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Semi-arid Vegetation Pattern, Stability and Suitability to Suppress Sand Movement in Central Sudan

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Abstract: Moving sand that threatens Gezira scheme is the dominant land degradation feature in central Sudan and the front line defence is the sparse scattered natural vegetation of the area. The study aimed to assess the role of this vegetation to suppress drifting sand and to monitor their ability to face the impact of climate change and human activity (deforestation). The dimensions of the sand captured by single tree of dominant species, *Acacia tortilis*, *Leptadenia pyrotechnica*, *Prosopis juliflora* and *Panicum turgidum* were measured and the volumes were calculated. To picture the drought pattern 5-year running means of annual rainfalls (1941-2007) of the study area were calculated and compared with long-term mean. Deforestation was indicated by local community wood consumption in relation to the average woody biomass (in good condition). The results show that scattered trees of the right densities had potentiality to settle drifting sand, but they were subjected to 20 years dry seasons followed by only 4 wet years and now are subjected to a new era of dry spell. This condition is not in favour of the semi-arid vegetation pattern sustainability and a suitable measure to enhance natural regeneration is needed. In addition, the community's wood demand was higher than the resource, where a person would destroy 0.5 ha/year compared to 0.9 ha/year per person available reveals the magnitude of deforestation. Encouragement of farmers to use alternative energy sources and functional application of laws and regulations to protect the existing vegetation remain crucial.

Key words: Combat, deforestation, desertification, drought, Gezira scheme

INTRODUCTION

The effectiveness of a biological barrier to reduce erosion is determined by wind speed and duration, erodibility of the surface, and biomass distribution, that is shape, height and porosity/permeability of the barrier. The wind dislodges transports and deposits particles, this way sorting the surface by selective and non-selective removal and deposition (Bagnold, 1941; Chepil and Woodruff, 1963; Wilson and Cook, 1980). Following Bagnold, quoted by Wilson and Cook (1980), the deposition of transported materials can be through sedimentation, accretion and encroachment. Sedimentation occurs through wind force reduction due to atmospheric changes, deposition containing particles from the three types of motion of saltation, creep and suspension. In accretion, which is due to local decreases in wind force by soil elements, sparse vegetation etc., and hence a decrease in the transportation rate, mainly creeping and saltating particles are deposited. Encroachment is caused by a local increase in the slope of the surface. Here creeping particles only are deposited (Mohammed *et al*., 1995). The effectiveness of sparse vegetation to reduce wind force and protect the surface, a situation more common in dry regions, was thoroughly considered by Nickling and Wolfe (1993). Importance of scattered trees in wind protection in general and wind erosion reduction in particular was recognized (Kainkwa and Stigter, 1994; Stigter *et al*., 1997) and wind problems impact and its biological control in African countries is highly considered (Stigter *et al*., 2002, 2003; Stigter and Al-Amin, 2007).

Vegetation is an important component of the global climate system. In semi-arid of Central Sudan, the climate change and rainfall reduction were aggravated by increasing disturbance of the natural relationship between vegetation and climate (Al-amin, 1999).This sparse vegetation is degraded and the area is under desertification process, particularly drifting sand, which is a real hazard to Gezira Scheme.

The most important causes of land degradation in Sudan, aggravated by drought are: (i) manmade land misuse due to overgrazing, (ii) cultivation of unsuitable and marginal lands, (iii) wood cutting and deforestation, (iv) clearance for cultivation expansion, and (v) declining (rainfed) food production (yields) (Luukkanen *et al*., 1999). It is necessary to protect large tracks of completely or nearly completely desertified land

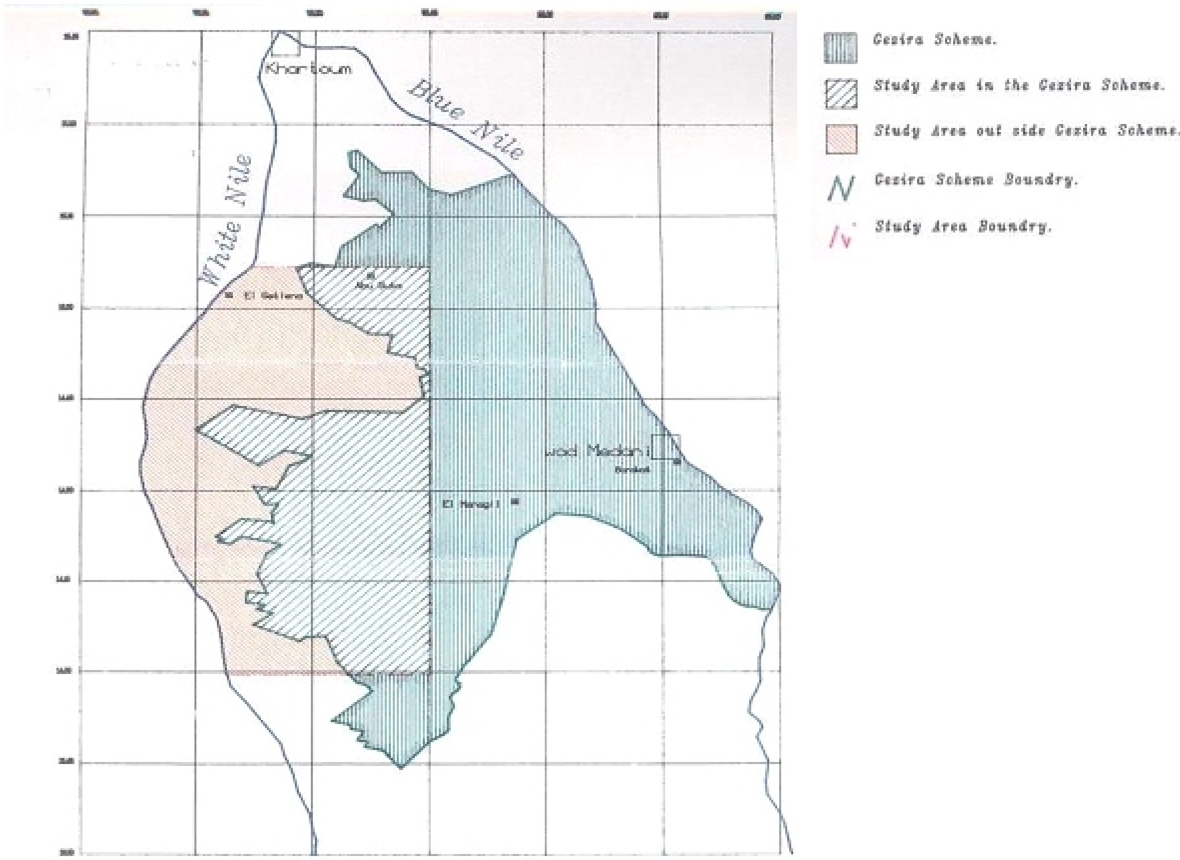

Fig. 1: The study area

in Central Sudan by natural vegetation (Al-Amin *et al.*, 2005, 2006). The role of the natural vegetation to suppress moving sand depends on their vegetative growth (morphology) and the vegetation density. These characters are sensitive for drought and deforestation.

Drought is a temporary, harmful and widespread lack of available water with respect to specific needs (Verstrate, 1989). Shortage of water for example changes the plant population structure towards species more tolerant to water stress or other species that can recover better from drought than the other. In rain fed agriculture, at the border between semi arid and arid climate, farmers expand their land into grazing area during wet season which has to be abandoned after prolong drought. The abandoned area then eroded and becomes as secondary sand source.

The sand measurements reported on here were established to determine the effectiveness of trapping sand by isolated biomass configurations that had been determined to be well establishing under the local conditions (Al-Amin *et al.*, 2006). It aimed to assess the role of this vegetation to suppress drifting sand and to investigate the climate change; these were drought and human activity (deforestation) interaction to find the most effective species and possible means to protect.

MATERIALS AND METHODS

The study area: The site is located at the eastern side of the White Nile, Central Sudan, between latitudes 14º and 15º N and longitude 32º and 33º (Fig. 1), with semi-arid climate. It consists of a vast bare soil without obstacles, with some scattered sand dunes and sand sheet with hummocks around the area. The area has batches vegetation pattern, feature common in semi-arid climate. The dominant wind directions are from south and southwest during summer time and from north and northeast during winter and as a result, the area is subject to blowing sand during these winds. Tow runs of measurements were conducted. The first run was during March- May 1994, with prevailing winds from north and north-west and in June with wind from south and south-west direction. The second run wastaken during January-April 1995 during north and north-west wind and in June 1996 with prevailing winds from south and south-west direction.

Deposited sand measurements: Sand captured by single tree of dominant species, *Acacia tortilis, Leptadenia pyrotechnica*, *Prosopis juliflora* and *Panicum turgidum* were measured and the volumes were calculated, during. Four well established biomass configurations from each species were selected in the field, the tree/grass heights and permeability were visually observed. Tree permeability (considered close to the surface) was rated as follows: I- Highly permeable; II- Moderately permeable and III- Little permeable.

In the first run, the sand settlement was estimated around *Leptadenia pyrotechnica* trees 4, 2.5, 1.66 and 2 meter high (tree No. 1.1.1, 1.1.2, 1.1.3 and 1.1.4) respectively. Single *Prosopis juliflora* trees of 3, 2.5, 4 and 3 m high (tree No. 2.1-2.4). Three single *Panicum turgidum* grass stands of 1.05, 0.9, 0.80 and 0.75 m (tree No. 3.2-3.4 respectively), To estimate the effectiveness of each tree/grass stand to trap sand, the shapes of deposited sand were drawn and their dimensions were measured. Then the total surface area of trapped sand was estimated.In a second season, the general shape of trapped sand was approximated and the surface areas of the drawn shapes were estimated. The height of sand was measured at representative places using a ruler, and average heights were used to calculate the volume of trapped sand. To compare the effectiveness of each species in trapping and settling sand, the following scale rates have been used to classify different species. Sand caught was: 1- None (eroded); 2-Traces; 3- little (small surface); 4- little (but over a large surface); 5- Average; 6- Considerable (surface only); 7- Considerable (surface and volume); 8- Large (surface only); 9- Large (surface and volume) and 10- Very large.

Drought and deforestation: The nearest meteorological station for the study area is Ed-Dueim, from where long term record of the annual rainfall were collected and made available by Sudan Meteorological Services. To picture the drought pattern, 5-year running means of annual rainfalls (1941-2007) of the study area were calculated and compared with long-term mean. Deforestation was indicated by local community wood consumption in relation to the average woody biomass (in good condition). Supportive MSc student dealt with the socio-economic of the study area where 26% of the total villages, at the study area, were examined. The total number of villages in the study area is 20 and total population was about 3240 capita and the family size was 5 person per family. The study area has two types of residents, settled group and resettled. The later were displaced people who moved from their desertified regions (Kordofan and Darfur) during drought and famine in the period 1980-1984. 6% of the population (202 respondents) were taken, 60 respondents from resettled and 142 from settled group where 41% of the whole respondents were women. The income, type of fuel used and amount of wood consumed by a family were investigated from which amount consumed per person were calculated, then the amount of forest area could be destroyed by person was estimated and compared with the available forest land per person (made available from literature).

RESULTS AND DISCUSSION

Sand trapping capability of the natural vegetation: The size and permeability of tree No. 1.1.2 explain the appreciable windward deposition, which was larger or comparable to that deposited leeward during north/northeast wind. During south/south westIn June 1994, after change of wind direction, this bush had a bit more sandy (total) surface left windward as it had formerly leeward, but the total settled was less. In tree No. 1.1.1, the increase in the permeability of this bush near the surface explains the larger sandy areas at the end (with south and southwest winds) than those of tree No. 1.1.2. (Table 1). Therefore, only very small amounts of sand were deposited and only with north and northeast winds on their leeward side, while the windward side had traces only and was partly eroded. Trees No1.1.3 and 1.1.4, although larger in size, had high permeability and their shapes explain the erosion of the area in the vicinity, windward, and the little sand accumulating leeward, only in the beginning with north and northeast winds, while with south and southwest winds only little was accumulating windward.

Table 1: Sand trapping capacity of *Leptadenia pyrotechnica*, depending on its height, its permeability and the wind direction

Tree description				Sand caught		
Tree No.	Height (m)	Permeability	Wind direction	Leeward	Windward	Inside tree
1.1.2	2.50	III	N/E*	10	9	10
			S/W**	2	6	10
1.1.1	4.00	III	N/E	9	3	9
			S/W	1	8	9
1.1.3	1.65	I	N/E	3	2	nothing
			S/W	1	4	
1.1.4	2.00	I	N/E	2	1	nothing
			S/W	1	1	

*: N/E = north and northeast wind direction; **: S/W = south and southwest wind direction

Table 2: Sand trapping capacity of *Prosopis juliflora*, depending on its height, its permeability and the wind direction

Tree description				Sand caught		
Tree No.	Height (m)	Permeability	Wind direction	Leeward	Windward	Inside tree
2.1	2.5	II	N/E*	9	3	9
			S/W**	2	1	9
2.2	3	II	N/E	10	3	nothing
			S/W	10	4	
2.3	4	I	N/E	5	1	nothing
			S/W	6	1	
2.4	Cluster	I	N/E	10	10	10
			S/W	10	10	10

*: N/E = north and northeast wind direction; **: S/W = south and southwest wind direction

Table 3: Sand trapping capability of *Panicum turgidum*, depending on its height, its permeability and the wind direction

Tree description				Sand caught		
Tree No.	Height (m)	Permeability	Wind direction	Leeward	Windward	Inside tree
3.1	1.05 m	III	N/E*	9	1	nothing
			S/W**	9	1	
3.2	0.9 m	II	N/E	6	2	nothing
			S/W	1	1	
3.3	0.8m	II	N/E	6	2	nothing
			S/W	3	1	
3.4	Cluster	III	N/E	9	1	nothing
			S/W	9	1	

*: N/E = north and northeast wind direction; **: S/W = south and southwest wind direction

In the case of *Prosopis* sp., trees 2.1 and 2.2 were to a certain extent similar in both size and porosity (permeability), although their shapes were different. For both, the windward sides were accumulating little sand. On the other hand, both trees were during northern winds accumulating large amount of sand leeward (Table 2). When the wind direction changed, tree No. 2.1 behaved very differently from 2.2. The former had almost nothing left and the latter accumulated more than double the sandy surface, in both cases leeward, so for different seasons at different sides. This may be explained if the angle of wind is considered and the upwind landscape of both trees was taken into account. Tree No. 2.3 was different in shape from tree 2.1 and tree 2.2 above, as well as in porosity and biomass distribution. Tree no. 2.3 was very permeable near the surface and the crown sloped away upwards with rather a high angle, which may explain the windward erosion instead of deposition, and the lower leeward depositions. The measurements around the fourth tree, No.2.4 (cluster), showed how effective this species is when found in a group.

Panicum turgidum was very small and rather impermeable, particularly near the surface, while its permeability increases sideward and upwards compared to the other species selected. During north wind the amount of sand of stand No. 3.1 was larger than that of 3.2, on leeward. Windward for both trees the area was eroded (Table 3). As the wind direction changed (south wind), all deposits of stand No. 3.2 had been removed (windward was eroded) while some of that of stand No. 3.1 remained, which again can be attributed to the smaller permeability of tree 3.1. Stand No. 3.3 was very small.

Plate 1: *Acacia tortilis*

The amount of deposited sand was high compared to its dimensions but overall may not be very effective in an environment of high flow rates. However, many of them could be very effective. This was very nicely demonstrated by cluster No. 3.4, which was a bush of grass like 3.1 with some other tiny bushes like 3.3 in its vicinity

The results show that *Acacia tortilis* even it grows into large tree does not capture moving sand, which can be attributed to its morphology (Plate 1). *Leptadenia pyrotechnica* (Plate 2a-c) species have capability to capture sand and provide relatively good protection against consequences from erosion. *Prosopis juliflora* (Plate 3) species have the capability of holding moving sand and protecting the area well, but they are unfortunately targeted by a government policy of

Plate 2a: *Leptadenia pyrotechnica*

Plate 2b: *Leptadenia pyrotechnica*

Plate 2c: *Leptadenia pyrotechnica*

complete eradication because they are considered too aggressive, which could will be an advantage under this condition conditions. *Panicum turgidum* (Plate 4) has high efficiency of collecting and capturing moving sand relative to their small sizes, in particular when found in association and advantage is that they are naturally present in relative abundance.

Drought pattern: 5-average running means indicate annual rainfall above the long-term main for the early decades (1941-1961), then long dry period for almost two

Plate 3: *Prosopis juliflora*

Plate 4: *Panicum turgidum*

Table 4: Distribution of respondents by type of fuel

	Settled		Resettled		All subject	
Income in $	No.	%	No.	%	No.	%
Wood	43	30	56	93	99	49
Charcoal	4	3	0	0	4	2
Wood and Charcoal	72	51	4	7	76	38
Kerosene		0	0	0	0	00
Electricity		0	0	0	0	00
Gas	0	0	0	0	0	0
Wood, Charcoal, gas	14	10	0	0	14	7
Charcoal and other	7	5	0	0	7	4
Wood ,Kerosene and Charcoal	2	1	0	0	2	1
Total	142	100	60	100	202	100

decades (1962-1979) interrupted by very short wet period (1976-1979). The second dry spell was between 1980 to 1991, that was almost a decade followed by wet period for about 5 wet year (1994-1999), from that to the end of data (2007) the area was experienced another dry period. The annual rainfall trend shows long dry period followed by short wet period, it seems that during early forties and sixties the wet period was longer (almost double) than eighties and nineties with short dry period (Fig. 2).

Deforestation: Table 4 shows that main occupation was casual labour (28%) for resettled to 55% for settled group. 31% of settled were farmer and governmental officer. All

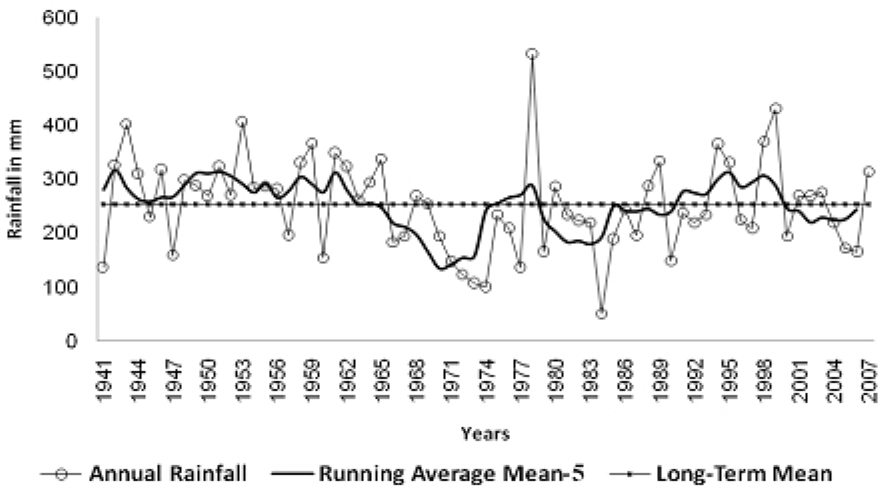

Fig. 2: Annual rainfall trends for the study area

Table 5: Distribution of respondents by income

	Settled		Resettled		All subject	
Income in $	No.	%	No.	%	No.	%
Low >100	90	63	42	70	132	65
Middle (100-133)	36	25	17	28		26
High (133-300)	16	12	1	2		9
Total	142	100	60	100		100

population suffered from poverty since the income for 90% of settled and almost all of resettled villagers was from below 180-100$ per year (Table 5). Poverty is the main factor that shapes the vulnerability of the human communities in the study area. They have low income, limited resources and lack skill for high earning jobs therefore resorted to immediately possible income resources, namely cutting trees for firewood and charcoal making. At the study area, the wood consumption for a family of 5 persons was 1.23 bundle/day and 0.89 bundle/day for settled and resettled group, respectively. The weight of the bundle is about 7 kg this means that average wood consumption per person per day is around 1.4 kg. In tropic wood consumption for domestic uses is about one kg per person per day. For average woody biomass (500-1000 kg/ha), a person destroys at least half hectare every year if there is no regeneration. Assuming regeneration every second year, each family of 5 person would destroy more than 1 ha/year (LeHouerou's, 1977 cited in Goude, 1990). In central Sudan, the available forestland per person is about 0.9 ha (World Bank, 1986). This implies that wood demand will soon be greater than available forestland in the study area, which reveals the magnitude of deforestation and future hazards, particularly in arid area subject to blowing sand and drought.

CONCLUSION

The results show that scattered trees of the right densities had potentiality to settle drifting sand, but they were subjected to 20 years dry seasons followed by only 4 wet years and now are subjected to a new era of dry spell. This condition is not in favour of the semi-arid vegetation pattern sustainability and a suitable measure to enhance natural regeneration is needed. In addition the community's wood demand was higher than the resource, where a person would destroy 0.5 ha/year compared to 0.9 ha/year per person available reveals the magnitude of deforestation. Encouragement of farmers to use alternative energy sources and functional application of laws and regulations to protect the existing vegetation remain crucial. Therefore, the protection of all existing vegetation, regeneration of local vegetation and use of all means to increase the numbers of scattered trees and grass stands for protection, with functional application of laws and regulations are recommended.

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