Full Length Research Paper

Deterioration of Acacia in western Butana plain, Sudan

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Acacia of the western Butana plain of the Sudan has undergone severe deterioration during last decades as demonstrated by a survey carried out in 2005. The majority of Acacia is non-succulent which are differing spatially, by soil type and in cover; frequency; abundance and density. There was a climax for Acacia in the study area prior to 1850, while its deterioration took place through four successive stages. The ecosystem carrying capacity of the study area was adequate to support Acacia up to the year 1900 when human exploitation of Acacia was balancing with its growth up to that year. Ecological disequilibrium started directly after 1970 and manifested by declining ecosystem carrying capacity and thus deterioration of Acacia. This deterioration of Acacia appears to be linked with the reduction in average annual rainfall. This paper demonstrates that, though important, this factor is not the sole, and may not even be the main factor involved. Government investment policy and associated population activities including, for example agricultural expansion which contributed by 40% in Acacia deterioration and fuel wood by 30%, are shown to have great significance, and cast doubt to any belief that a return to higher rainfall levels would reverse the current deterioration processes.

Key words: Acacia, deterioration, Butana, rainfall fluctuation, Sahel zone, rainfed agriculture human factors, community education.

INTRODUCTION

Acacia is a Greek word means "thorns", which is a Genus for trees and shrubs of Mimosaceane family. They are drought resisting trees where there are more than 300 types of Acacia in Australia, 1000 types in America while there are more than 400 types in Africa and Asia with restricted types in arid and semi arid parts. Many types of Acacia exist together such as Simaroubaceae, Capparideceae and Tamaricaceae and Rhamnaceae. They are identical and sensitive to climate and soil factors and therefore, they occur in forms of dense or sparse forests, except those ones subjected to human interference. There are many types of succulent; non-succulent and evergreen perennials Acacia. Acacias generally grow in the range of 200 to 600 mm rainfall with different adaptations. Succulent Acacia store water in their stems for times of water deficiency while the non succulent Acacia extend their roots deep into the soil searching for water, and the evergreens have adapted to resist drought (Walton, 1979; Hills, 1966; Clarke, 1954).

Acacia species generally took the umbrella shape. They used to grow in whatever topographic characteristic were, but due to change of climatic conditions they mostly confined to depressions where water is expected.

Acacia species are mostly found in arid and semi arid parts of the world, but the most suitable places for their distribution lie between 10° north and south of the Equator up to the Cancer and Capricorn. Recent studies (Mensching, 1988; Kamur, 1995) show that the home of Acacia is Sudan, Nigeria, Mali, Pakistan and India. In Africa it extends from the Senegal to Red sea across the Sahelian and Soudao zones. Generally, adaptation methods of Acacia depend on rainfall amount, temperature, topography, soil type and plant abundance.

Many studies confirmed the ecological benefits of Acacia in the improvement of soil fertility, soil protection and retention of water as well as reducing erosion effects and heat. *Acacia albida* raises soil fertility and increase Bulbrush millet (Dukhun) and sorghum vulgarize (Dura) production in the Gezira plain of the Sudan (Obeid and Sif Eldin, 1970). Also it increases nitrogen content of soil and cation exchange by 50% (Dancette and Poulain, 1969).

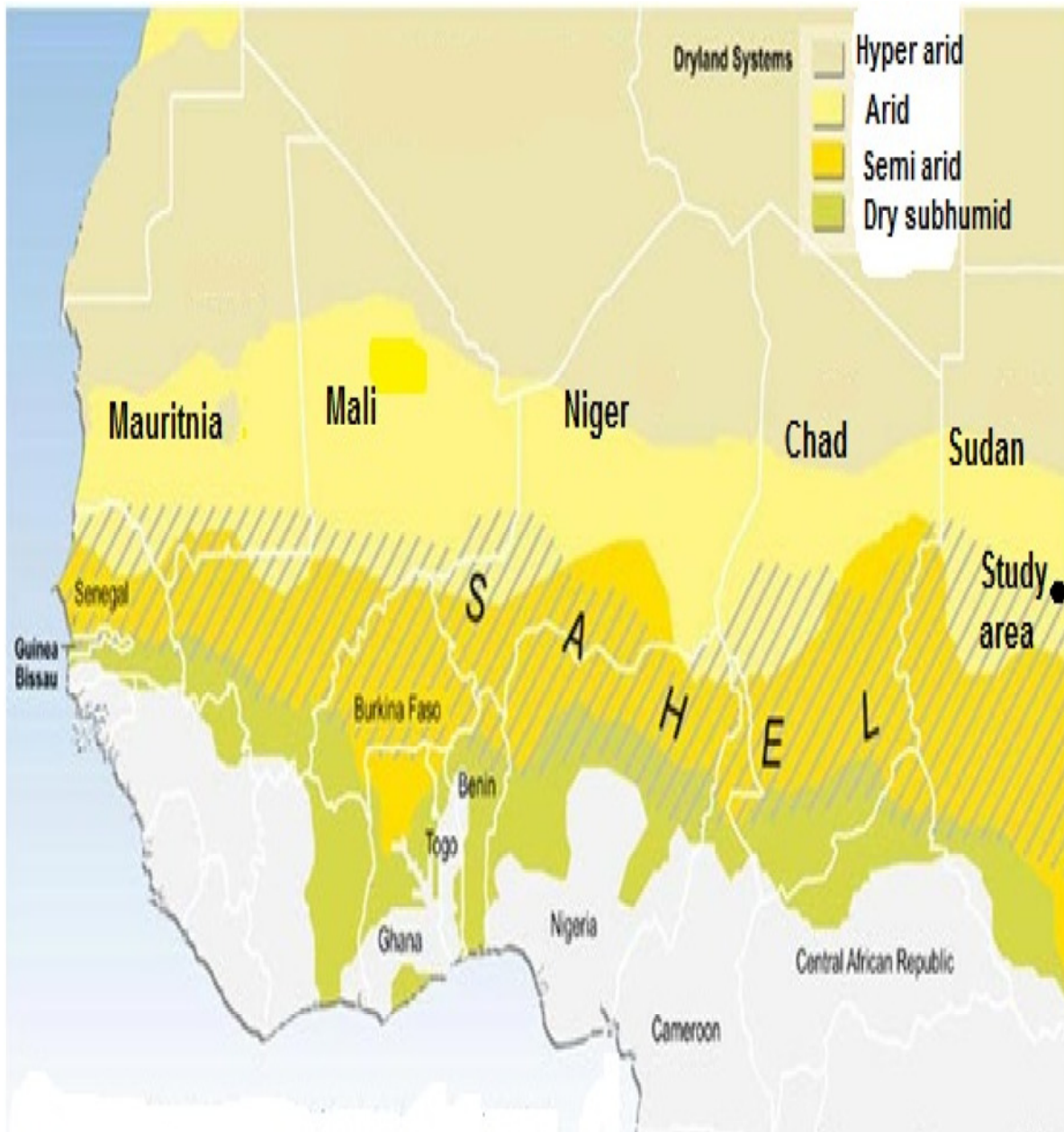*Corresponding author. E-mail: samiralredaisy@yahoo.com.

Figure 1. Dry land system and location of the study area in the Sahel.

The present investigation assesses spatial variability of Acacia deterioration and the contribution of natural and human factors that resulted in that deterioration in western Butana area. This deterioration suggests a rundown of the of natural resources in the region. Furthermore, this area was classified by the UN Conference of 1977 as being under "very high risk" of desertification (Figure 1). This paper examines deterioration of Acacia that has occurred within this region by looking at the results of a survey carried out in 2005 and the notification of studies covering the period from 1928 to 1999.

DATAS AND METHODS

The study area of western Butana of Sudan is remarkably lying between the Blue Nile in the west and Sahara desert in the north, at 14 to 16°N and 33 to 35°E. The area is chosen because it is one of the most hit areas by Acacia deterioration in Sudan. Physically, the study area is part of the Butana region which is a plain surface intermitted by dispersed hills covered with alluvium. Topography of Butana includes three major units. Firstly, highlands and isolated mountains in the southeast. Secondly, plain area dominating the area and characterized by clayey soil (45 to 80% clay particles) either flat or slow sloped. Thirdly, Wadis (valley) area including depositional areas around seasonal rivers like Atbara and Rahad. Most of the area is underlain by Basement Complex of Tertiary.
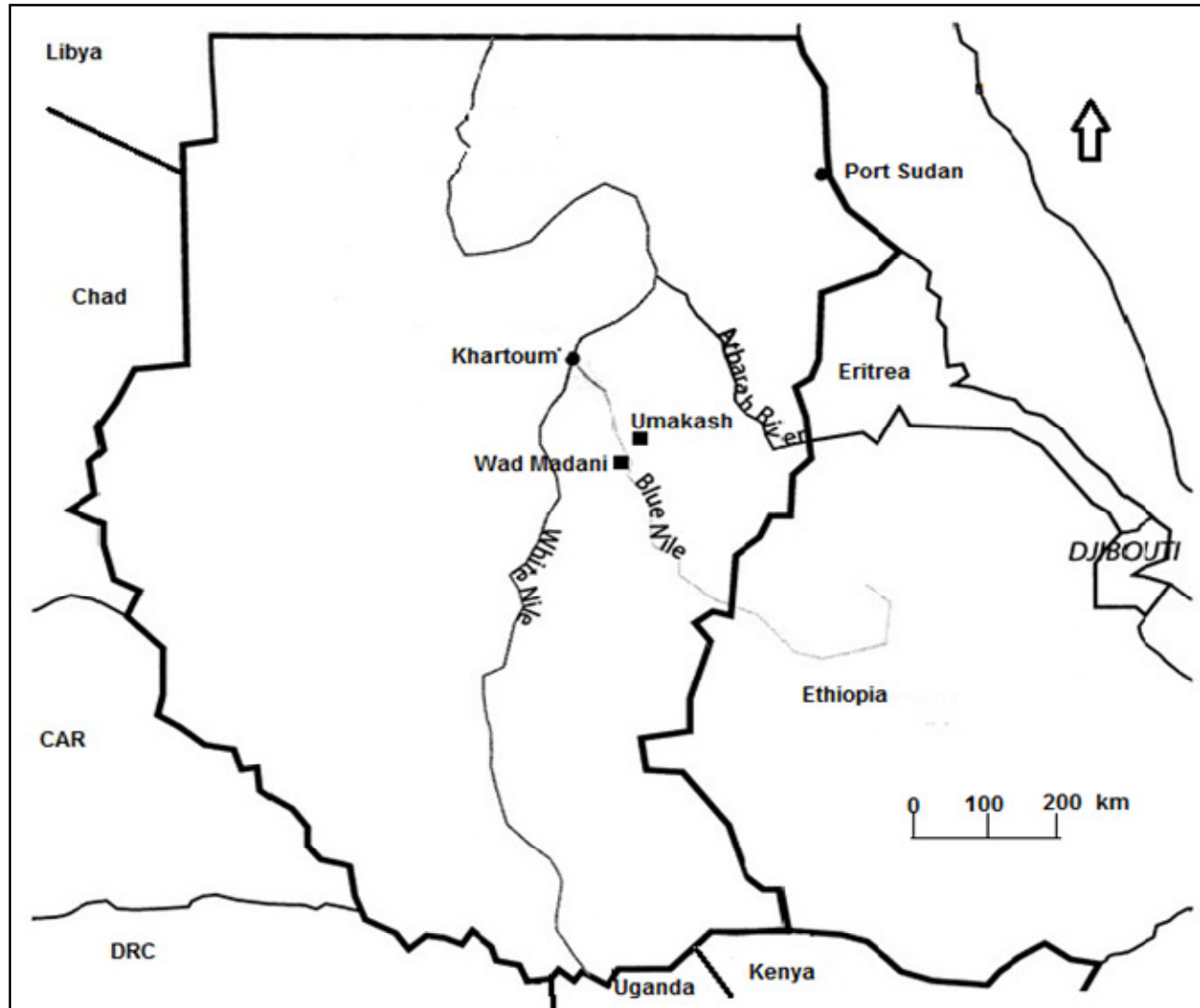
Figure 2. Location of the study area as indicated to by Umakash. Source: After Department of Survey, Sudan 2008.

Basalts both of which provide little water except in the detrital material around the occasional hills and small supplies to be found along joints in the rock (Davies, 1964). Two distinctive climatic belts are found in Butana area. The first one is semi arid climate found in the north and northwest and characterized by summer seasonal rains during July to October. The second one is a wet climate found in the eastern and southern parts of the state with average rainfall of 500 to 900 mm/year and maximum mean temperature of 47°C.

This is an experimental study designed to trace Acacia deterioration in western Butana plain of Sudan. The type of the experiment is integrated including Acacia and human data. Data for Acacia is collected by dividing the study area into three main zones indicated to by A, B and C letters according to density and diversity of Acacia and location with respect to the Blue Nile (Figure 2). Each zone is divided into squares. 5 to 7 squares are chosen for each direction line, with distance interval of 2 to 3 km. The midpoint at which the eight major and minor directions meet together is specified at the village of Um Akash (Figure 2), from which data are collected towards that direction. The area of each square is 10,000 m^2 (100 × 100 m). Then vegetative data is collected following laws for arid lands fieldwork on vegetation survey which requires that, for each plant type in every square number of species for every plant type; % of vegetative cover for each plant type; height of a plant; % of frequency; type abundance; type density and number of plants should be satisfied. Following Walton (1979), Hills (1966) and Clarke (1954), Acacia cover in the study is classified into succulent perennials, non-succulent perennials and evergreens.

Data for soil samples are done by collecting 21 samples from 7 sites (3 for each site). Composite samples are done by collecting sufficient number of sub-samples supposed to be reprehensive to the original population. These sub samples are mixed together to produce one composite homogeneous sample. The stage of judgment sampling is done from Ahamda forest from areas ranging into Acacia density from dense through sparse to bare of Acacia, with soil depths in ranges of 0 to 15 cm and 15 to 30 cm to collect 30 samples from 15 sites. Five soil properties were investigated including pH; E.C; O.C; Na and Ca and the physical properties of clay – silt- sand.

Data for human factors is collected through a sample size of 200 individuals, distributed into 12 villages representing 13% of total number of villages in the study area and also representing 10 to 15% of total population in each village. In addition, interviewing

Table 1. Occurrence of Acacia by zone and soil type; cover; frequency; abundance, density and life cycle in western Butana plain, Sudan.

Local name	Latin name	Zone			Soil type			Cover, frequency, density and abundance by zone												By total area			
								Cover			Frequency			Abundance			Density						
		A	B	C	Clayey	Sandy	Loamy	A	B	C	A	B	C	A	B	C	A	B	C	Cover	Frequency	Abundance	Density
Sunut	A. nilotica ^	+	-	-	-	-	+	2.8	-	-	18.1	19.3	-	3.5	-	-	0.6	-	-	1.5	4.2	3.5	0.04
Sial	A. tortillis vor raddiana^	+	+	+	+	+	+	24.1	5.9	23.5	90.9	0.8	41.8	5.9	1.4	4.6	5.4	0.2	1.9	19.3	24.6	4.5	1.9
Talieh	A. seyal vor fistula^	+	-	-	+	-	+	1.6	-	-	18.1	0.7	-	2.0	-	-	0.4	-	-	0.8	4.2	2.0	0.04
Kitir	A. mellifera^	-	-	+	-	-	+	-	-	3.0	-	-	25.0	-	-	1.0	-	-	3.0	0.7	6.4	1.0	0.06
Hashab	A. seyel vor sayal^	+	-	+	-	+	-	-	-	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-
Haraz	A. albida*	+	-	-	-	-	+	0.8	-	-	18.1	8.0	-	1.0	-	-	0.2	-	-	0.4	4.2	1.0	0.04
Laaot	A. nobica*	+	+	-	+	+	+	9.8	4.2	8.2	63.6	-	16.6	3.4	0.6	4.0	2.2	0.2	0.7	8.0	25.5	3.0	0.8
Samur	A. tortillis vor tortillis^	-	+	+	-	+	-	-	-	-	-	4.8	-	-	-	-	-	-	-	-	-	-	-
Higlig	Balanites aegyptiaca*	+	+	+	+	+	+	4.0	10.2	-	63.6	-	-	1.4	1.2	-	0.9	0.5	-	4.8	36.2	1.3	0.5
Sarah	Maerua crassifolia^	-	+	-	-	+	-	-	-	-	-	2.3	-	-	-	-	-	-	-	-	-	-	-
Tundub	Capparis deciduas^	-	+	-	+	-	-	1.6	2.5	2.0	18.1	0.6	16.6	2.0	1.5	2.0	0.4	0.1	0.3	2.3	8.1	1.8	0.2
Sidir	Z. spina Christi"	+	-	-	-	-	+	-	1.7	1.0	-	3.0	8.3	-	1.0	1.0	-	0.08	0.08	0.6	6.4	1.0	0.06

Life cycle: * Succulent, ^ non Succulent , " evergreen.

with eldest farmers and herders to collect data concerned with past vegetation in the study area, as well as some government officials are carried out.

Measurement methods included quantitative methods to calculate Acacia coverage, frequency, density and abundance.

Frequency (%) = no. of squares for one type (A) × 100/total number of squares under study = number %.

Cover (%) = no. of one type × 100 / total number of Acacias = number %.

Density (type/ a square) = number of individual of one type (A) / total number of the studied squares = number of Acacia/square.

Abundance (type/square) = number of individuals of one type (A) /number of squares where that type (A) is found.

In addition, some descriptive statistical methods are applied on human data. Latin names equivalent with local names for *Acacia* species were obtained from Faculty of Forestry, University of Khartoum.

RESULTS

Spatial patterns

The majority of Acacia is non- succulent which are differing spatially, by soil type and in cover; frequency; abundance and density (Table 1). Zone A has the highest occurrence of *Acacia* species, followed by Zones B and C respectively. *Acacia tortillis vor raddiana* and *Acacia nilotica* dominate Zone A which lies close to the Blue Nile, forming closed forests such as Rufa'a, Dalawat, Hibaika and Ahamda forests. Zone B lies in the middle of the study area which exposed to heavily and extensive traditional rainfed agriculture where by now there is one Acacia tree species per five feddans (1feddan = 1.038 acres). They are mostly of Balanites aegyptiaca. Zone C has little Acacia occurrence, mostly of *Acacia mellifera.* Differences on Acacia occurrence are depicted by soil types (Table 1). Acacia is diverse on clayey soil and although of that, they are less occurring On sandy soil, Acacia is more diverse and. dispersive but, less denser. On the loamy soil, Acacia nilotica are abundant with few *Acacia seyel vor fistula.*

Table 1 also depicts cover; frequency; abundance and density of Acacia in the study area. Although these statistics are low in Zone A, excepting forests close to the Blue Nile, they are the highest compared to the other two zones. In Zone A, *Acacia tortillis vor raddiana* ranked high by 24.1% cover, 90.9% frequency, 5.9 abundance and 5.4 density. Fieldwork indicated that (Figure 3),
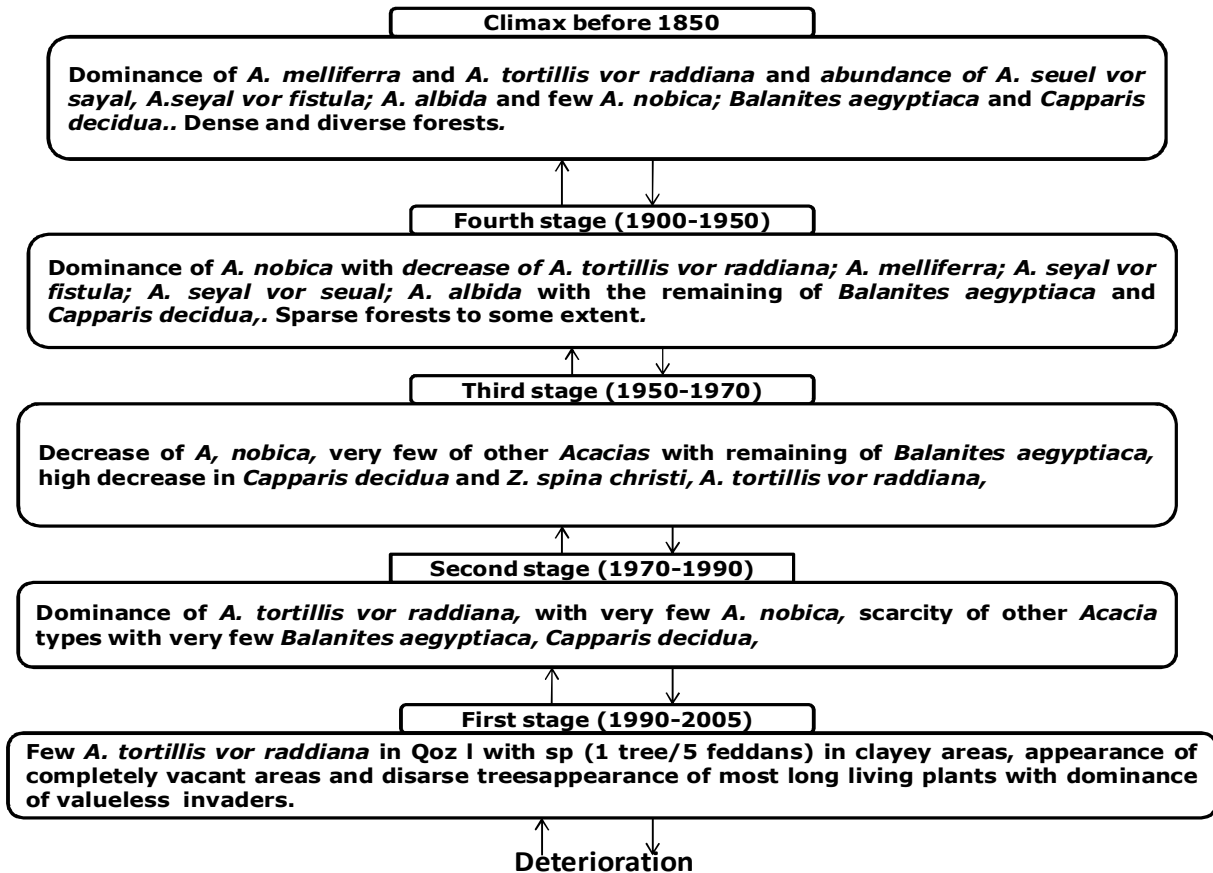
Figure 3. stages of Acacia deterioration in western Butana plain, Sudan.

Acacia trees which were dominating in the past in this zone were not only A. *tortillis vor raddiana,* but they were *Acacia nobica, A. albida, Balanites aegyptiaca* and all of *Acacia seuel vor seyal, Maerua crassifolia, A. tortillis vor tortillis*; *A. seyel vor fistula*, all of which are very few at the present time (Table 1). Zone B is dominated by B. aegyptiaca and *A. tortillis vor raddiana*, while the remaining Acacia trees did represent more than 5% covering. *A. tortillis vor raddiana* and *B. aegyptiaca, Ziziphus spina christi, A. seyel vor sayal, A. seyel vor sayal, Maerua crassifolia, A. nobica* and *Capparis deciduas* are very rare while they were dominant in the past (Figure 3). *Acacia* species dominating clayey and sandy soils is *A. tortillis vor raddiana* by 19.3% cover and 24.6% frequency. In zone c*, A. tortillis vor raddiana* dominates sandy soil by 23% cover, 41.3% frequency, 4.6 abundance and density by 1.9. It is followed by *A. nobica* with 8.2% cover, 16.6 % frequency, 4 abundance and 0.7 density. This zone had experienced *A. mellifera* in the past which formed forests while by now representing only 3% of the total Acacia cover. *A. seyal vor seyel, A. albida* and *A. seyel vor fistula* have disappeared. Also *Blepharis edulis, Arianthema pentandra, Cymbopogen nervatus* and *Pennisetum*

pdystachyum have deeply deteriorated.

Deterioration of Acacia

Based on studies carried out from 1928 to 1999 and the fieldwork (2005), there was a climax for Acacia in the study area prior to 1850, while its deterioration took place through four successive stages (Figure 3). During the climax, abundant and diverse Acacia trees were dominating in forms of dense forests. During the fourth stage, from 1900 through 1950, *A. nobica* was dominating, while many other Acacia trees such as *A. tortillis vor raddiana* decreased although they were dominating during the climax and there seems to be a general decrease in the number of Acacia trees. During this stage, according to Richard (1928) as indicated by Harrison (1955), Butana area was very dense with varieties of forests and there were abundant *A. mellifera, A. nobica, A. seyel vor fistula, A. seyel vor seyel* and *A. albidia.* The dominant Acacia was *B. edulis* which is highly nutritive to animals. Such *Acacia* species were covering vast areas of Sufiaak; Raida; Jebel Mundara and Abaytor. Smith (1966) indicated that *A. melifera,*
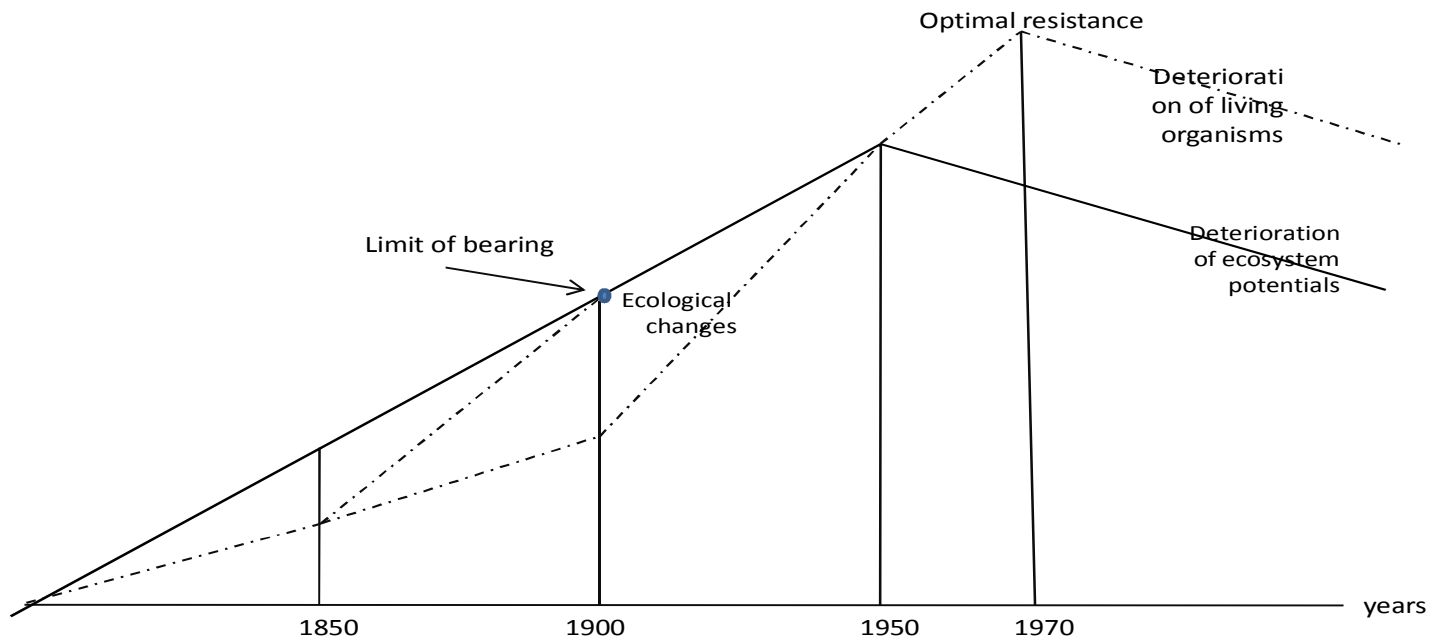
Figure 4. Ecosystem carrying capacity and Acacia resistance and deterioration.

A. nobica, A. tortillis vor raddiana, A, sayel vor seyal and C. deciduas as dominating and they were main sources for animal feeding.

During the third stage, from 1950 through 1970, still there was continuous decrease of *A. nobica* and other types of Acacia which became very few. Harrison (1955) mentioned that the dominant Acacia at that time was *B. edulis,* besides abundant *A. melifera*, *M. crassifolia, A. seyel vor fistula, C. deciduas.* During the 1960s, Lebon (1965) indicated the state of vegetation cover as very dense and diverse around Khartoum and Abu Delaig " close to the study area "where *A. tortillis vor tortillis* was dominating.

During the second stage from 1970 through 1990, there was one Acacia type dominating, while there was scarcity of major other types. According to fieldwork results, Acacia sharply deteriorated soon following 1970 where huge bare areas with wide sparsely trees formed the landscape. Bashar (1985) comparatively studied the statistics of Harrison (1955) and his own statistics in 1985, and concluded that Acacia had deteriorated in terms of density, cover and frequency following 1960. Butana became almost bare of trees where the remaining ones had confined to valleys and depressions, while *A. mellifera* occurred in plains and was replaced by *A. nobica* after being subjected to fire for agricultural purposes. Bashar (1985) further added that, trees which were replacing the old ones were unpalatable, where *Calotropis procra* had replaced *A. mellifera. A. seyel vor fistula* and *A.seyel vor seyel,* for example. Generally there is decline in Acacia by cover, frequency,

abundance and density in clayey areas and dominance of low nutritive value *Acacia* species (Pflaumbaum, 1994).

These successive stages of Acacia deterioration (Figure 3) are expressed as ecosystem carrying capacity to support Acacia in western Butana plain (Figure 4).

The ecosystem carrying capacity of the study area was adequate to support Acacia up to the year 1900. Following that year, environmental changes spanning over 50 years had affected that ecosystem carrying capacity, up to 1950, by when that ecosystem carrying capacity collapsed, while Acacia continued to resist these ecological changes up to 1970. Since 1970 Acacia severely deteriorated.

Environmental and human factors

Ecological disequilibrium in the study area started directly after 1970 (Figure 4), and manifested by declining ecosystem carrying capacity and thus deterioration of Acacia. Environmental factors responsible for Acacia deterioration in the study area might include successive droughts, declining rainfall, retreat of isohyets and temperature rising. Climatic variability has an impact on the Acacia dynamics (Joaquín and Gabriel, 2000). High annual rain variability (ca.35%) and the very high evaporation rate, ca. 3 mm per day in the dry season were real in the study area (Farouk and Abu Sin, 1982). Rainfall ranges between 100 to 600 mm. However, average annual rainfall for the period 1922 through to1994 was 408.9 mm. During 1994, rainfall records in

Sahel rainfall from 1900 to 2007 averaged over June, July, August, September, and October
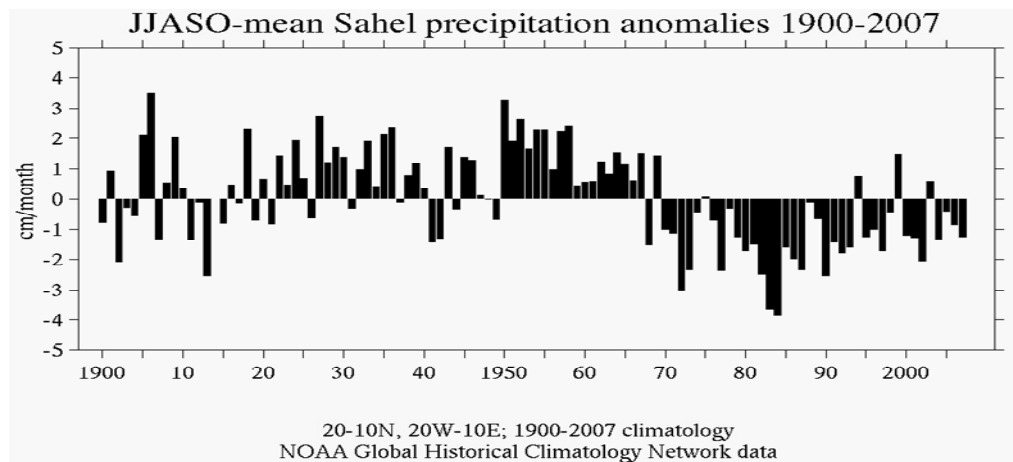

Figure 5. Precipitation anomalies in the Sahel, 1900 to 2007. Source: Stewart (2009).

some major stations in Butana area, for example, were 777 mm. in Gedarief, 669.5mm in Wd el Houri and 616 mm in Gedambalia while it was 600 mm in Hawata (Meteorology Office-Gedarief, 1994). Elagib (2010) studied the rainfall seasonality index (SI), precipitation concentration index (PCI) and modified Fournier index (MFI) for rainfall erosivity for the hyper-arid region of Sudan consisting of monthly rainfall measurements spanning over 60 years, 1945 to 2007, for three index meteorological stations, two on the Nile corridor and one on the Red Sea coast. The region is characterized by high year-to-year variability in rainfall leading to extreme seasonality/irregular distribution of rainfall over the year. Although prevalent diminishing rainfall amounts have been witnessed, there are marked tendencies for some months to become wetter, indicating changing intra-annual rainfall variability and thus monthly rainfall erosivity. No statistically significant trends were observed in rainfall seasonality and concentration during the common data period of 1945 to 2007. Cases of high and very high erosion powers were detected. A significant decreasing trend in erosivity is shown for one inland station (Elagib, 2010).

According to Hulme (1990) rainfall depletion has been most severe in semi-arid central Sudan between 1921 to 1950 and 1956 to 1985 annual rainfall has declined by 15%, the length of the wet season has contracted by three weeks, and rainfall zones have migrated southwards by between 50 and 100 km. This depletion has been due more to a reduction in the frequency of rain events rather than to a reduced rainfall yield per rain event. Ayoub (1999) compared long-term rainfall in four sub regions in Sudan and showed that rainfall decline had been in the magnitude of 30-40%. The western parts of the Sudan (Kordofan and Darfur) experienced extreme

rainfall anomalies than the eastern and central parts (Gedarief "Butana" and Damazin), and had suffered greater periods of desiccation than the eastern and central parts. The decadal rainfall means showed below average rainfall for the last three decades in all these sub regions. Hulme (1990) assessed the role of an upper troposphere synoptic feature of importance in modulating surface rainfall over Sudan in the eastern Sahel. The Tropical easterly Jet (TEJ) provides an example of an inter-regional circulation feature linking the Sahelian and Southeast Asian monsoons and ultimately, perhaps, forced by ENSO-related anomalies in the Sahelian zone. Recent work by meteorologists and oceanographers (Stewart, 2009) has shown that much of the recent year-to-year changes in Sahel rainfall are forced by changes in sea-surface temperature in the Gulf of Guinea (on the equator near the prime meridian) and by El Niño in the Pacific. When the gulf is warm, the Intertropopical Convergence Zone shifts south away from the Sahel reducing the African monsoon that draws moist air into the Sahel. Longer term changes in rainfall from decade to decade are forced by changes in sea-surface temperature in the western Indian and tropical Atlantic oceans. When these areas are cool, Sahel rainfall increases (Figure 5). At the same time a period of severe drought led to large-scale environmental degradation.

Fieldwork results depicted changes in soil chemical and physical properties; appearance of compact salty soils, ultra alkalinity; poor organic matter content. There is increase in Na rate; Ph range was 8-8.5 tending towards more alkalinity; E.C at depth of 0-45 cm was 0 to 1.1, while at depth of 45-90 it was 0 to 1 millimoze. Organic Carbon was very low and there is an increase in Calcium. Topography of the study area is also changing, manifested by its distraction; increase of dust storms,

damping of valleys and depressions; villages and water reservoirs and destruction of wild life.

As far as human factors responsible for Acacia deterioration are concerned, our fieldwork results revealed that in 1993, population of Butana were 1076430, density was 50.8/km^2. In 2005, average family size was 6.6 while population annual growth rate was 2.23%, birth rate was 37.7% and migration constituted 21% among the studied population. Age structure depicted children less than 15 yrs old as constituting 50.2%; adults as 44%, elders as 5.5% of the total population. Females were 46.3% and males 53.7%. This population consumes fuel wood which contributed by 40% for deterioration of Acacia in the study area according to our fieldwork survey. A family of 7 persons living close to the Blue Nile consumes on average 8 pounds/day of fuel wood when the weight of a tree is estimated at 75 pounds. This means that such a family consumes 3.3 trees/month or 40 trees /year.

On the other hand, a family of the same size living remote from the Blue Nile, when the weight of a tree is estimated at 50 pounds, consumes half of a tree per day, 15 trees /month or 180 tree/year. People particularly prefer *A. mellifera, A. nilotica* and *A. seyal vor fistula* for fueling. Stebbing (1972) mentioned that Rufa'a area supplemented Khartoum by 1000 ton/year of fuel wood in 1936 and increased to 5000 ton/year in 1956 of *A. mellifera*, *A. nilotica* and *A. seyal vor fistula*.

Concerning agricultural expansion, fieldwork survey revealed that it had contributed by 30% for Acacia deterioration. Agriculture started since 1940s as it was just estimated after the Second World War that of the 100000 tons of Dura marketed annually in the Sudan, 30000 tons came from the Gedaref "Butana" area (Jefferson, 1949). This diverted people from grazing to agriculture when rainfalls were abundant and high production created competition among people to open new agricultural lands far exceeded their affordability to cultivate, where more than 20 feddans/person was individual holding (Fieldwork, 2005). All these activities had cleared up Acacia from Butana area (Abu Sin, 1970). Similarly Grazing highly contributed by 20% for Acacia deterioration. For building of animal fences, which are renewed annually, people prefer thorny *A. mellifera* and *Z. spina christi* in particular and they also used to fill forage gab during summer by grazing and logging of Acacia branches, fruits, leaves and grazing on small shrubs and offshoots. Building purposes contributed by 7% for Acacia deterioration particularly Tamarix tenx "Athal" while use of Acacia for Folk crafts and for making of agricultural tools contributed by 3% for Acacia deterioration.

DISCUSSION

Several studies depicted the ecological deterioration of vegetation cover in Sudan where dense tropical forests were used to cover most areas of the country (Stebbing, 1972). The Sahara desert was flourished with animal and plant life where fossil trees, buried valleys are evident. Many clues are evident that tropical forests were near to Cairo up to mid Pleistocene. Walton (1979), Nichelson (1978), studied paleoclimate of the Sahelian zone and explained that there were warm, rainy and humid periods and there were also dry periods. Before 18,000 years ago, these areas witnessed a drought period which led to formation of sand dunes and drying up of lakes. In the last 12,000 years climatic conditions changed to heavy rains, while the last 3,000 years rainfall decreased which exposed lands to erosion and deposition processes when recent sand dunes are formed.

The three focal sub areas of western Butana plain are distinctly different in Acacia distribution by occurrence; soil type; cover; frequency; abundance and density, so the identification of the factors that characterize those places provides insight into environmental and human factors and help to target control and amelioration strategies. Based on the analysis, the pattern of Acacia distribution by zones in 2005 may indicate several different underlying processes. Firstly, zones may be near a common place for human exploitation, where high affected parts are in places with conditions that are especially well suited for that such as areas close to the Blue Nile where high population concentration is expected. Secondly, the Acacia deterioration may be related to past and concurrent socio-economic conditions that are reflected in agricultural expansion and fuel resources use. Thirdly, Acacia deterioration may occur where official government control was not sufficient.

In the first instance, the most affected areas by Acacia deterioration are located where people were close enough to an area abundant with Acacia. The type of environment in which people live is partly defined by the landscape and housing characteristics. Housing characteristics are a result of available domestic building materials produced locally and mostly of forests produce. Landscape of the Butana is that suitable for both irrigated and rainfed agriculture. Irrigated agriculture included all the schemes close to the Blue Nile and Rahad river such as Gunied Sugar production scheme which dates back to 1964 and the Rahad agricultural schemes which dates back to 1975. This type of agriculture had cleared up huge lands rich enough with Acacia for agriculture use. Mechanized rainfed agriculture which started during World War 2 was done similarly. In this rainfed sector, land ownership politicization dates back to Sudan's division by colonial administrators in 1923 into tribal homelands. The strong relationship between a tribe and its homeland has allowed the major tribes to use and monopolize the natural resources within their homeland. Competition over land for agricultural and exploitation purposes were further politicized by the 1970 Unregistered Lands Act (Ayoub, 2006). The legislation entitling the government to use force in safeguarding "its" land and encouraging the accumulation of land by a
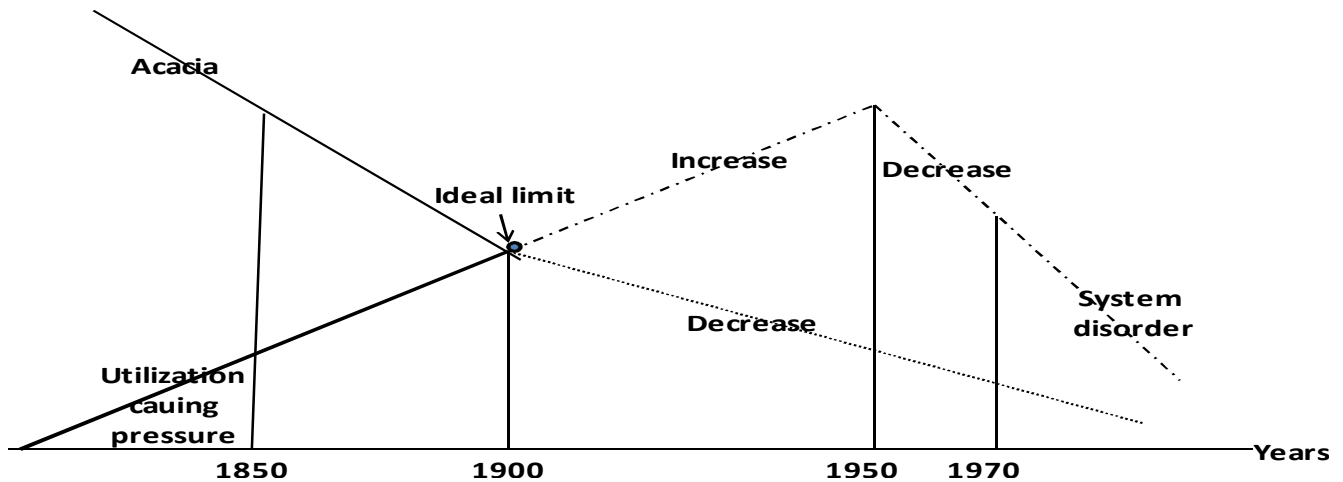
Figure 6. Human exploitation of Acacia versus its deterioration.

minority of rich local and foreign investors. The 1970 Act also enabled the government to implement a development policy based on the expansion of the agricultural sector, especially mechanized farming, and by 2005 the total area under mechanized farming had increased fifteenfold (Ayoub, 2006).

In addition, vast tracts of land in Butana area have been allotted to private capital investments since the 1990. Investment Act, substantially cutting rural communities' rights to land. Mechanized farming remains a major source of sealing off nomadic routes, water points and pastures, fostering a culture of land-grabbing. The processes behind this agriculture exploitation have led to extensive deterioration of Acacia in the region which is noticed by (Figure 6), which is further supported by Figure 4.

Human exploitation of Acacia was balancing with its growth up to the year 1900 (ideal limit). Following that year, human exploitation continuously increased till the year 1950, while Acacia started declining. Human exploitation decreased respectively after the year 1950, due to the general ecosystem disturbance where Acacia is no longer adequately available. As Acacia communities change, so will the associated micro-organism, fungus and animal species. Joaquin et al. (2000) explored the validity of three responses of Acacia to increased soil erosion, reduction of Acacia cover, number of species and reduced substitution of species in the intensely eroded Eocene marls of the Prepyrenees in north east Spain. Acacia degradation explained 48% of the species number variance. In the later stages of degradation a significant substitution of species was not observed, only a lower frequency of occurrence of several species that appeared in the whole set. Through the process of degradation, 47% of species displayed significantly reduced frequencies as degradation increased, none showed a significant increase in frequency. It is

concluded that there are no characteristic species in these Acacia communities that survive in the severely eroded marls. Among the few species that had increased in frequency, most only colonized favorable micro-environments (Joaquin et al., 2000). The solutions for replacement of the cut off Acacia in Butana area were not always adequate to keep on with Acacia strategies for conservation. Closed Acacia and replanted Acacia forests were created suffered from a general inattention. These forests likely proved an excellent place for logging.

Social factors are very complex and are related to environmental factors. People without adequate assurance of income or who are unaware of the possibility that Acacia cutting and logging will lose their most precious wealth might be under poverty line or may be less likely to have adequate income. This may be reflected in the locations of most affected areas by Acacia deterioration and may play a role in the identifiable patterns and factors. The most disappeared *Acacia* species may be biased toward more areas of higher socio-economic populations. It is also possible that the social factors of education and occupation are only associated with the Acacia exploitation indirectly due to their correlation with environmental factors, or there is a real increased risk from behaviors that are linked to these two factors.

Social and environmental factors are interrelated making it more difficult to create a clear cut and concise limit in the study area. Population density is related to areas close to water sources, and higher income populations are more likely to live in urban places demanding for forests and animal products. The human demographic variables are related to general behaviors towards Acacia exploitation and deterioration. The specific importance of the background of Arab Nomads in the study area needs further exploration. By way of comparison, tree logging has also brought out a potential

link to Arab Nomads.

Conclusions

The example of deterioration of Acacia in western Butana plain of the Sudan can be a showcase for whole the country. Deterioration of Acacia in Sudan has cut part of the GNP of the country and severely affected rural economies living there. It caused food gab, tribal conflicts, outside migration and changing ethnic and labor force structure of urban and agricultural areas of Sudan.

The introduction of irrigated and mechanized agriculture into the Butana area since World War 2 is a situation that should not be replicated in the future, unless good plans that consider conservation of the environment were put. The Government and local population have now adjusted measures to better control of Acacia species and coordination of efforts and the recognition of the importance of this coordination are positive outcomes of the awareness of Acacia deterioration. While the ongoing deterioration of Acacia is a risk to human economic benefits, the natural dangers by climatic change to human population most likely has increased and the susceptibility of ecological degradation has been increased either through drastic reduction in numbers of Acacia cut down annually, so the number in the near future will be replicated. Improved surveillance of Acacia species across the region as well as vigilance in reduction in Acacia bare grounds through re-plantation will have a significant impact on reducing the risk for deterioration. Places where agricultural development occurred during the rapid growth of the 1950s may benefit in particular from greater attention to reducing deteriorating habitats.

This analysis of the spatial patterns of Acacia and factors for its deterioration resulted in many further questions and firm conclusions. The environmental and human factors are the keys to pinpointing hotspots and will be the focus of future work. Because the systematic data collection needed to detect the timing, intensity and location of environmental and human activity did not occur across Sudan, this aspect of the ecology is limited. The assessment of Acacia deterioration cannot be made outside of the context of the rural environment in which it is present. It is clear that the propensity for the deterioration to be more present in some places is greater than for others, but the effect of control also is important. Further research in the response of Acacia to the environmental risk and a qualitative assessment of the environmental and social factors related to exploitation and control of Acacia should also be a matter of concern. Acacia logging control combined with appropriately targeted community education outreach are key factors to reduce Acacia deterioration. However, recognition of the continued development of coupled climate-Acacia models worldwide will facilitate the exploration of a broad range of global change issues, including the potential role of Acacia feedbacks within the climate system, and the impact of climate variability and transient climate change on the terrestrial biosphere where Acacia specie are significant for Butana and for Sudan which is famous with Gum Arabic, a precious produce of A. seyel vor sayal "Hashab".

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