regeneration in selected areas of Zalingei locality, Central Darfur State, Sudan.

This study is the first one conducted after the study of Wickens (1976), which had shown the importance of the various ecological zones in the area. Samples were distributed based on the ecological zones namely, contemporary flood plains, lower terraces, upper terraces, clay plains, sedentary plains, lower hill slopes and stony hill slopes.

Twenty nine tree species were identified and recorded in the selected sites. This number of species is considerably low compared to group discussion results of fifty six tree species, reflects high degree of species richness in the area.

The number of trees per hectare was 70 trees whereas natural regeneration was found to be 389 seedlings per hectare, this makes the ratio of mature trees to seedlings in the study area at a rate of approximately 1:6.

Soil texture in the study area is generally sandy loam in lower terraces, lower hill slopes and stony hill slopes**,** sandy clay loam at upper terraces and sedentary plains, loamy sand at contemporary flood plains and clay plains**.** Generally, there are differences between sites in the chemical properties such as Na, Ca+Mg, Ca, Mg, K and Cl. Soil at the study area is acidic, non-saline and non-sodic.

The results showed that the dominant woody species were *Faidherbia albida* on contemporary flood plains and lower terraces, *Balanites aegyptiaca* on upper terraces, and *Acacia seyal* on clay plains. On sedentary plains *Albizia amara* association with *Acacia senegal* were *dominating*. *Albizia amara* on lower hill slopes. *Boswellia papyrifera* is a dominant tree species on stony hill slopes.

The diversity index for the ecological zones ranged between 0.15 - 1. The highest diversity was at the lower terraces (0.15) and the lowest diversity (1) was at the contemporary flood plain.

Similarity coefficient between the areas Zalingei, Traje and Abata for the similar site such as Upper terraces, lower terraces and stony hill slope is less than 39%.

There is a high relationship between mature trees and seedlings. All species have more than one source of natural regeneration e.g. *Albizia amara*, *Balanites aegyptiaca, Dichrostachys cinerea* which is renewed by seeds, coppices and sprouts, other species have two sources of regenerations; namely seeds and coppices.

The wood volume is 14.87 m^3/ha at the area, and the percentage of the vegetation cover in the area is 17.96%. There is variation in the deterioration of crown vegetation cover between the seasons due to continuous tree removal. There is a great deterioration in crown vegetation cover at the sites especially the upper terraces in Zalingei which is more close to IDPs stetting and the incread charcoal making, lower hill slope Abata and sedentary plain Abata due to overgrazing .

The three dominant species in the study area were *Albizia amara, Faidherbia albida* and *Balanites aegyptiaca*, the later has a different pattern of phenology.

The main factors behind forest degradation are the adverse human activities pushed by livelihoods demands and climatic variations.

5.2 Recommendations

- The natural regeneration was found to be 389 seedlings per hectare There fore the abundant natural regenerations needs to be managed; possible scenarios may include the introduction of sustainable forest management approach.
- There is a great deterioration in crown vegetation cover at the study area thus government efforts for the conservation of natural forests would only materialized if local people have been involved, hence community participation in management of these natural forests is very important.
- Some efforts need to be exerted towards the involvement of nomadic communities in the rehabilitation, protection, conservation and management of forest cover at Zalingei area, including extension activities and services to the nomadic groups at the area.
- The main factors behind forest degradation are the adverse human activities pushed by livelihoods demands and climatic variations there fore, government needs to consider developing forest regulations, policies and laws that are enforced in local communities.
- Further research work is needed at areas of forest management, and natural regeneration taking into account the experience of Sahelian countries.

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Appendices

Table 31. Temperature(C°), Annual rainfall (mm) and Relative humidity % of Zalingei area for 50 years.

Period	Temperature(C°)	Relative humidity %	Annual rainfall(mm)
1967- 1971	24.42	57.44	680.94
1972- 1976	26.34	49.16	606.26
1977- 1981	24.28	43.54	454.68
1982- 1986	26.1	43.9	437.04
1987- 1991	26.72	45.34	456.8
1992- 1996	25.9	50.18	581.08
1997- 2001	25.14	46.86	509.6
2002- 2006	26.44	47.68	496.18
2007- 2011	25.92	50.74	539.28
2012 - 2015	25.72	49.86	530.86

Source .Meteorological station Zalingei 2015.

Plate. 8. General view of contemporary flood plain at the left and general view of lower terraces at the right.

Plate. 9 . General view of upper terraces at the left and general view of clay plain at the right.

Plate. 10. General view of sedentary plain at rainy seasons at the left and general view of lower hill slope at the dry season at the right.

Plate. 11. General view of stony hill slope at rainy seasons at the right and general view of stony hill slope at the dry season at the left.

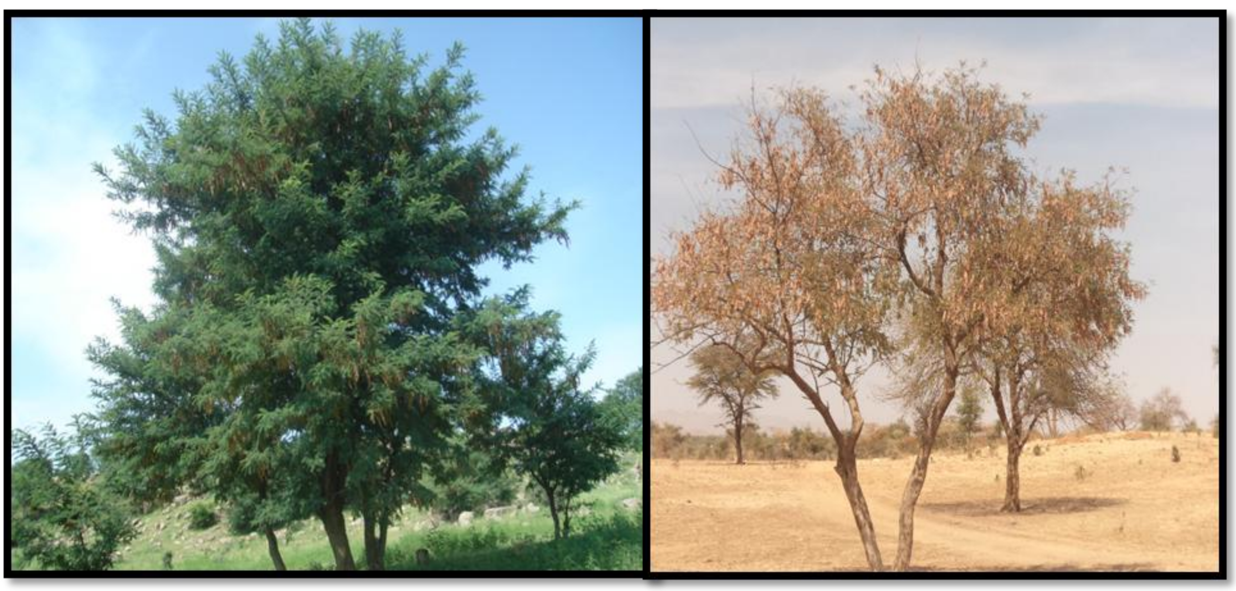

Plate. 12. *Albizia amara* at rainy seasons with leaves and fruiting at the left and *Albizia amara* at the dry season without leaves and the fruit still in the trees at the right.

Plate. 13 *Faidherbia albida* at rainy seasons without leaves at the right and *Faidherbia albida* at the dry season with leaves and fruiting at. the left.

Plate. 14. *Balanites aegyptiaca* in rainy seasons with leaves and fruiting at the left and *Balanites aegyptiaca* in the dry season with leaves at the right.

Plate. 15. The process of fixing metal pegs in the center of sample plot at the left and metal pegs after fixed at the right.

Plate. 16. Global Positioning System (GPS) at the left and a caliper at the right.

Plate. 17. Hypsometer at the left and over grazing by goats at the right.

Plate. 18. Accumulation of dead weeds at *Faidherbia albida* seedlings at the left and illegal cutting of trees at the right.

Plate. 19. Cutting of *Faidherbia albida* branches for camel feeds at the left and burning of *Faidherbia albida* stems for agriculture expansions at the right.

Plate. 20. Using ax for cutting *Balanites aegyptiaca* tree at the left and agroforestry with *Faidherbia albida* at the right.

Table 32. Source of natural regeneration and density by species in Zalingei.

Species		≥ 1			≤1			/ ha
		Seed	Coppice	Sprout	Seed	Coppice	Sprout	
Albizia amara	A1	149	61	122	104	87	43	**84.4**
	S1	140	60	114	51	76	39	**71.6**
	A2	153	64	118	87	57	35	**76.2**
	S2	130	60	99	84	54	33	**68.66**
Average for seasons		**143**	**61.3**	**113.3**	**81.5**	**68.5**	**37**	**75.31**
Acacia senegal	A1	102	97	0	156	86	0	**65.82**
	S1	89	88	0	103	84	0	**54.33**
	A2	128	101	0	138	67	0	**64.78**
	S2	99	95	0	80	62	0	**50.15**
Average for seasons		**104.5**	**95.3**	**0**	**119.3**	**74.7**	**0**	**58.78**
Faidherbia albida	A1	48	29	0	8	6	0	**13.58**
	S1	6	12	0	1	3	0	**3.28**
	A2	23	10	0	7	6	0	**6.87**
	S2	3	5	0	2	4	0	**2.09**
Average for seasons		**20**	**14**	**0**	**4.5**	**4.8**	**0**	**6.46**
Albizia anthelmintheca	A1	1	0	0	3	1	0	**0.75**
	S1	1	0	0	0	0	0	**0.15**
	A2	0	0	0	1	0	0	**0.15**
	S2	0	0	0	0	0	0	**0.00**
Average for seasons		**0.5**	**0**	**0**	**1**	**0.25**	**0**	**0.26**
Acacia girrardii	A1	13	5	0	37	18	0	**10.90**
	S1	7	5	0	16	10	0	**5.67**
	A2	12	6	0	29	15	0	**9.25**
	S2	9	4	0	14	9	0	**5.37**
Average for seasons		**13**	**5**	**0**	**24**	**10.5**	**0**	**7.84**
Acacia seyal	A1	191	56	0	474	86	0	**120.45**
	S1	98	32	0	216	59	0	**60.45**
	A2	209	44	0	202	111	0	**84.48**
	S2	72	29	0	59	87	0	**36.87**
Average for seasons		**142.5**	**40.3**	**0**	**237.8**	**85.8**	**0**	**75.58**
Acacia sieberana	A1	4	2	0	4	1	0	**1.64**
	S1	0	1	0	2	1	0	**0.60**
	A2	0	0	0	2	0	0	**0.30**
	S2	0	0	0	1	0	0	**0.15**
Average for seasons		**1**	**0.8**	**0**	**2.3**	**0.5**	**0**	**0.69**
Acacia nilotica	A1	61	17	0	78	29	0	**27.61**
	S1	38	11	0	71	19	0	**20.75**
	A2	39	13	0	83	29	0	**24.48**
	S2	28	09	0	50	19	0	**15.82**
Average for seasons		**41.7**	**12.5**	**0**	**70.5**	**24**	**0**	**22.19**
Acacia mellifera	A1	18	9	0	17	11	0	**8.21**
	S1	12	5	0	13	3	0	**4.93**
	A2	22	4	0	18	7	0	**7.61**
	S2	10	2	0	12	4	0	**4.18**
Average for seasons		**15.5**	**5**	**0**	**15**	**6.3**	**0**	**6.24**

≤1 = the height of seedlings less than one m ≥ 1= the height of seedlings more than one m

Continue table 32

Species		≥ 1			≤1			/ ha
		Seed	Coppice	Sprout	Seed	Coppice	Sprout	
Acacia tortilis	Y1	0	0	0	1	0	0	**0.24**
	Y2	0	0	0	0	0	0	**0**
	Y1	0	0	0	0	0	0	**0**
	Y2	0	0	0	0	0	0	**0.00**
Average for seasons		**0**	**0**	**0**	**0.3**	**0**	**0**	**0.04**
Acacia polycantha	Y1	1	0	0	1	0	0	**0.30**
	Y2	0	0	0	0	0	0	**0.00**
	Y1	0	0	0	0	0	0	**0.00**
	Y2	0	0	0	0	0	0	**0.00**
Average for seasons		**0.3**	**0**	**0**	**0.3**	**0**	**0**	**0.09**
Acacia oerfota	Y1	4	0	0	8	2	0	**2.09**
	Y2	3	0	0	3	0	0	**0.90**
	Y1	5	2	0	5	1	0	**1.94**
	Y2	4	2	0	2	1	0	**1.34**
Average for seasons		**4**	**1**	**0**	**4.5**	**1**	**0**	**1.57**
Ziziphus spina-christi	Y1	37	31	0	61	41	0	**25.37**
	Y2	21	27	0	31	32	0	**16.57**
	Y1	33	29	0	34	36	0	**19.70**
	Y2	35	31	0	12	19	0	**14.48**
Average for seasons		**31.5**	**29.5**	**0**	**34.5**	**32**	**0**	**19.03**
Ziziphus abyssinica	Y1	31	14	0	20	15	0	**11.94**
	Y2	20	9	0	12	7	0	**7.16**
	Y1	27	8	0	38	14	0	**12.99**
	Y2	18	6	0	10	9	0	**6.42**
Average for seasons		**24**	**9.3**	**0**	**20**	**11.3**	**0**	**9.64**
Anogeissus leiocarpus	Y1	3	0	0	1	0	0	**0.60**
	Y2	1	0	0	0	0	0	**0.15**
	Y1	1	0	0	0	0	0	**0.15**
	Y2	0	0	0	0	0	0	**0.00**
Average for seasons		**1.25**	**0**	**0**	**0.25**	**0**	**0**	**0.22**
Sclerocarya birrea	Y1	1	0	0	4	0	0	**0.75**
	Y2	0	0	0	2	0	0	**0.30**
	Y1	0	0	0	0	0	0	**0.00**
	Y2	0	0	0	0	0	0	**0.00**
Average for seasons		**0.25**	**0**	**0**	**1.5**	**0**	**0**	**0.26**
Dichrostachys cinerea	Y1	61	26	23	189	29	24	**52.54**
	Y2	58	24	22	119	19	20	**39.10**
	Y1	82	29	31	89	32	26	**43.13**
	Y2	76	23	25	49	22	18	**31.79**
Average for seasons		**69.3**	**25.5**	**25.3**	**111.5**	**25.5**	**22**	**41.66**
Dalbergia melanoxylon	Y1	2	0	0	4	0	0	**0.90**
	Y2	2	0	0	1	0	0	**0.45**
	Y1	2	0	0	9	1	0	**1.79**
	Y2	1	1	0	4	1	0	**1.04**
Average for seasons		**1.8**	**5**	**0**	**4.5**	**0.5**	**0**	**1.76**

≤1 = the height of seedlings less than one m ≥ 1= the height of seedlings more than one m

Continue table 32

Species		≥ 1			≤1			**/ ha**
		Seed	Coppice	Sprout	Seed	Coppice	Sprout	
Bauhinia rufescens	Y1	11	5	0	13	3	0	**4.78**
	Y2	6	4	0	8	2	0	**3**
	Y1	19	7	0	21	5	0	**7.76**
	Y2	11	3	0	11	3	0	**4.18**
Average for seasons		**11.75**	**4.75**	**0**	**13.25**	**3.35**	**0**	**4.94**
Xeromphis nilotica	Y1	9	7	0	7	4	0	**4.03**
	Y2	6	4	0	7	4	0	**3.13**
	Y1	9	3	0	13	7	0	**4.78**
	Y2	2	1	0	11	5	0	**2.84**
Average for seasons		**6.5**	**3.75**	**0**	**9.5**	**5**	**0**	**3.7**
Balanites aegyptiaca	Y1	103	83	59	162	42	59	**75.8**
	Y2	84	79	61	118	21	39	**60**
	Y1	147	76	**55**	122	49	**61**	**76.12**
	Y2	139	63	48	99	38	32	**62.54**
Average for seasons		**118.25**	**75.25**	**55.75**	**125.3**	**37.5**	**47.75**	**68.63**
Boswellia papyrifera	Y1	3	6	0	5	9	0	**3.43**
	Y2	0	3	0	0	4	0	**1.04**
	Y1	0	1	0	3	4	0	**1.19**
	Y2	0	0	0	0	2	0	**0.30**
Average for seasons		**0.75**	**2.5**	**0**	**2**	**4.75**	**0**	**1.49**
Azanza garckeana	Y1	1	0	0	2	1	0	**0.60**
	Y2	1	0	0	0	1	0	**0.30**
	Y1	2	2	0	1	0	0	**0.75**
	Y2	2	2	0	0	0	0	**0.60**
Average for seasons		**1. 5**	**1**	**0**	**0.75**	**0.5**	**0**	**0.34**
Combertum glutinosum	Y1	1	0	0	4	0	0	**0.75**
	Y2	0	0	0	1	0	0	**0.15**
	Y1	0	0	0	1	0	0	**0.15**
	Y2	0	0	0	0	0	0	**0.00**
Average for seasons		**0.25**	**0**	**0**	**1. 5**	**0**	**0**	**0.04**
Terminalia mollis	Y1	6	0	0	3	0	0	**1.34**
	Y2	3	0	0	1	0	0	**0.60**
	Y1	0	0	0	11	0	0	**1.64**
	Y2	0	0	0	4	0	0	**0.60**
Average for seasons		**2.25**	**0**	**0**	**4.75**	**0**	**0**	**1.04**

≤1 = the height of seedlings less than one m ≥ 1= the height of seedlings more than one m
Y1W = survey in the rainy seasons of first year Y2W = survey in the rainy seasons of second year
Y1D = survey in the dry seasons of first year Y2D = survey in the dry seasons of second year

Table 33. Natural regeneration of tree in the different site of Zalingei area

Species		CF		LT		UT		SP		CP		LH		SH		Total	S R
		≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1		
Albizia amara	Y1	0	0	0	0	14	2	15	13	0	0	108	109	97	208	566	**-**
	Y2	0	0	0	0	5	1	13	12	0	0	77	101	71	200	480	**84.8**
	Y1	0	0	0	0	7	4	12	20	0	0	65	112	95	199	514	**-**
	Y2	0	0	0	0	5	3	10	18	0	0	51	99	74	200	460	**89.5**
Acacia senegal	Y1	0	0	0	0	2	0	35	31	7	4	151	87	47	77	441	**-**
	Y2	0	0	0	0	1	0	31	29	4	4	103	71	48	73	364	**82.5**
	Y1	0	0	0	0	6	1	85	44	11	6	65	90	38	88	343	**-**
	Y2	0	0	0	0	3	1	61	32	5	4	44	82	29	75	336	**77.4**
Faidherbia albida	Y1	16	1	45	10	14	3	2	0	0	0	0	0	0	0	91	**-**
	Y2	2	1	13	3	2	0	1	0	0	0	0	0	0	0	22	**24.2**
	Y1	0	1	30	7	2	3	1	1	0	0	0	0	0	0	45	**-**
	Y2	0	0	7	3	1	2	0	1	0	0	0	0	0	0	14	**31.1**
Albizia anthelmintheca	Y1	0	0	0	0	0	0	4	1	0	0	0	0	0	0	5	**-**
	Y2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	**20**
	Y1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Acacia girrardii	Y1	0	0	0	0	3	2	8	3	5	2	29	4	10	7	73	**-**
	Y2	0	0	0	0	2	2	4	2	3	2	10	3	7	3	38	**52**
	Y1	0	0	0	0	8	1	9	2	14	4	7	6	6	5	62	**-**
	Y2	0	0	0	0	3	0	6	1	7	2	4	6	3	4	36	**58.1**

Continue table 33

Species		**CF**		**LT**		**UT**		**SP**		**CP**		**LH**		**SH**		**Total**	**S R**
		≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1		
Acacia seyal	Y1	0	0	0	0	248	44	5	6	244	132	78	40	15	25	910	**-**
	Y2	0	0	0	0	96	38	3	5	99	47	69	26	8	14	443	**48.7**
	Y1	0	0	0	0	165	67	16	4	78	134	34	31	20	17	628	**-**
	Y2	0	0	0	0	91	47	9	1	44	43	9	6	11	4	301	**47.9**
Acacia sieberana	Y1	0	0	1	0	0	0	0	0	0	0	3	6	1	0	11	**-**
	Y2	0	0	1	0	0	0	0	0	0	0	2	1	0	0	4	**36.4**
	Y1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	**-**
	Y2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	**50**
Acacia nilotica	Y1	0	0	22	5	7	11	7	8	6	8	42	29	23	17	185	**-**
	Y2	0	0	30	10	3	9	4	3	3	5	35	6	15	16	139	**75.1**
	Y1	0	0	33	12	16	8	11	9	10	6	20	3	20	14	162	**-**
	Y2	0	0	19	9	6	7	6	5	6	3	23	2	9	11	106	**65.4**
Acacia mellifera	Y1	0	0	0	0	3	0	6	3	12	25	6	0	0	0	55	**-**
	Y2	0	0	0	0	2	0	5	2	7	14	3	0	0	0	33	**60**
	Y1	0	0	0	0	2	1	2	3	22	19	0	2	0	0	51	**-**
	Y2	0	0	0	0	1	0	0	4	11	10	0	2	0	0	28	**54.9**
Acacia tortilis	Y1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Y1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Continue table 33

Species		CF		LT		UT		SP		CP		LH		SH		Total	S R
		≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1		
Acacia polycantha	Y1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	2	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Y1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Acacia oerfota	Y1	0	0	0	0	0	0	10	4	0	0	0	0	0	0	14	**-**
	Y2	0	0	0	0	0	0	5	3	0	0	0	0	0	0	8	**57.1**
	Y1	0	0	0	0	0	0	6	7	0	0	0	0	0	0	13	**-**
	Y2	0	0	0	0	0	0	3	6	0	0	0	0	0	0	9	**69.2**
Ziziphus spina-christi	Y1	0	0	15	2	11	18	4	1	26	18	44	27	2	2	170	**-**
	Y2	0	0	11	2	8	15	5	1	12	8	26	20	1	2	111	**65.3**
	Y1	0	0	16	4	12	13	1	4	18	15	11	31	4	3	132	**-**
	Y2	0	0	7	6	8	14	1	4	9	10	4	27	2	5	97	**73.5**
Ziziphus abyssinica	Y1	4	0	12	5	15	33	0	0	4	7	0	0	0	0	80	**-**
	Y2	2	0	6	2	10	24	0	0	1	3	0	0	0	0	48	**60**
	Y1	1	0	20	7	17	24	0	0	14	4	0	0	0	0	87	**-**
	Y2	0	0	2	2	11	18	0	0	6	4	0	0	0	0	43	**49.4**
Anogeissus leiocarpus	Y1	0	0	0	0	1	0	0	0	2	1	0	0	0	0	3	**-**
	Y2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	**33.3**
	Y1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Continue table 33

Species		CF		LT		UT		SP		CP		LH		SH		Total	S R
		≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1		
Sclerocarya birrea	Y1	0	0	0	0	0	0	0	0	0	0	4	1	0	0	5	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	**40**
	Y1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Dichrostachys cinerea	Y1	0	0	50	43	129	6	23	5	8	7	3	6	29	43	352	**-**
	Y2	0	0	37	42	74	27	16	5	3	7	2	1	26	22	262	**74.4**
	Y1	0	0	51	50	47	30	17	9	16	8	0	0	16	45	289	**-**
	Y2	0	0	29	43	25	29	10	12	8	5	0	0	15	35	211	**73**
Dalbergia melanoxylon	Y1	0	0	0	0	0	0	0	1	0	0	1	1	3	0	6	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	**50**
	Y1	0	0	0	0	0	0	2	0	0	0	5	1	3	1	12	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	4	0	0	1	5	**41.7**
Bauhinia rufescens	Y1	0	0	2	0	0	0	1	1	5	8	7	4	1	0	29	**-**
	Y2	0	0	1	0	0	0	1	1	3	6	4	4	1	0	21	**72.4**
	Y1	0	0	3	0	0	0	5	0	10	6	8	6	0	1	39	**-**
	Y2	0	0	2	0	0	0	1	0	5	4	6	3	0	0	21	**53.8**
Xeromphis nilotica	Y1	0	0	0	0	0	0	0	0	1	0	3	0	7	16	27	**-**
	Y2	0	0	0	0	0	0	0	0	1	0	3	0	6	11	21	**77.8**
	Y1	0	0	0	0	0	0	0	0	0	0	0	2	12	18	32	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	0	2	3	14	19	**59.4**

Continue table 33

Species		CF		LT		UT		SP		CP		LH		SH		Total	S R
		≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1	≤1	≥ 1		
Balanites aegyptiaca	Y1	0	0	11	15	190	169	2	3	2	1	34	20	24	37	508	**-**
	Y2	0	0	15	17	108	145	2	4	1	1	34	19	18	38	402	**79.1**
	Y1	0	0	14	16	134	173	12	3	20	1	15	43	27	42	500	**-**
	Y2	0	0	17	15	101	150	8	3	10	1	14	40	19	41	419	**83.8**
Boswellia papyrifera	Y1	0	0	0	0	0	0	0	0	0	0	2	1	12	8	23	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	1	0	3	3	7	**30.4**
	Y1	0	0	0	0	0	0	0	0	0	0	3	0	4	1	8	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	**25**
Azanza garckeana	Y1	0	0	1	3	0	0	0	0	0	0	0	0	0	0	4	**-**
	Y2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	**50**
	Y1	0	0	1	4	0	0	0	0	0	0	0	0	0	0	5	**-**
	Y2	0	0	0	4	0	0	0	0	0	0	0	0	0	0	4	**80**
Combertum glutinosum	Y1	0	0	0	0	0	0	0	0	0	0	4	1	0	0	5	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	**20**
	Y1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Terminalia mollis	Y1	0	0	0	0	0	0	0	0	0	0	0	0	3	6	9	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	1	3	4	**44.4**
	Y1	0	0	0	0	0	0	0	0	0	0	0	0	11	0	11	**-**
	Y2	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	**36.4**

Were:

≤1 = the height of seedlings less than one m

≥ 1= the height of seedlings more than one m

Y1W = survey in the rainy seasons of first year

Y2W = survey in the rainy seasons of second year

Y1D = survey in the dry seasons of first year

Y2D = survey in the dry seasons of second year

CF =Contemporary flood plain

LT = Lower terraces

UT = Upper terrace

SP =Sedentary plain

CP =Clay plain

LH =Lower hill slope

SH = Stony hill slope

S R = Survival rate