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Drifting Sand Endangering Gezira Irrigation Scheme in Central Sudan, History and Impact

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Abstract: This study was carried out at Gezira area in Central Sudan that lies between longitude 32° and 32° 50′ and latitude 14˚ and 14°15′. It dealt with the history of the sand, its source and rate of movement towards Gezira scheme and monitored the trend of blowing sand over 10 years. To find out the origin of drifting sand, sand samples were collected from the sandy area west to the White Nile and from the study area. Heavy minerals analysis was carried out on these samples and its mineral assemblage was matched with the mineral of both sand at western bank of the White Nile and the Blue Nile. To picture the trend of moving sand, Multispectral Scanning System (MSS, 1975), and Thematic Map (TM, 1985) were used to delineate the sandy areas and their trend with time. The rate of the blowing sand was quantified using Bottemane sand catcher. The heavy mineral results showed that the mineral of the drifting sand in the study area are quite similar to the sand of sand dune west to the White Nile indicating the same origin. The sand was transported by southern and southwestern winds through a corridor across the White Nile to its eastern bank, where the most likely water transported sediment was reworked by wind and transported further to the northeast. Between 1972 and 1985, the sand invaded the area at an average rate of about 30 km^2 per year and map of 1985 demonstrated a corridor across the White Nile for sand movement. The area was subject to 7 days sand storm with an average of 35 kg/m.d and in summer time, the average amount of moving sand was about 28 kg/m.d. These results demonstrated the future hazard of drifting sand and its impact, which has to be tackled immediately to protect Gezira scheme.

Key words: Sand, gezira, sand catcher, sand mineralogy.

1. Introduction

In Sudan, many cultivated areas, both irrigated and rain fed, are subject to land degradation. A most serious hazard is sand movement, which is pronounced in Northern Nile, Northern Kordofan, Northern Darfur, White Nile, Khartoum and Gezira states. In these areas, fertile soil, seasonal water courses and irrigation canals had already been buried under sand [1-2]. In Gezira scheme, some land had already been abandoned due to the sand [3]. In central Sudan (the White Nile State), the area is vulnerable to wind erosion. The equatorial forest belt shifted southwards and consequently, the vegetation cover reduced, precipitation decreased and the major rivers dwindled, exposing their steep valleys [4-6]. Susceptibility of a soil to erosion is an integrated response related to the inherent soil properties, properties of the erosion agent and their interaction with climate. Driving forces of the erosion agent opposed by the soil resistant forces determine the soil erosion and the soil resistant forces are a function of physical and hydrological, chemical and mineralogical, and soil profile characteristics [7].

The land use pattern in the study area revealed the extent and the risk of soil degradation, which if continue might change the area into real desert. The sand dunes area alternated with non-cultivated land (poor grazing) and as approaching the Gezira scheme, the dunes become less and the area gradually changes into a continuation of non-cultivated (poor grazing) land alternated with rain fed-cultivated areas. Further,

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eastward, towards the Gezira scheme, traditional rainfed agriculture was the dominant land use type. This land use pattern where sand dunes engulfing the rainfed cultivated areas, reveal the risk of wind erosion and the future hazard of continuing disturbances of balances between the natural resources, human activities and drought [8]. These dunes were considered of Blue Nile paleochannels deposits, for two reasons: (1) the sands in the area are similar to the present Blue Nile bed loads in texture and (2) both the sand of the dunes and the sand in the main channel of the Blue Nile have the same mineral compositions [4]. Mineralogical investigation carried out on two sand samples, one from Goz sand in Kordofan and the second from the Blue Nile channel (riverbed) showed the dissimilarity between the two samples, the sand of the Blue Nile is of volcanic origin [5]. Adamson [9] supported this idea excluded the other possibilities of being borne by northerly winds or being brought by a diversion of the White Nile eastwards and rejected long distance wind transport of sand from Kordofan. Contributions from the west bank close to the White Nile are not excluded by the above data.

Gezira scheme nowadays is threatened by drifting sand, from the study area, where some land in the scheme had already been abandoned due to the sand [3]. Thorough investigations were carried out by TTMI –project, assessed the situation and suitable and possible measures to protect and mitigate the hazard and helps farmers in the endangered areas [10-13]. The following research was the baseline study for those investigations. It aimed to identify the main source(s) of the drifting sand presently blown over the area, its trend over 10 years and rate of movement.

2. Materials and Methods

To assess the possible contribution of windblown sand to the area under study, sand samples from sand dunes west and east of the White Nile were collected throughout the study area and analyzed. The samples were sifted through sieves with the following order of aperture: 0.425 mm; 0.250 mm; 0.125 mm; 0.063 mm 0.031 mm. The weight of each fraction was expressed as percentage of the original samples. The highly magnetic minerals were separated from non-magnetic ones using a simple hand magnet. The non-magnetic fractions again were subject to heavy liquid separation where heavy fractions were separated from the light ones. As a result, the fractions were separated into light fractions and heavy fractions. The heavy (liquid) residue obtained from the heavy liquid separation was then again separated by electromagnetic separation. Here the moderately and weakly magnetic fractions were separated from non-magnetic ones using an electromagnet. Then the following three groups were identified: (1) Highly magnetic fraction, which were neglected (very small amount); (2) Non-magnetic fraction which can be separated into heavy fraction (such as limonite, tourmaline, epodite group and garnet group) and light fraction (such as quartz feldspars group, beryle); (3) Moderately and weakly electromagnetic fractions. The heavy mineral composition of the sand from the study area was matched with the mineral of the sand of the White Nile and the Blue Nile.

For temporal variation of sandy area, Land sat Multispectral Scanning System (MSS) image dated 07 Nov. of years 1975 and Thematic Map image dated 07 Nov. 1985 were visually interpreted followed by field survey for ground truth data. The main elements used are colour or tone, texture and pattern. Four classes were considered for land cover classification that were: Alluvial plain, sand sheet and hummocks, alluvial plain with thin sand sheet and sand dune and then maps were developed. From the maps, the total area for each class was calculated and the general trends of the classes were depicted.

Bottemanne sand catcher (calibrated at the study site) was used in the field to quantify the moving sand and its duration. Ten sand catchers were distributed on one line perpendicular to the prevailing wind, 50 m apart to a length of 500 m, in an area without any vegetation and topographical obstacle or building. The sand samples were collected, weighed and corrected to the actual amount of moving sand using the results of the calibration and the area of one meter (7 cm is diameter of the cup of the catcher) as follows:

$$Q_{m}=\frac{Q_{c}}{0.07CE} \quad (1)$$

$$Q_{m}=14.3*\frac{Q_{c}}{CE} \quad (2)$$

Taking the sand catcher efficiency (as 0.028 [14]), then Eq. (3) gives:

$$Q_{m}=510*Q_{c} \quad (3)$$

Where:

Q_m = amount of moving sand in kg per meter /day(kg/m.d);

Q_c = amount of sand caught in the catcher in Kg/m.d;

CE = catcher efficiency.

3. Results and Discussion

3.1 Source of the Drifting Sand

The heavy mineral of the sand of the riverbed of Blue Nile origin is characterized by hornblende -augite-epodite association and basalt fragment and titaniferous which indicate volcanic origin [5]. The heavy minerals analysis (Table 1) showed that the blowing sand was dominated by apatite, epodite, garnet, hornblende, ilmenite, rutile, tourmaline and zircon, which are of metamorphic origin (sandstones mineral assemblage) therefore are not of Blue Nile origin. They are quite similar in composition of components to the mineral assemblage of sand from the area west from and close to the White Nile (Table 1) indicating the possible source of the drifting sand in the area to be sand dune areas west and close to the White Nile. The sand transported by water, through a wind corridor (Fig. 2), deposited on the shore and reworked by wind and carried further northeast to the study area and towards the Gezira scheme.

3.2 Quantification of Drifting Sand

Table 2 displays the area in km^2 of each class of the maps developed by image interpretation of 1975 and 1985. Fig. 1 shows the dominant class was alluvial plain and the areas of the other class were comparable. In 1985, the picture was opposite, the class of sand sheet with hummocks was the dominant followed by sand dune area and disappearance of the alluvial plain with thin sand sheet (Fig. 2). The remarkable change of the alluvial plain (24 % of the area was invaded by

Table 1 Heavy mineral composition size in mm of sand samples from eastern (samples E) and from western side of the White Nile (samples W).

Location	Ilmenite	Hornblende	Granite	Tourmaline	Zircon	Apatite	Rutile	Epodite
1 E	0.125-0.4	0.05-0.225	0.04	0.2	0.225	0.1-0.2	0.125-0.2	-----------
2 E	0.1-0.45	0.20- 0.4	0.2-0.23	-----------	0.5	0.2	0.35	0.2-0.5
3 E	0.05-0.5	0.075-0.25	0.5	0.15-0.45	0.07-0.12	0.1	0.05-0.35	-----------
4 E	0.05-0.3	0.05-0.3	0.25	0.4	0.07-0.3	0.17	0.3	-----------
5 E	0.075-0.3	0.45	0.3	0.4	0.12-0.35	0.15-0.45	0.25	0.2
6 E	0.05-0.5	0.075-0.75	0.3	0.7	0.12-0.25	-----------	0.075-0.3	-----------
1 W	0-0.325	0.15-0.2	0.2-.23	0.2-0.3	0.1-0.3	0.2	0.25	-----------
2 W	0.05-0.4	0.01-0.45	0.1-0.25	0.15-0.2	0.15-0.25	0.15	0.25	0.15-0.2
3 W	0.05-0.375	0.125-0.2	-----------	0.15-0.2	0.45	0.3	0.1	-----------
4 W	0.05-0.625	0.175-0.45	0.25-0.45	< 0.4	0.25	0.15	-----------	0.25

Table 2 Area measurements of the map's units in km^2 of the areas of the map units for the area between lat. 15° and 14° N and long. 32°45′ and the White Nile.

Year	Alluvial plain	Alluvial plain with sand sheet	Sand sheet and sand hummocks	Sand dune	Total area
1975	1,351	341	293	293	2,208
1985	851	0	1,032	1,032	2,245

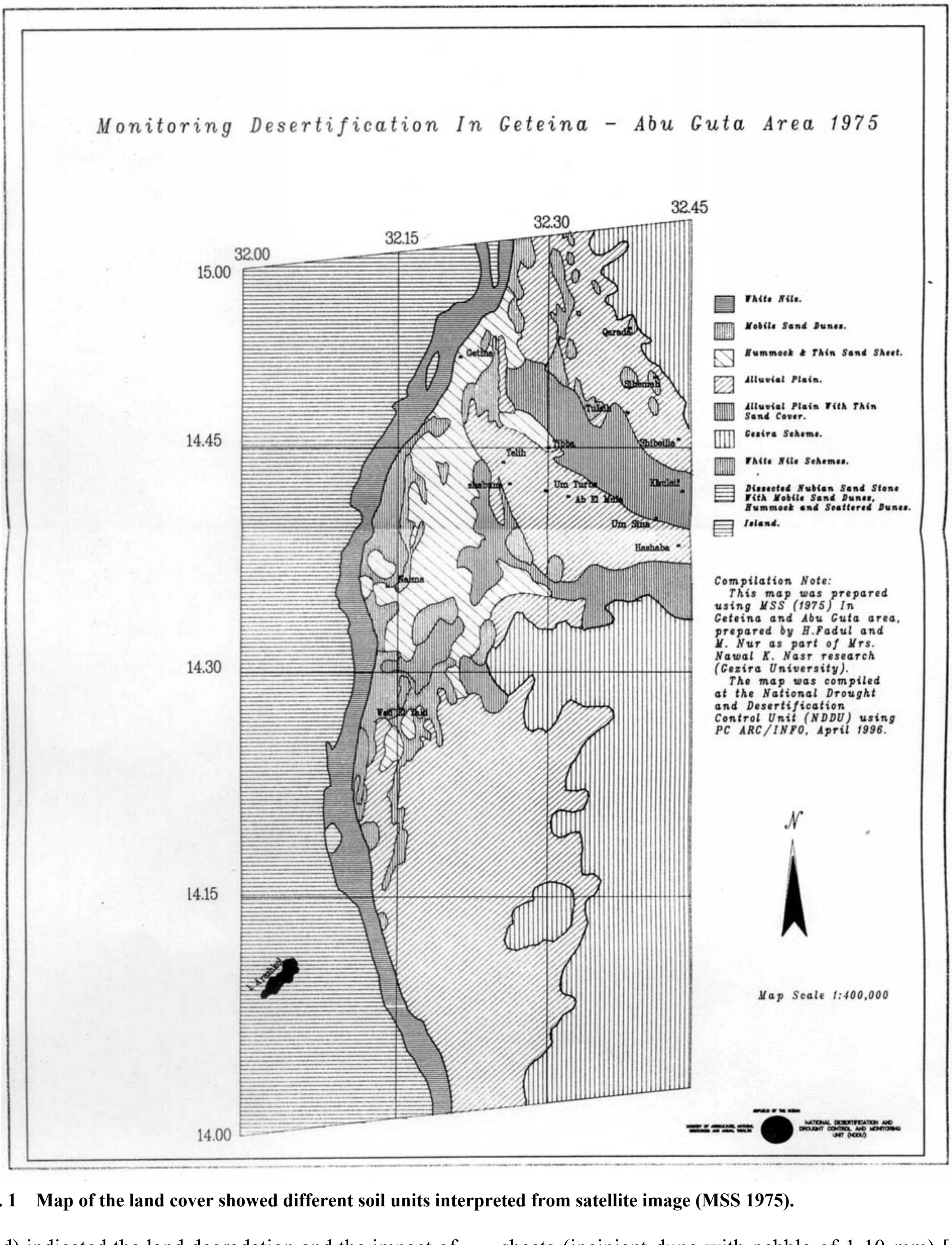

Fig. 1 Map of the land cover showed different soil units interpreted from satellite image (MSS 1975).

sand) indicated the land degradation and the impact of drifting sand. Deflated sandy areas tend to inhibit the growth of dunes, and to encourage the gradual building up of flat or very gentle undulating sand sheets (incipient dune with pebble of 1-10 mm) [15]. On the other hand, diminishing of the unit of alluvial plain with thin sand sheet implies that the pebble surface is acting only as a reservoir: The sand is stored

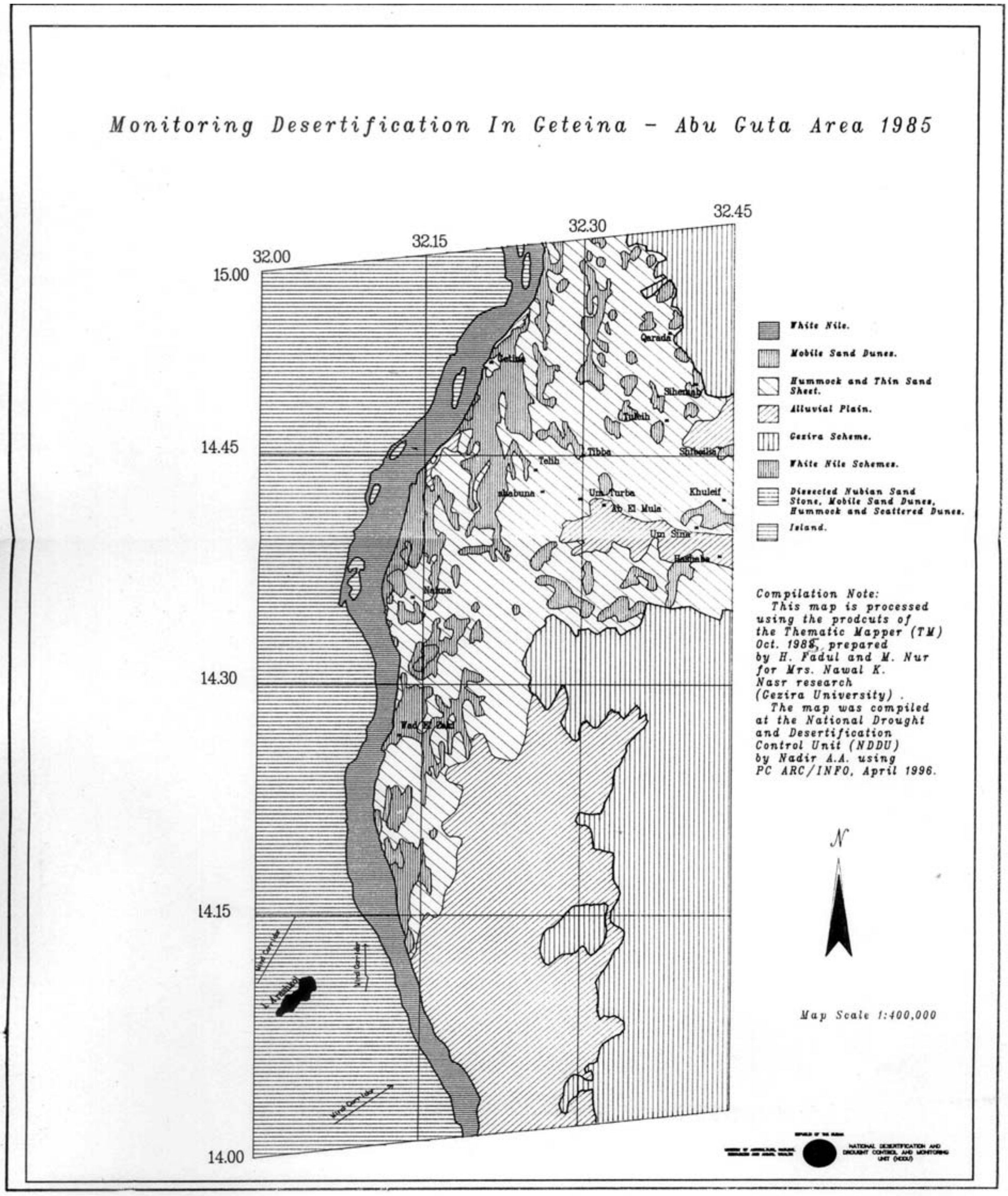

Fig. 2 Map of the land cover showed different soil units interpreted from satellite image (TM, 1985).

during periods of gentle wind, and it is removed from it by sudden wind and sand storms. Fig. 3 shows the general trend of each class percentage relative to the total area with time, revealed the real hazard if the situation and condition in the area continues.

The amount of moving sand per metre width was calculated using equation 3 and results are in Table 3. In March and April 1994, the average amount of moving sand was 30.2 kg/m.d and 27.2 kg/m.d respectively. The storm duration was of an average of

7 days. During the rainy season (June-September 1994) the measurements were affected by the rains as the storms started just a few minutes before the rains in most cases. January to April 1995 was a calm season, no sand movement was observed in the area of measurement. That was also because grasses and creeping plants growing near the area stabilized sands. In June 1996 one storm lasted for 3 days, with the highest average of moving sand of about 58 kg/m.d, while in September the storm duration was rather longer, 10 days with an average of moving sand of 15 kg/m.d. These showed that the wind with sand blowing from the north has longer durations but carries lower quantities while wind with sand from the south is shorter in duration but carries huge amounts of sand (Table 3).

4. Conclusion

The sand primary source could be the sand dunes area west to the White Nile (north Kordofan). The desertified area of north Kordofan, where sands are accumulating southwards from the Libya desert are exposed to the southwester wind, during summer time, which transports the sand through corridors from north Kordofan to the area. A resistance of unknown magnitude to this flow of sand is formed by the White Nile that has to be crossed. The future hazard of moving sand is a real serious problem, and drifting sand has to be suppressed from its primary source far away from Gezira scheme border. Protection of Gezira scheme depends on the protection of the natural scattered, vegetation, which is drought sensitive, and subject to destruction.

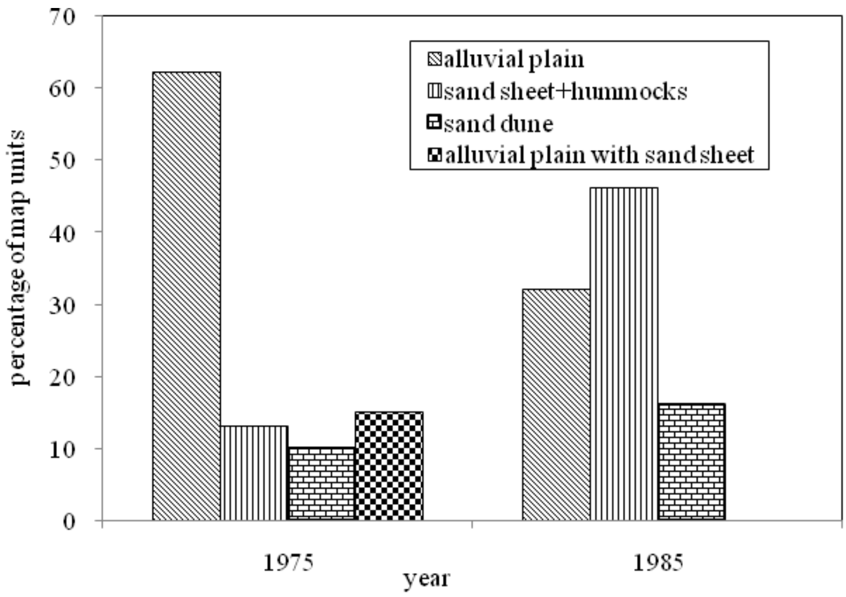

Fig. 3 Units area percentage of each class relative to the total area of the map.

Table 3 Duration (days) and quantity of drifting sand (kg) per meter width and per day.

Date	No. of samples	Duration (days)	Average amount caught (gm)	Q_m	Otal amount passing (kg/100 m)
March 94	1	7	321.4	22	55
April 94	1	8	309.5	18.4	52.3
	2	7	439.8	29.9	
	3	5	349.2	33.3	
September 95	1	10	312	14.9	14.9
April 95	0	0	0	0	The area was well vegetated and no sand was moving
October 95	0	0	0	0	The area was well vegetated and no sand was moving

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