Sand Dune Stabilization for Increased Biological Productivity in the Arid Parts of Kenya.

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Introduction

Surrounding the productive highlands of Kenya is an arch of semi-arid and arid land. It occupies 80% of the total landmass, supports 20% of human population, and at least 80% of livestock in the country. In general, it displays the classic characteristics of drylands throughout Africa. Low and variable precipitation, high evaporation rates, sparse vegetation, and widely spaced rivers with seasonal flows, loose dry sandy soils, and periods of strong winds. Wind erosion is a serious problem in such areas (Skidmore, 1988). It has been observed that wind erosion has become an increasing important problem for vegetation and crop production in the Sahel because of its damaging effects on vegetation and loss of fertile top soil (Taylor-Powell, 1991). Despite this fact, our quantitative knowledge about the amount of soil removed from areas under continuous pastoral use, how much soil can be stabilized if natural range regeneration is encouraged, and associated aboveground biomass production in all cases as a result of wind erosion is very limited.

Increase in human and livestock population, establishment of administrative boundaries, and land demarcation in the high potential areas has led to over exploitation of available resources leading to increased wind erosion. The amount of dust arising from the Sahel zone has been reported to be around or above 270 million tons per year which corresponds to a loss of 30 mm per m^2 per year or a layer of 20mm over the entire area (Stahr *et al* 1996). Problems due to poor land management, i.e. utilization without conservation measures and rest periods, are common. The unprotected soil may be eroded and the area becomes bare and dusty, a situation characteristic of the study area.

Studies of sand dune stabilization have been carried out in the Sahel (Lusigi, 1984; El Maghraby, 1996; Gupta, 1996) among other areas in the world. In all cases, the use of plastic sheets, plant residues, bitumen, and elemental sulphur lead to improved chemical properties of dune sand. This was reflected in significant increases in plant height, number of branches, crown cover and crown volume. As a result, the shifting sands were sharply decreased by 47.2 to 96.7% in the stabilized areas. Planting of natural wind breaks/shelter belts, stabilization of sand dunes, minimum tillage, and conservation of rainwater are some of the measures found effective in checking wind erosion.

In Kenya large areas of woodland and shrubland around settlement areas are in danger of drying out due to lack of adequate recruitment. An area which was originally woodland has been turned into a man made desert due to excessive felling of trees and overgrazing. Overstocking of animals has led to localized destruction of range resources especially when the human population increased both in total numbers and in localized densities due to settlement and sendantarisation. While nomadic use of the range allows for rest and recovery between grazing period, this has not been possible in a settled situation and the vegetation has been depleted. Continuous grazing and trampling lead to changes in plant composition and the reduction of palatable species, which have flourished, in addition to enhancing accelerated wind erosion. The objective of the study was to determine vegetation primary biomass production under wind erosion conditions, quantify the influence of recruited vegetation community in sand dune stabilization, and determine the amount of soil loss in both cases.

Materials and methods

The study was conducted between 1991 and 1992 in Kargi location, Marsabit District within a radius of 80 km. The area is situated in ecological zone VI with mean annual rainfall of 290 mm and potential evaporation of more than 2500 mm per year. Data on vegetation aboveground biomass and effect on sand dune stabilization was determined from four sites, exclosures (120 m by 100m), and three transects (set out at 1, 4 and 10 km from the exclosure respectively.) The exclosures acted as a reference point. Each treatment was replicated twice within a radius of 80 km in the areas under continuous grazing. Data for aboveground biomass was determined within one of the 100 x 120 m exclosures and in the other treatments. This was carried out by clipping $1m^2$ quadrat along 1 x 100 m belt transect replicated four times in each of the four treatments, every three months. The samples were oven dried at 60^0 C for 24 hours and weighed to give dry weight in kg/ha/yr. Plant cover measurements were determined by paced transect method along 1 x 100 m transect. Soil loss and sand dune stabilization was monitored using twenty six erosion pins (1m long, 5 mm thick) randomly installed in the four treatments. This was carried out after every three months from the changes in height of the exposed erosion pins within each treatment. Wind speed in meters per day was obtained from anemometer situated in a central position. An average wind speed was thus related to a certain amount of soil lost. Five to six soil samples within an area of $1m^2$ were taken to a depth of 10 cm using 5 cm diameter split tube (Chepil, 1957) for analysis. Replicate samples were mixed, dried and pushed to pass through 2 mm sieve. Soil analysis was determined using standard procedures in National laboratories (Hinga *et al* 1980). Jensen (1976) reported that, highly erosive sand grains vary in size approximately between 0.05 and 0.5 mm in diameter.

Results and discussion

During the study period total annual rainfall in Kargi was 182.9 and 227.7 mm for 1991 and 1992 respectively. Table I shows mean textural class in the upper 10 cm in all the treatments as well as soil deposition (+), removal (-) and equivalent soil loss in mm. Mean annual production of primary biomass kg/ha/yr, and percent plant cover for the two years. 1991/92 mean annual wind velocity was 5 m/s. In general, wind velocity of about 6.5 m/s initiates soil movement for heterogeneous virgin material although an average of 4.5 m per second may be more common for grazed sand dunes (Jensen, 1976).

The average sand content in the sampled layer was lower within the exclosures than in the other treatments over the study period. The exclosure had higher clay content than the other plots. Within the exclosure, clay particles aggregate into large sizes after deposition. The large sizes resist abrasive break-down more than silty aggregates. Similar results were obtained by Chepil (1957) while researching on characteristics of dust storms in the United States of America. Sorting by wind may possibly cause changes in soil textural class. Although the results do not represent many years of monitoring, the sites (Table I) have soil with two different soil textural classes within the same area. Loamy sand to sandy loam within the enclosure. This agrees with Touber (1991) who found the soils in the area being an association of excessively drained, shallow to moderately deep, reddish calcareous, slightly gravelly, loamy sand to sandy loamy soils. Acacia-Indigofera vegetation community acts as windbreak or screen to reduce wind velocity and hence deposition on both windward and leeward sides of the vegetation.

Table I Mean annual production of aboveground biomass kg/ha/yr, plant cover %, effect on deposition/removal t/ha/yr, equivalent mm/h/yr and textural class in the upper 10 cm of the soil in each treatment.

Treatment	soil deposition (+) removal (-) t/ha/yr	equivalent mm/yr	Textural class	Primary Biomass kg/ha/yr	plant cover (%)
Exclosure	**+ 446.5**	**+ 63.8**	**SL/SL**	**784.5**	**67.8**
1 km[a]	**- 72.3**	**- 10.3**	**S**	**100.5**	**22.7**
4 km[b]	**- 112.0**	**- 16**	**S**	**66.2**	**12.7**
10 km[c]	**- 101.2**	**- 14.5**	**S**	**308.3**	**27.0**
Mean of a, b, & c	**- 95**	**- 13.5**	**S**	**158.3**	**20.8**

Biomass production and vegetation cover.

Dry matter results showed that natural vegetation produced 67.8% and 784.5 kg/ha/yr of vegetation cover and aboveground biomass respectively compared with an average 20.8%, and 158.3 kg/ha/yr from other unprotected pastoral grazing areas. This compares favourably with 1982/83 data by Lusigi *et al*. 1986 attained when evaluating the effects of exclosures in rangeland productivity. He found that aboveground biomass production under continuous grazing conditions was lower by a factor of 75% than that recorded within the exclosures where utilization by livestock has been excluded for range recovery.

Sand dune stabilization and soil loss.

Due to low vegetation cover (Table 1) wind erosion is dominant in the open areas where sand drifts at a rate of 95 t/ha/yr (13.5mm) compared with within the exclosure where soil is deposited at a rate of 446.5 t/ha/yr (63.8mm). This explains the common occurrence of dunes in areas where some vegetative cover exist. During the study period Acacia species represented large shrubs while Indigofera species, Sporoborus species represented small shrubs and grasses respectively. The high rate of soil removal was due to high wind velocities coupled by poor vegetative cover which acted as windbreak outside natural regeneration exclosures. Winds created large clouds of fine dust particles which were deposited when the vegetation or rock outcrop reduced the velocity. That occurs when an area is closed for at least four years (Lusigi *et al.* 1986).

When our results are compared with Requier (1978) standard land degradation values, it is observed that soil losses were high falling in the 51-200 t/ha/yr class. The results of the other studies (Gupta, 1979) to determine the status of moisture was in some sand dunes of the Indian desert, particularly with an objective of arresting their movement through afforestation showed 80-120 mm soil moisture stored in 1.8 m profile of unstabilized sand dunes even during the peak period of evaporation. Gachimbi (1996) also associated an upsurge of vegetation cover in stabilized dunes with high water retention despite high evapotranspiration and mineralization of organic matter.

Conclusion

It can be concluded that wind erosion is a serious problem affecting biological productivity in the arid lands. Wind erosion in Northern Kenya reduces aboveground biomass production by at least 80%. Aboveground biomass growth under natural regeneration leads to, though short lived sand deposition at a rate of 63 mm /yr and soil losses of 13.5mm/ha/yr under pastoral land use practices. The results showed that sand dune stabilization by use of wind breaks can be effective in erosion control in arid zones. Various other mechanical, chemical and vegetative measures need to be tested for sand drift under Kenyan conditions.

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