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Vegetation dynamic in semi arid Butana plain, Sudan

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Natural vegetation of the western Butana plain of Sudan, at 14 to 16°N and 33 to 35'E, which is composed mostly of Acacia of the Mimosaceane family, has undergone dynamic changes during the last decades as demonstrated by a survey carried out in 2005. The majority of the vegetation is of Acacia trees, shrubs and grasses which are differing spatially, by soil type and in cover; frequency; abundance and density. There was a vegetation climax prior to 1850, while its dynamic changes took place through four successive stages. The ecosystem carrying capacity of the study area was adequate to support natural vegetation up to the year 1900, when human exploitation of vegetations was balancing with their growth. Ecological disequilibrium started directly after 1970 and manifested by declining ecosystem carrying capacity, dynamic changes and deterioration of vegetation. This dynamic change 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 40% in vegetation change and 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 changes and deterioration processes.

Key words: Acacia, vegetation change, succession, deterioration, Butana, rainfall fluctuation, Sahel zone, rain-fed agriculture, human factors, community education.

INTRODUCTION

Savannah region is dominated by Acacia trees, shrubs and ephemeral grasses which are adapted specifically to the location and characteristics of the region. The climatic variation means that the vegetation has a short life cycle so as to conserve water to survive. The majority of the plants are xerophytic and characterised by small, spindly leaves, with waxy layers to reduce evapotranspiration. Trees have gnarled trunks to reduce water loss and extensive root systems to absorb as much water as possible. Vegetation cover starts high above the ground to reduce animal destruction such as the Acacia which has leaves that start 5 to 7 m above the ground (Waugh, 1999). Acacia is a Greek word which means "thorns", which is a genus for trees and shrubs of Mimosaceane family. Recent studies (Menschign, 1988; Kamur, 1995) show that the home of Acacia is Sudan, Nigeria, Mali, Pakistan and India. In Africa, it extends from Senegal to the Red Sea across the Sahelian and Soudao zones.

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Acacias generally grow in the range 200 to 600 mm rainfall with different adaptations, but the most suitable places for their distribution lie between 10 degrees north and south of the Equator up to the tropics of Cancer and Capricorn. Generally, adaptation methods of Acacia depend on rainfall amount, temperature, topography, soil type and plant abundance.

However, literature on vegetation cover in savannah region and worldwide discussed the deterioration due to human pressure and climate change. Many earlier studies have focused on the degradation of vegetation due to human pressure and climate change. Concerning human pressure, results aggregated to the national level in Senegal show moderate change, with a modest decrease in savannas from 74 to 70% from 1965 to 2000, and an expansion of cropland from 17 to 21%. However, at the ecoregion scale, rapid change in some and relative stability in others was observed (Tappana et al., 2004). Also, the land use by its various interests, and including man, in Târgovişte Plain, Romania led on the one hand to restrict the areas occupied by natural plant formations (replaced by crops, secondary plant formations or become unproductive due to land degradation), and on the other hand, changes more or less pronounced in the composition and structure of vegetation cover in parts where the natural vegetation was maintained. This is all the greater as an agricultural activity has attracted the circuit area where the initial spontaneous vegetation was replaced by different other cultures (Mihaela et al., 2010). In addition, Michael et al. (2003) identified the human induced pressure and their impacts on water resources in Wtirm catchment in the Neckar River basin in southwest Germany, that the impacts detected are much more severe in this catchment compared to assessment results, which were derived in other catchments with lower degrees of human pressures.

The study on the evaluation of environmental degradation in northern Ethiopia revealed that, evergreen scrub vegetation type appeared to be expanding with increasing human influence signifying a decrease in biomass of vegetation as a result of collecting wood for fuel and other domestic uses. Bushland appeared to be expanding with the same trend (Enrico et al., 2002). The importance of trampling as an ecological factor, especially in relation to the increasing use of the countryside for informal recreation is stated by Liddle (1975). Anthropogenic impacts have affected a large proportion of Armenia, and have led to damage and destruction to natural habitats. Over the last 50 years, agricultural intensification has resulted in the loss of natural grasslands and wetland ecosystems, while felling of forest areas has resulted in substantial losses in biodiversity.

During the course of the experiment (Gordon, 2000), on the effects of grazing pressure (between-tussock sward height 4 to 5 cm or 6 to 7 cm) and mixed (cattle and sheep) or monospecies (sheep) on Nardus tussock cover and structure, vegetation dynamics, animal performance and invertebrate biodiversity, showed the decline of Nardus cover by 22% units on the cattle-plus-sheep treatment grazed at a between-tussock sward height of 4 to 5 cm (Gordon, 2000). Although grazing is primarily an issue arising from the pressure of introduction of new species to the land (pasture, in some cases, exotic pasture, replacing native vegetation and introduced animals replacing native animals), overgrazing also has the potential to completely remove ground cover. Study on recent large-scale disappearance of Egyptian vulture breeding territories in Spain which identified the combined effects of habitat features, human pressure, and the social behavior of the species on the risk of extinction from a territory (Martina et al., 2006). Deviance partitioning showed that, a complex mix of factors is significantly related to the disappearance of more than 400 territories throughout Spain (Martina et al., 2006). In 1962, Keita in the centre of the Republic of Niger, had plateaus and slopes which were entirely covered by forest. Starting in 1972, evident signs of forest degradation appeared and in 1984, this forest had completely disappeared. A negative synergistic process struck the ecosystem, bringing it close to the break point (Andrea et al., 2007). In the Middle Atlas region of Morocco, the forests have become less diverse, more open, and scrub-dominated as a result of human exploitation and deciduous oak, once abundant, has become rare (Lamb et al., 1991).

Waugh (1999) attributed 70% of the problem of desertification to many factors among which is uncontrollable population growth. Population growth puts pressure on natural resources in drylands by that; firstly, increased population means an increased demand for food, which has to be produced by increasing productivity or production by expansion into marginal and fragile lands that are highly susceptible to degradation. Secondly, increased family size means a parcelling of land resources with each subsequent beneficiary owning an increasingly smaller plot, which is then over-cropped (Waugh, 1999). However, the response of fragmented vegetation to human impact in degraded and degrading areas in Lake Manyara in Tanzania demonstrated that, the vegetation types are strongly related to the degree of human impact and that, the corresponding vegetation patches show different degrees of permeability to the species of the surrounding landscape (Enrico et al., 2003).

The potential impacts of human activity-induced climate change on natural vegetation in China confirmed northward shift of vegetation types, with an increase in the areal extent of tropical rain forests and decrease of cold temperate coniferous forest and tundra (Wang and Zhao, 1995). In Israel, biodiversity is urban development and agriculture cause rapid habitat destruction, fragmentation into smaller habitats and loss of connectivity between populations all leading to species extinction (Guy and Uriel, 2000). The impacts of climate change on vegetation have been documented worldwide. There is evidence that in the 20th century, warming was faster than the shifts in species ranges (Houghton, 1990), what may lead to extensive biodiversity losses (IPCC, 1996). Increases of 2 to 3°C are predicted for Armenia's climate, along with declines in rainfall, resulting in increased risks of desertification. This is likely to severely affect wetland habitats and associated species, while changes in the distribution of habitats may affect the range and viability of a number of species (Liddle, 1975). The decrease of mean air temperature with elevation appears to be in close correlation with the general decrease of species' richness with elevation (Grabherr et al., 1995). Precipitation regimes determine oceanity or continentality, which in turn influence plant distribution (Zimmermann, 1996; Kienast et al., 1998; Pache et al., 1996). Timberline is very likely growth-determined, with a lower thermal threshold defined by seasonal values of mean air temperature between 5.5 and 7.5°C (Körner, 1998, 1999).

In Indian tropical moist deciduous and wet evergreen forests, climate change could potentially result in increased productivity and shift forest type boundaries along altitudinal and rainfall gradients, with species migrating from lower to higher elevations and the drier forest types being transformed to moister type (Ravindranath and Sukumar, 1996). Donald (2008) reviewed the impacts of climate change on British Columbia's biodiversity and indicated that, between 1888 and 1992 Growing Degree Days (gdd), a measure of the heat energy available for plant and insect growth, increased by 5 to 16% across the province. Changes in vegetation structure influence the magnitude and spatial pattern of the carbon sink and, in combination with changing climate, also freshwater availability (Cramer et al., 2001). The annual growth period of individual trees for the state of Saxony will be further extended, mainly because of the shift of spring phases and changes in the timing of phenophases and the average timing of these phenophases could be advanced by 3 to 27 days by 2050 (Frank et al., 2005). The actual forest area has decreased in North America and Asia, the potential forest area in these continents also benefitted from the climate change and in the end, the remaining continents tended to bear the brunt of the climate change (Gyunqsoo, 2001).

Since Mediterranean biomes are projected to shift 300 to 500 km northward and 300 to 600 m uphill with a 1.5°C warming, the Negev ecosystems may be expected to replace Mediterranean ecosystems in Israel. The ecotone between the desert and non-desert regions of Israel—where peripheral populations of both ecosystems meet—are expected to show the first impacts of climate change (Guy and Uriel, 2000). The response of vegetation distribution to increasing temperatures was characterized by a shift in dominance from needle-leaved to broad-leaved life-forms and by increases in vegetation productivity, especially in the relatively cool and mesic regions of California State (James et al., 2003). With regard to the recent climate-based trends of Potential Natural Vegetation (PNV), all natural spatial units in Central Germany are affected by progressing continentality (that is, dryness) during the growing season and the resulting deterioration of the site potential (Franke and Köstner, 2007). The area of potential beech forest at lower elevation has decreased in favour of oak forest as PNV, while less change is observed in the montane area (Franke and Köstner, 2007). Richard et al. (1999) indicated that most notably in the short grass steppe, that increased spring T_{MIN} was correlated with decreased net primary production by the dominant C_4 grass (*Bouteloua gracilis*) and with increased abundance and production by exotic and native C_3 forbs. Reductions in *B. Gracilis* may make this system more vulnerable to invasion by exotic species and less tolerant of drought and grazing.

However, climatic phenomena may also have a significant impact upon the Madagascar's island flora and fauna that there is a dynamic pattern in Madagascar's vegetative cover of increasing anthropogenic degradation of its natural habitats, both annually and seasonally throughout 1982 to 1999 (Carter, 2004). The study area is not exceptional from these human pressures and climate change as to influence its vegetative cover seriously. The present study objects to investigate the process of vegetation dynamics in western Butana plain of Sudan and works to explain the contribution of natural and human factors; because the study was classified by the UN Conference of 1977 as being under "Very High Risk" of desertification (Figure 1), it is expected that such investigation will highlight the problem and show the importance of environmental conservation based on geographic grounds. Vegetation dynamic that has occurred within this region is examined by looking at the results of a survey carried out in 2005 and the notification of studies covering the period from 1928 to 1999.

DATA AND METHODS

The study area of western Butana of Sudan is lying between the Blue Nile in the west and Sahara desert in the north, at 14 to 16°N and 33 to 35°E (Figure 2). The area was chosen because, it is one of the most hit areas by vegetation dynamic and 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 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 (Farouk et al., 1982).

The process of fieldwork is sketched in Figure 3. Umakash is taken as the central point for the study area from which three main zones A, B and C are determined and eight directions were specified. Locations of quadrants for collection of plant data are specified along these directions. The total number of the quadrants is 24, equally distributed within the three main zones A, B and C. This is based on the criteria of soil type which changes from clayey to sandy eastward from the Blue Nile and consequently, the density and diversity of vegetation types (Figure 2).The distance interval between each quadrant and another is 5 km. The size of a quadrant is 100x100 m which gives an area of 10,000 m^2. From Umakash northwards and southwards was 5 km each while for eastwards and westwards it was 15 km each. Distance from Umakash northeastwards, southeastwards, northwestwards and southwestwards was 20 km each (Figure 3). Within each quadrant, on either direction, an area of 1x1 m is taken to collect data for grasses.

Following Walton (1979), Hills (1966) and Clarke (1954), Acacia trees in the study are distinguished as succulent perennials, non-succulent perennials and evergreens, while grasses are identified according to life cycle into long living and ephemerals. Then data is collected according to fieldwork methods used for arid land vegetation survey. Such fieldworks require data to be collected for

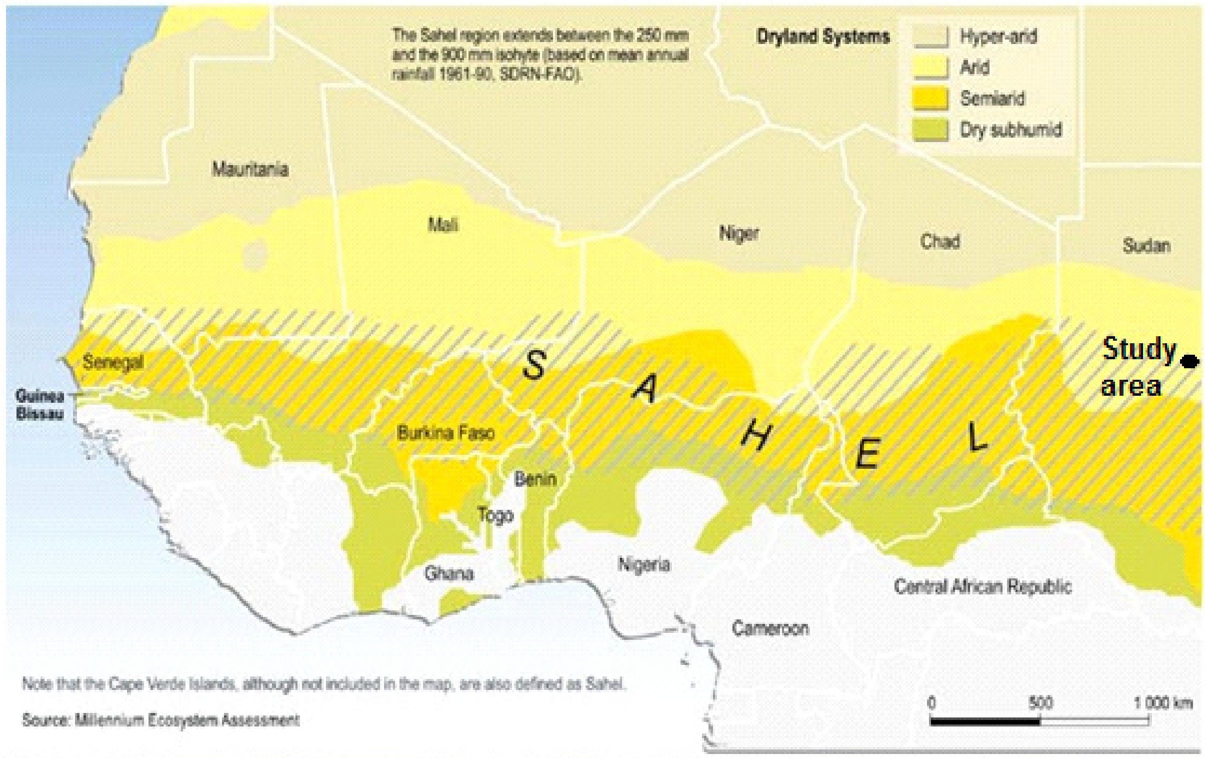

Figure 1. Dry land system and location of the study area in the Sahel. Source: After Millennium Ecosystem Assessment.

each quadrant by counting number of plant species by type, % of vegetative cover by type, height of a plant, its frequency, abundance and density. This methodology is followed in each quadrant to collect trees and grass data. Latin names equivalent with local names for *Acacia* species were obtained from the Faculty of Forestry, University of Khartoum. Measurement methods included calculation of coverage, frequency, density and abundance of Acacia trees, only while it is found difficult to apply for grasses. The following formulas are applied for each.

$$\text{Coverage} = \frac{\text{Number of one type of species}}{\text{Total species}} \times 100$$

$$\text{Frequency} = \frac{\text{Number of quadrants where type (A) is found}}{\text{Total number of quadrants studied}} \times 100$$

$$\text{Density} = \frac{\text{Number of species of one type (A)}}{\text{Total number of quadrants studied}}$$

$$\text{Abundance} = \frac{\text{Number of species of one type (A)}}{\text{No. of quadrants contain that type (A)}}$$

Seven locations were chosen in the three zone to collect soil data (Figure 3). In each location, three soil samples are taken which give the total of 21 samples for the whole area. Soil data are collected to test pH, EC, OC, Na and Ca and the other physical properties of Clay – Silt- Sand, and was collected during the dry month of March. This is in order to see if there is any relation between deterioration in soil properties with the disappearance of plant species and vice versa. Choice of locations for soil samples is based on plant density and diversity and slope difference from east to west towards the Blue Nile. Depths for three samples were 0 to 25, 25 to 50 and 50 to 75 cm. Soil properties investigated were pH, to decide alkalinity and acidity of the soil, E.C. to determine salinity, O.M. for organic matter, Na and Ca as they relate to salinity E.C. These soil properties are tightly connected with ecosystem elements and reactions into nutrition and plant physiology, material cycle and energy flow within the ecosystem.

Percentage of clay, sand and silt are in accordance with the American classification. Soil data was compared with normal and international rates. pH is considered equalized between 7 to 8, if the rate is less than 7 it will be acid and if more than 8 it will be alkaline and there are specified rates described if it is acute, moderate light or equalized. For the E.C., the soil is considered normal if the average is less than 4 millimole, moderate saline between 4 to 8 millimole, and acute saline if exceeded 8 millimoze. O.C. is usually expected at 3.25% and in arid region soils, it is expected between 0.4 to 1%. Ca rate expected is 0.7 to 3.6 and in arid regions soils it is to be 1.0. Na if the rate exceeded 15 part /one million soil will be sodas and if exceeded 30 part/million will be very sodas (Cline, 1944; Jackson, 1958). Data for human factors is collected through a sample size of 200 individuals distributed into 12 villages which represent 13% of the total number of villages of 91 village, 4 villages in each zone as illustrated in Figure 3. These villages were chosen because of their relatively big population size and to some extent they serve the surrounding smaller villages by marketing some commodities. In each village, the sample size is taken into a percent range of 10 to 15% of total population in each village. Questions included information about family size, types of trees logged for different purposes and agriculture and grazing. This is as well as direct interviewing with the eldest farmers and herders to collect data concerned with past vegetation history in the study area and similarly interviewing with some government officials was carried out.

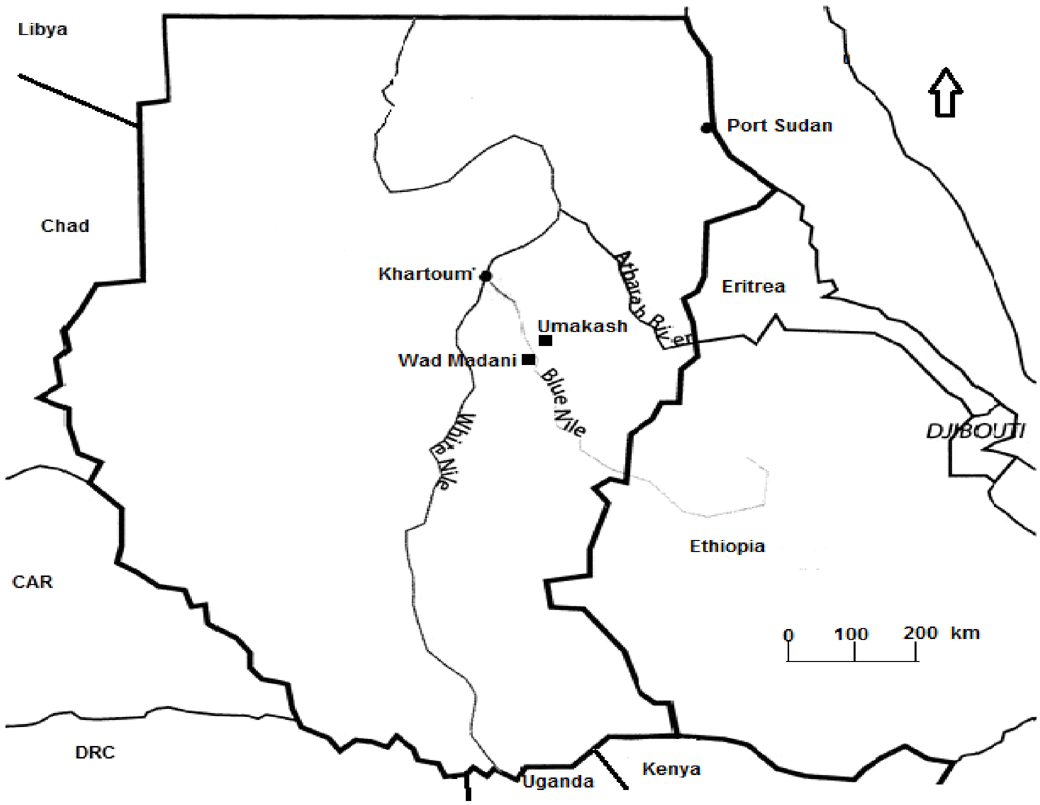

Figure 2. Location of the study area as indicated to by Umakash. Source: After Department of Survey, Sudan 2008.

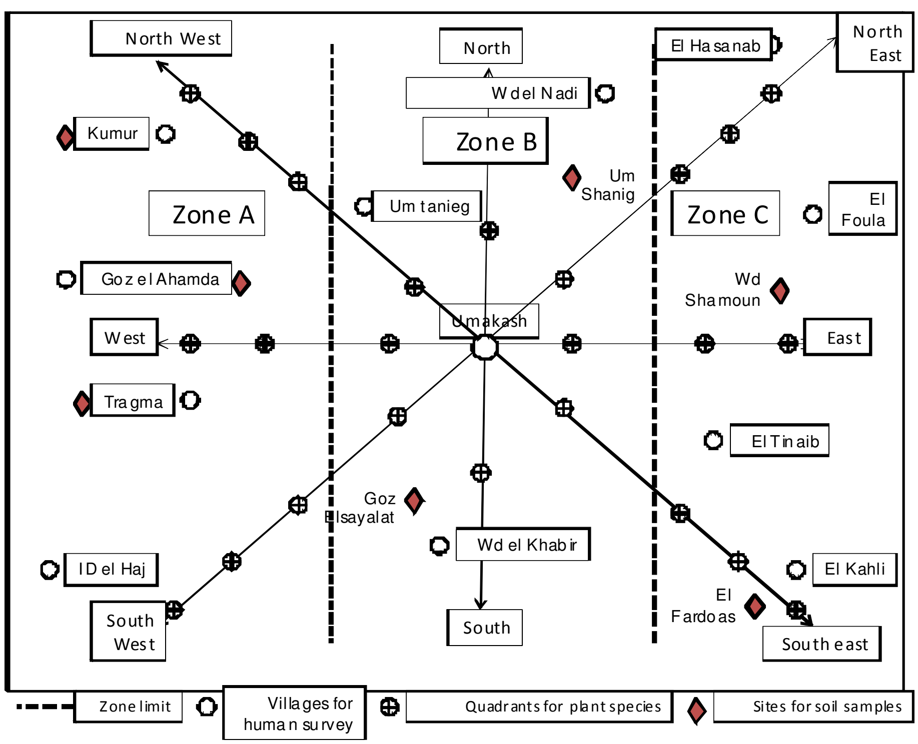

Figure 3. Sketching locations for data collection of plants, soil samples and villages for human survey in the study area. Fieldwork (2005).

Table 1. Occurrence of Acacia by zone and soil type.

S/No.	Local name	Latin name	Zone			Soil type		
			A	B	C	Clayey	Sandy	Loamy
1	Sunut	*A. nilotica ^*	+	-	-	-	-	+
2	Sial	*A. tortillis vor raddiana^*	+	+	+	+	+	+
3	Talieh	*A. seyal vor fistula^*	+	-	-	+	-	+
4	Kitir	*A. mellifera^*	-	-	+	-	-	+
5	Hashab	*A. seyel vor sayal^*	+	-	+	-	+	-
6	Haraz	*A. albida**	+	-	-	-	-	+
7	Laaot	*A. nobica**	+	+	-	+	+	+
8	Samur	*A. tortillis vor tortillis^*	-	+	+	-	+	-
9	Higlig	*Balanites aegyptiaca**	+	+	-	+	+	+
10	Sarah	*Maerua crassifolia^*	-	+	-	-	+	-
11	Tundub	*Capparis deciduas^*	-	+	-	+	-	-
12	Sidir	*Z. spina Christi"*	+	-	-	-	-	+
13	Ushar	*Calotropis procera*	+	-	+	+	-	+
14	Dahsier	*I. oblongifolia*	-	-	+	+	-	-
15	Senna Mecca	*Cassina senna*	+	+	+	+	+	+
16	Hanzal	*Citrullus colocynthis*	+	-	+	-	+	_
17	Um Shuaila	*Guiera senegalensis*	+	+	+	+	+	+
18	Irig Agrab	*Clitoria tematea*	-	+	_	_	_	+
19	Gudaim	*Geruria tanar*	-	+	_	_	+	_

Life cycle: *Succulent, ^non-succulent, "evergreen, + found, - not found. Source: Fieldwork (2005).

RESULTS

Spatial patterns of vegetation

Spatial distribution of *Acacia* species and grasses by zones and soil types are shown in Tables 1 and 2, while Acacia distribution according to frequency, density cover and abundance are shown by Table 3. Acacia are mostly of non- succulent type which differ spatially and by soil type (Table 1). Zone A has the highest occurrence of *Acacia* species, followed by zones B and C respectively. Out of the 19 counted *Acacia* species in zone A only 7 were not found by a percent of 36.8%. *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 is exposed to heavy and extensive traditional rainfed agriculture whereby, now there is one Acacia tree species per five feddans (1feddan=1.038 acres). They are mostly of *Balanites aegyptiaca*. Out of the 19 counted *Acacia* species in zone B, 9 species were not found by a percent of 47.7%. Zone C has little Acacia occurrence, mostly of *Acacia mellifera*. Out of the 19 counted *Acacia* species in zone C,10 species were not found by a percent of 52.6%. There are difference between the three zones in the percent of disappeared *Acacia* species as big as 10.9% between zones A and B, 15.8% between zones A and C and by 4.9% between zones B and C. This indicates that such differences increase eastwards from the Blue Nile and such differences become less between zones away from the Blue Nile. Table 1 also shows that, if any *Acacia* species is not found in a particular zone, it would be found in another indicating that complete disappearance of a specified type is not found in the study area. For example *A. nilotica*, is detected in zone A and absent in the other two zones while *A.* *mellifera* is found in zone C and absent in the other two zones.

These differences by zones might be further depicted by soil types in the study area. Generally, all types of *Acacia* species are found by all soil types. On the clayey soil, out of the 19 counted *Acacia* species, 10 species were not detected by our fieldwork. This gives a percent by 52.6% while it was 47.7% for sandy soil and 36.8% for loamy soil. These give reverse result to the occurrence of Acacia by zones in the study area and depict a percent of difference by 4.9% between clayey and sandy and 15.8% between clayey and loamy and 10.9% between sandy and loamy. More *Acacia* species have not been detected by our fieldwork in clayey soil compared to the other two types, while the least percent was detected in the loamy soil. *Acacia* species are diverse on clayey soil and although of that, they are less occurring. On sandy soil, *Acacia* species are more diverse and dispersive, but less dense. On the loamy soil, *A. nilotica* are abundant with few *Acacia seyel vor fistula.*

Furthermore, occurrence of ephemerals and long living grasses by zone and soil type are shown in Table 2.

Table 2. Occurrence of grasses and ephemerals by zone, soil type and life cycle.

S/No.	Local name	Latin name	Zones			Soil types		
			A	B	C	Clayey	Sandy	Loamy
1	Dambalab	*Schoenefeldia gracilis**	+	-	+	-	-	+
2	Maharaib	*Cymbopogon proximus^*	-	-	+	-	+	-
3	Huntout	*Ipomea cardoiospelala**	+	-	+	+	-	+
4	Safra	*Tephrosia spp**	+	+	-	+	+	-
5	Gao	*Aristida spp**	-	+	-	-	+	-
6	Tibir	*Ipomea cordofana**	+	-	+	+	-	+
7	Dhuraisa	*Tribulus terrestris**	+	+	+	+	+	+
8	Gibain	*Solamum aethiopicum**	-	+	-	+	-	-
9	Buda	*Striga hermothica**	+	+	+	+	+	+
10	Turba	*Limeum viscosum**	+	+	-	+	-	-
11	Nal	*Cymbopogon nervatus^*	-	-	+	+	+	-
12	Saad	*Cyperus compacutus**	+	-	+	+	-	+
13	Bous	*Dipterygium glaucum^*	-	-	+	+	+	-
14	Suraib	*T. emeroides**	+	-	+	+	+	-
15	Anies	*S. purpureo sericeum**	+	-	-	+	+	-
16	Saha	*Blepharis edulis**	-	-	+	+	-	-
17	Rabaa	*Arianthema pentanda**	+	+	-	+	-	+
18	Khadra baryia	*Corchorus olitorius**	+	+	+	+	-	+
19	Umlaban	*Euphorbia aegyptiaca**	+	+	+	+	-	+
20	Umginaigra	*Penniseetum pdystachyum**	+	-	-	+	+	+
21	Mulaita	*Picridium tingitanum**	+	+	-	+	-	+
22	Fagous	*Cucumis melo**	-	+	-	+	-	+
23	Huskaniet	*Cenchrus catharticus^*	+	+	-	+	-	+
24	Fakha	*Achyranthes aspera**	-	+	-	+	-	-
25	Rihan	*Ocimum basilicum**	-	+	-	+	-	+
26	Tamalaika	*Gunandropsis gynandra**	+	-	-	+	-	+
27	Umasabi	*Dactylocternium aegyption^*	+	-	-	+	-	+
28	Umgalagil	*Aristolochia bractteata**	+	-	-	+	-	-
29	Sharaia	*I. Semitrijuge**	-	+	-	+	-	-
30	Dafra	*Echino chillia coloruain**	+	+	-	+	-	+
31	Waika baria	*Hibiscus aescalentus**	+	+	+	+	-	+
32	Ummaliha	*Dinebra Arabica**	+	+	-	+	-	+
33	Halfa	*Desmestachya cynosuroidea^*	+	-	-	+	-	-
34	KhadraeBagar	*B. marrubifolia^*	-	+	-	+	-	+
35	Adar	*Sorghum spp^*	+	-	+	+	-	+
36	Tifa	*Urocboa trichopus**	-	+	-	+	-	-

Classification by life cycle *quickly disappearing, ^long living, + found, - not found. Source: Fieldwork (2005).

Zone A has the highest occurrence of grass species, followed by zones B and C respectively. Out of the 36 counted grass species in zone A, 12 species were not found by a percent of 33.3%. In zone B, out of the 36 counted grass species, 16 species were not found by a percent of 44.4% while zone C has little grass occurrence and out of the 36 counted Acacia species,21 species were not found by a percent of 58.3%. Zonal differences by such percents scored 11.1% between A and B, 25% between A and C and 13.9%.between B and C. These zonal differences increase eastwards and even became lesser, away from the Blue Nile. Table 2 also shows that, if any grass species is not found in any particular zone, it would be found in another one indicating that, complete disappearance of a specified type is not detected in the study area. The most disappearing grass species are the ephemeral ones by 66.6% (8 out of 12) in zone A, 62.5% in zone B (10 out of 16) and 80.9% (17 out of 21) in zone C. In addition to being palatable they were not left to mature in order to regenerate seed for the coming rainy season.

Distribution of ephemeral and long living grasses

Table 3. Occurrence of Acacia by cover, frequency, abundance, density and life cycle in western Butana plain.

Local name	Latin name	Cover, frequency, density and abundance by zone												By total area			
		Cover			Frequency			Abundance			Density			Cover	Frequency	Abundance	Density
		A	B	C	A	B	C	A	B	C	A	B	C				
Sunut	*A. nilotica ^*	2.8	-	-	18.1	-	-	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	29.8	41.8	5.9	1.4	4.6	5.4	0.2	1.9	19.3	42.6	4.5	1.9
Talieh	*A. seyal vor fistula^*	1.6	-	-	18.1	-	-	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^*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Haraz	*A. albida**	0.8	-	-	18.1	-	-	1.0	-	-	0.2	-	-	0.4	4.2	1.0	0.04
Laaot	*A. nobica**	9.8	4.2	8.2	63.6	20.0	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^*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Higlig	*Balanites aegyptiaca**	4.0	10.2	-	63.6	41.6	-	1.4	1.2	-	0.9	0.5	-	4.8	36.2	1.3	0.5
Sarah	*Maerua crassifolia^*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tundub	*Capparis deciduas^*	1.6	2.5	2.0	18.1	12.5	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	-	8.3	8.3	-	1.0	1.0	-	0.08	0.08	0.6	6.4	1.0	0.06
Ushar	*Calotropis procera*	2.0	-	9.2	27.2	-	25.0	1.6	-	3.0	0.5	-	0.8	3.0	51.6	2.8	0.3
Dahsier	*I. oblongifolia*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Senna Mecca	*Cassina senna*	34.0	47.5	27.5	100.0	62.5	66.6	7.5	3.7	3.4	7.5	3.2	2.3	36.0	72.3	4.8	3.5
Hanzal	*Citrullus colocynthis*	2.0	2.5	16.1	18.1	8.3	6.6	2.5	1.5	3.0	0.5	0.1	0.5	3.0	12.8	2.3	0.3
Um Shuaika	*Guiera senegalensis*	13.5	22.0	21.4	90.9	41.6	41.6	3.3	2.6	4.2	3.0	1.0	1.8	19.6	53.2	3.2	1.7
Irig Agrab	*Clitoria tematea*	3.3	3.4	-	18.1	12.5	-	2.6	1.3	-	0.7	0.2	--	3.6	12.8	2.0	0.3
Gudaim	*Geruria tanar*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Life cycle: *Succulent, ^non-succulent, ''evergreen. Source: Fieldwork (2005).

show more occurrence and diversity in the clayey soil other than sandy and loamy ones (Table 2). Out of 36 counted grass types in the clayey soil, only 3 were not there (8.3%). This contrast sandy and loamy soils which have lost as much as 26 (72.2%) and 15 (41.7%) grass types respectively. The percent difference on occurrence of grass by soil type is 63.9% between clayey and sandy, 33.4% between clayey and loamy, while it is 30.5% between sandy and loamy. These findings generally agree on with the earlier finding on zonal distribution of *Acacia* species (Table 1). However, the majority of the disappeared grass species are the ephemeral ones. Out of the 3 species disappeared in the clayey soil, 2 (66.6%) were ephemeral, 22 (85%) out of 26 on the sandy soil and 11 (73.3%) out of 15 in the loamy soil.

Furthermore, spatial patterns of vegetation distribution are depicted by coverage, frequency, abundance and density of *Acacia* species in the study area (Table 3). Although *Acacia* species seem low in zone A, excepting forests close to the Blue Nile, they were recorded highest in this zone compared to the other two zones. In zone A, *A. tortillis vor raddiana* ranked high by 24.1% cover, 90.9% frequency, 5.9 abundance and 5.4 density. Fieldwork indicated that (Figure 4), Acacia trees which were dominating in the past in this zone were not only *A. tortillis vor raddiana*, but they were *Acacia nobica, Acacia albida, B. aegyptiaca* and all of *Acacia seuel vor seyal, Maerua crassifolia, Acacia 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

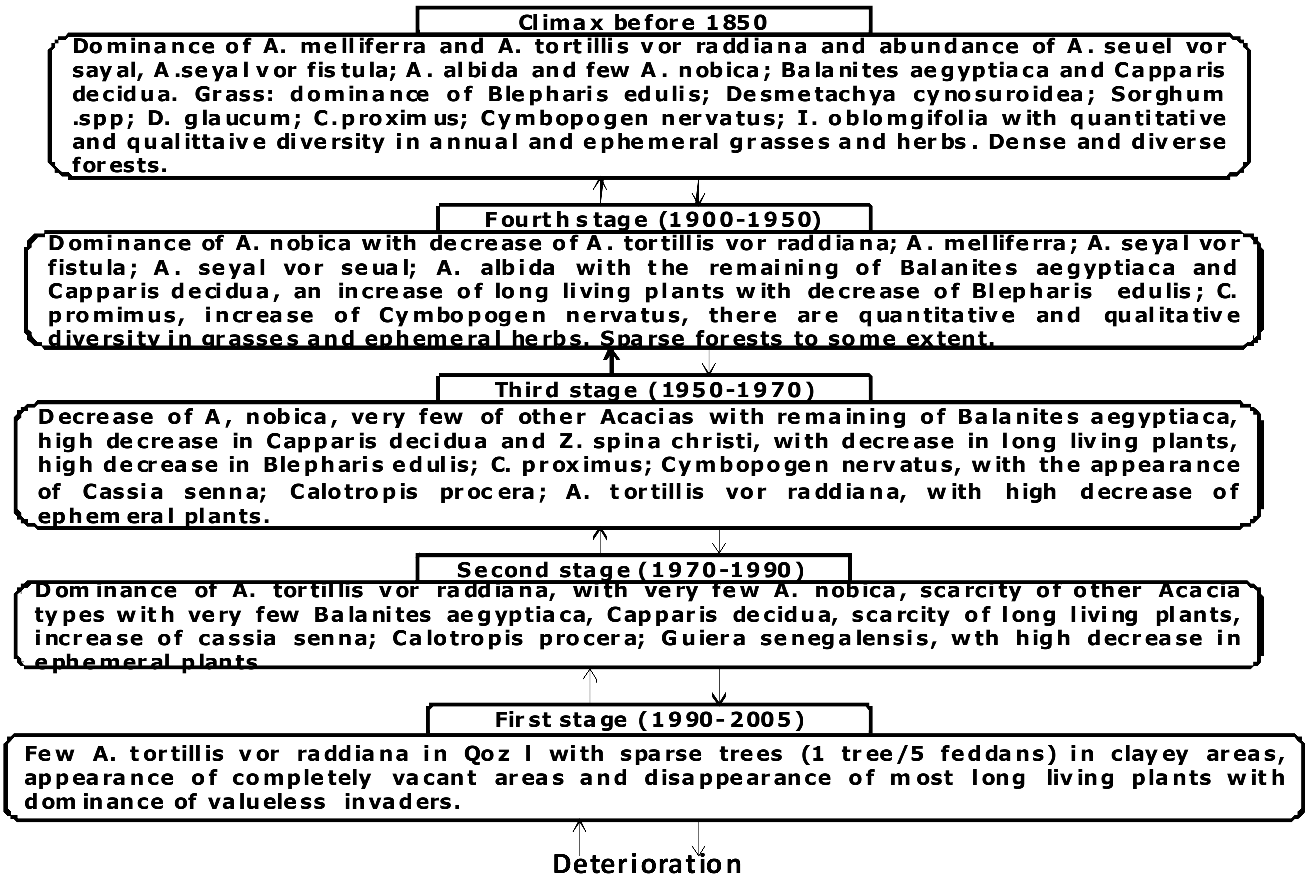

Figure 4. Stages of vegetation dynamic in western Butana plain, Sudan. Source: Fieldwork (2005).

5% covering. *A. tortillis vor raddiana and B. aegyptiaca, Ziziphus spina Christi, A. seyel vor sayal, M. crassifolia, A. nobica and Capparis deciduas* are very rare while they were dominant in the past (Figure 4). *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, *Blepharisedulis, Arianthema pentandra, Cymbopogen nervatus and Pennisetum pdystachyum* have deeply deteriorated. Senna Mecca *Cassina senna* is the most frequent, abundant and densest and similarly covering huge parts of the study area. In plant coverage, frequency and density, *A. albida* was the lowest besides A. *seyal vor fistula* and *A. nilotica* (Table 3). Concerning plant abundance, *A. albida* is accompanied by *Z. spina Christi* and *A. mellifera* as less abundant *Acacia* species. This is an indication to excessive demand on *A. albida* trees compared to other ones due to its valuable characteristics as traditional building material.

Vegetation dynamic

Based on studies carried out from 1928 to 1999 and the fieldwork (2005), there was a climax for vegetation in the study area prior to 1850, while its dynamic took place through four successive stages (Fig.4). 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 *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

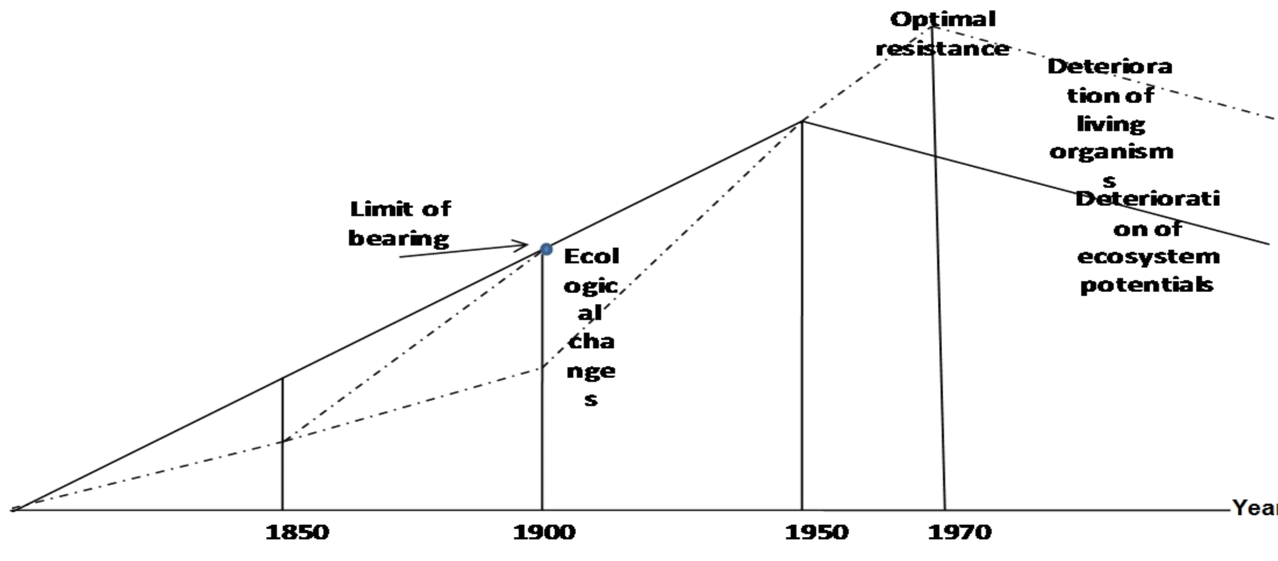

Figure 5. Ecosystem carrying capacity and vegetation resistance. Source: Fieldwork (2005).

(1966) indicated *A. melifera, A. nobica, A. tortillis vor raddiana, A. sayel vor seyal* and *C. deciduas* as dominating and they were the 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 to 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. There is high decrease in *C. decidua* and *Z. spina christi*, with decrease in long living plants, high decrease in *B. edulis*, *Carausius proximus*, *C. nervatus*, with the appearance of *C. senna*, *Calotropis procera*, *A. tortillis vor raddiana,* with high decrease of ephemeral plants. During the 'second' stage from 1970 through 1990, there was one Acacia type dominating, while there was scarcity of major other types. According to our 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 *C. procera* 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).

From 1990 to 2005, the 'first' stage, dominance of Acacia and grasses decrease eastwards by zone and soil type from the Blue Nile and there was few A. *tortillis vor raddiana* in Qoz I with sparse trees (1 tree/5 feddans) in clayey areas, appearance of completely vacant areas and disappearance of most long living plants (Tables 1, 2, and 3) with dominance of valueless invaders. These successive stages of vegetation dynamics (Figure 4) correspond with the study area's ecosystem carrying capacity to support vegetation (Figure 5). The ecosystem carrying capacity of the study area was adequate to support vegetation up to the year 1900. Following that year, environmental changes spanning over 50 years had affected that ecosystem carrying capacity up to 1950. From 1950, that ecosystem carrying capacity collapsed but, vegetation continued to resist these ecological changes up to 1970. Since 1970 vegetation severely deteriorated.

Environmental and human factors influencing vegetation dynamic in the study area

Ecological disequilibrium in the study area had started directly after 1970 (Figure 5) and manifested by declining ecosystem carrying capacity and deterioration of Acacia. Environmental factors responsible for Acacia deterioration in the study area could include successive droughts, declining rainfall, retreat of isohyets and temperature rising as well as human pressures. Climatic variability

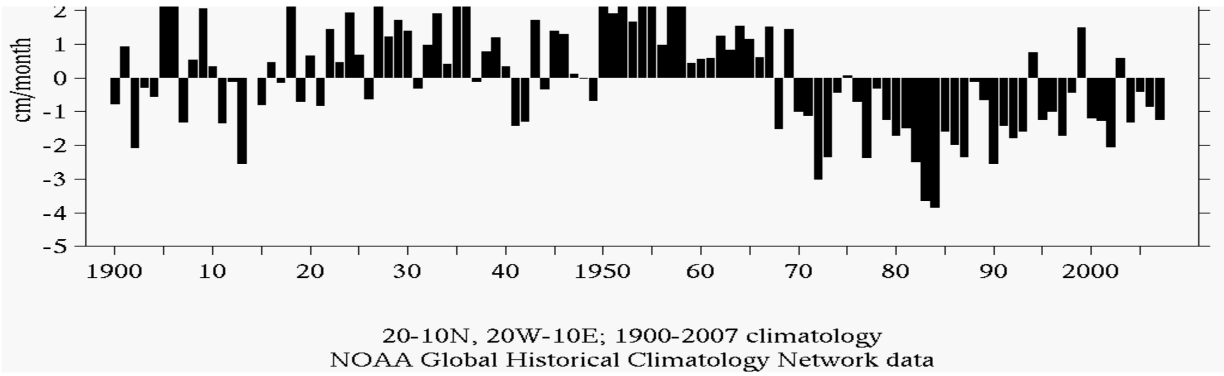

Figure 6. Precipitation anomalies in the Sahel, 1900 to 2007. Source: Stewart, (2009), oceanography in the 21st century – An online textbook. URL: http// oceanworld.tamu.edu/ocean.401.

has an impact on the Acacia dynamics (Joaquín and Gabriel, 2000) and 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). However, average annual rainfall for the period 1922 through to 1994 was 408.9 mm (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 1945 to 2007 for three index meteorological stations, two on the Nile corridor and one on the Red Sea coast. He indicated that 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 (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 south-wards 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 to 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.

In addition, Hulme et al. (1989) 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 6). At the same time, a period of severe drought led to large-scale environmental degradation.

Results of soil physical analysis in the study area (Table 4) shows that, Goz elahamda and Qoz Elsayalat locations have more sand content which is decreasing with increasing depth. In Kumur soil is silty in the low depth and becomes more clayey with increasing depth. In Um Shanig and Tragma soils tend towards clayey content. Soils of El Fardoas and Um Shamoun are more disaggregated clayey and sand content is increasing and they are subject to erosion and transportation by wind and water. Clay content increase with increasing depth in

Table 4. Physical characteristics of soil of the study area.

Location	Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Zone
	0-25	20	10	70	
Goz elahamda	26-50	22	13	65	A
	50-75	30	15	55	
	0-25	70	20	10	
Tragma	26-50	80	15	5	A
	50-75	80	15	5	
	0-25	40	50	10	
Kumur	26-50	50	45	5	A
	50-75	65	30	5	
	0-25	65	20	15	
Um Shanig	26-50	70	20	10	B
	50-75	85	10	5	
	0-25	15	10	75	
Goz Elsayalat	26-50	25	5	70	B
	50-75	30	5	65	
	0-25	60	20	20	
El Fardoas	26-50	75	20	10	C
	50-75	70	25	5	
	0-25	60	10	30	
Wd Shamoun	26-50	65	5	30	C
	50-75	70	5	25	

Source: Fieldwork (2005).

the study area indicating sand encroachment and areas close to the Blur Nile which have sand content close to those areas away from the Blue Nile. Silt content is independent of increasing depth and fluctuate while sand is decreasing with depth increasing.

The general evaluation of physical properties indicate that many soil locations are subject to erosion by water and winds particularly eastern parts like Wd Shamoun and El Fardoas. Also, some elements have been transported to other areas according to slope as in eastern parts of the study area. Cases of solidified soils have been detected specially on Goz and clayey plain in eastern parts of the study area. Change is detected in soil texture and its horizons especially in northern and eastern parts by increase in sand content where some locations have been buried up to 100 cm. What is called dead land starts to appear in the study area where no vegetation grows, all of which influence plant life. Chemical analysis depicted appearance of compact salty soils, ultra alkalinity; poor organic matter content. There is increase in Na rate; pH range was 8 to 8.5 tending towards more alkalinity and soil is more alkaline in Um Shanig and Tragma by exceeding 8.5. The values of E.C. did not exceed normal values indicated under methodology, but some increasing values are noticed in Um Shang and Tragma and E.C at depth of 0 to 45 cm was 0 to 1.1, while at depth of 45 to 90; it was 0 to 1 millimole. Organic carbon was very low as 0.5 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. These soil physical and chemical characteristics are, of course, have influenced vegetation dynamic in the study area.

As far as human factors responsible for Acacia deterioration are concerned, our fieldwork results revealed that, tree logging contributed by 40%, agricultural expansions by 30%, grazing by 20%, used as building martial by 7%, other human uses by 2% and for manufacturing agricultural tools by 1%. These factors are being enhanced by growing population where in 1993, population of Butana was 1;076,430 and density was

50.8 /km^2 (MFEP, 1995). This population increased to 13,164,430 in 2005 as calculated by 2.23% annual growth rate provided by (MFEP, 1995). The fieldwork results in 2005 gave an average family size of 6.6, birth rate of 37.7% and migration constituted by 21% to population increase. Age structure depicted children less than 15 years 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 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 (1954) mentioned that, Rufa'a area used to supply Khartoum town by 1000 ton/year of fuel wood in 1936 and that 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 30% for Acacia deterioration. Agriculture started since the 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 3% for Acacia deterioration.

DISCUSSION

Vegetation dynamic in the study area is manifested by:

1. Disappearance of many tree and shrub species and palatable grass species for human and animal and appearance of plant invaders.
2. Changes in chemical and physical properties of the soil, appearance of compact salty soils, ultra alkaline and weakness of organic matter and increase in Na rate.
3. Changes in topography, its distraction, increase of dust storms, damping of valleys and depressions, villages and water reservoirs.
4. Destruction of wild life and its migration to more rich and protected areas.

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. *A. 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). 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) and 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 helps 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. First, 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. Second, the Acacia deterioration may be related to past and concurrent socio-economic conditions that are reflected in agricultural expansion and fuel resources use. Third, 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.

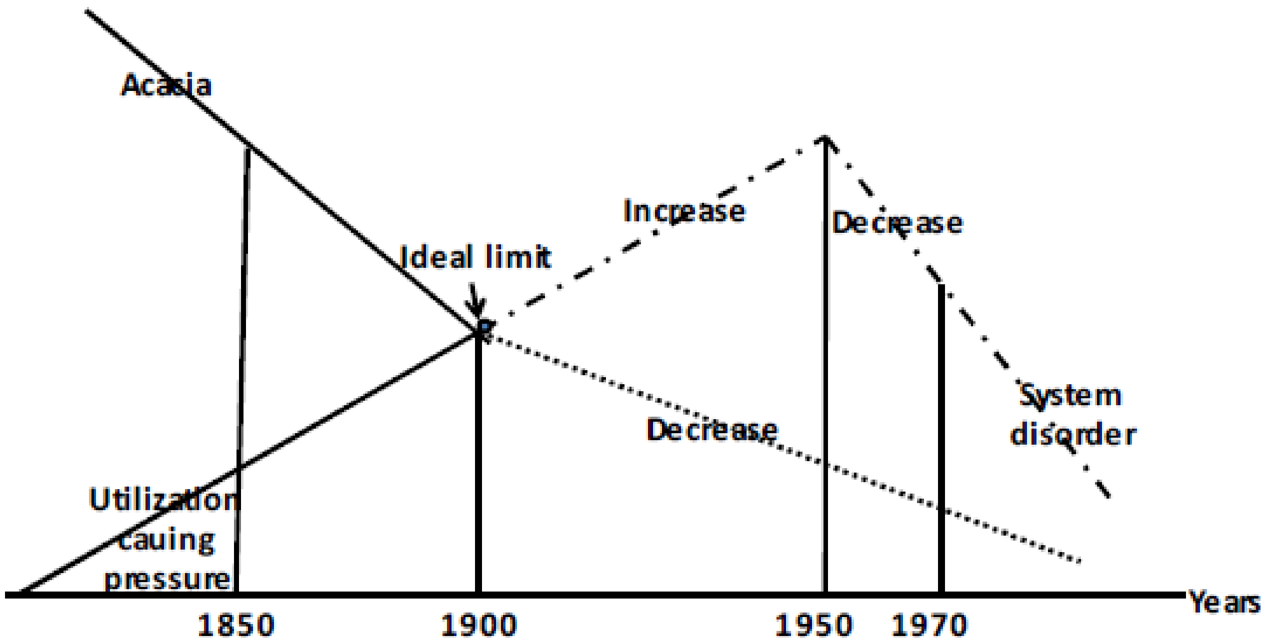

Figure 7. Human exploitation of vegetation as exemplified by *Acacia* species versus its dynamics. Source: Fieldwork (2005).

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 11 did 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 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 15 fold (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 has led to extensive deterioration of *Acacia* in the region which is noticed by Figure (7), which is further supported by Figure (5).

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 (Joaquín 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 the whole 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 II 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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