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Drift Sand Reclamation of Walvis Bay, South West Africa

by

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INTRODUCTION

Walvis Bay is situated on the West Coast of Africa in the delta of the Kuiseb River. Protective measures against sand encroachment and floods were respectively initiated in 1950 and 1961 as the town was flooded during 1934. During the same year dune sand was piled up to roof height of buildings (Keet, unpublished data).

The danger of the town being flooded again was prevented during 1961 when a 7 km long wall was built across the Northern arm of the Kuiseb River (Stengel, 1963). Although various measures have been undertaken to protect the town against sand encroachment these methods have not yet been entirely satisfactory.

The sand dunes of the Namib Desert cover an area of approximately 28 000 km^2 and extend in an unbroken sea of sand for 460 km from Walvis Bay to Lüderitz. The width of the dune area varies from 50 to 120 km.

The dune area which threatens Walvis Bay is situated to the south of the town between the lagoon and the Atlantic Ocean on the Western boundary and the southern arm of the Kuiseb River on the Eastern and Southern boundary.

HISTORICAL REVIEW

Due to the ever encroaching sand from the desert and the threat of inundation during floods, the original houses in Walvis Bay were built on piles. As the threat of sand and water continued, Keet (1927) inter alia, recommended the building of sea-walls in the form of soil dykes, to protect the town against floods.

After the flood in 1934 various indigenous plant species became established in the Kuiseb River. This river is only occasionally in flood resulting in the salinity of the underground water to increase gradually till a level is reached which kills part of the vegetation.

As the influx of sand continued to be a problem in the town, Keet (unpublished data) recommended the erection of barrier dunes with the aid of poles. During 1950 the Water Affairs branch of the South-West African Administration commenced with the erection of 12.8 km pole barriers with the object of establishing two artificial dunes to protect the town and access roads against encroaching sand.

The sand reclamation work that was done by the Water Affairs branch is described by Stengel (1963). Since May 1970 this work is being conducted by the Department of Forestry.

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PROBLEMS ENCOUNTERED

The local problems encountered in establishing a vegetative cover on the dune sands can only be mentioned briefly, and are:
(1) The average annual rainfall in the Namib Desert near Walvis Bay is less than 11 mm per annum;
(2) due to the aridity and high salinity (ohm R 60°F = 238) of the dune sand and the salinity of the wet silt (ohm R 60°F = 8) only plants with a very high resistance to saline conditions will be able to thrive here;
(3) the prevailing S to SW winds which have an average velocity of 20.2 km/h and an average annual frequency of 3 435;
(4) that the precipitation of the saline fog on the dune sand and silt flats increases the salinity of the soil and kills any vegetation not resistant to the salt on its leaves;
(5) the only water which is available in unlimited volumes for irrigation is sea-water, of which the electroconductivity in micromohms/cm at 20°C is 47.5 (EC x 10^3), and underground water of which the conductivity ranges from 35 to 250 (EC x 10^3).

METHODS EMPLOYED IN COMBATING DRIFT SAND PROBLEMS

POLE BARRIERS. The pole barriers (Fig. 1), which have been used since 1950, have been employed with a fair amount of success. Although large volumes of sand have been deposited at these barriers, the sand has by no means been stabilised. To ensure that these barriers are continually effective, they must be lifted regularly.

Fig. 1. Erecting a pole barrier.

A major problem encountered at Walvis Bay is that the increased wind velocity between the poles removes the sand in this area forming a V-shaped gully. When this gully is approximately 20 to 30 cm deep the poles topple resulting in the adjoining poles following.

To eliminate this damage (Fig. 2), a solution of 1 part Surfasol in 40 parts water has been sprayed with a watering-can in a 15 cm wide strip on the windward side against, and between, the poles in the barrier. This solution dries rapidly leaving a hard layer which, to a large extent, prevents wind damage to the barriers.

Fig. 2. Severe damage done to the barriers by strong winds.

DUNE STABILIZATION. Since 1964 the Municipality of Walvis Bay has stabilised the dunes nearest the residential and industrial areas with either gravel, old motor-car oil or ash from the local power station.

While the gravel stabilised areas are the most durable, the cost of R0-35 ($ 0.46) per m^2 for covering the sand with a 2.5 cm layer, is prohibitive. Areas that have been covered with coal-ash since 1964 have been suitably stabilised. The ash must have a thickness of about 1.5 cm. The total cost involved when stabilising sand with ash is R0-07 ($ 0.093) per m^2.

The most economical method employed in dune stabilisation is to spray the sand with old motor-car oil. The cost of spraying the sand with oil is R0-05 ($ 0.067) per m^2. The depth of penetration must be at least 5 - 10 mm. The minimum rate of application is 10 m^3 oil/ha.

A higher rate of application must be applied in all areas liable to severe wind erosion eg. at the sides of barchan dunes. Regular maintenance to oil sprayed surfaces is essential whereas coal-ash or gravel covered areas are practically maintenance free.

EXPERIMENTAL BARRIERS AND TRIAL PLANTINGS

PLASTIC BARRIERS. Due to the expense involved when erecting pole barriers, experiments were conducted with various plastic barriers to determine whether they would be more economical and easier to erect and to raise than the pole barriers.

The plastic barriers have a thickness of 3 to 5 mm, are 40 and 100 cm in height and have a permeability varying between 30 and 53%. These barriers have yielded disappointing results due to.

(a) the wind undercutting the barriers;
(b) their flabbiness. They tend to curl resulting in a decreased height of the barrier;
(c) the extreme difficulty experienced in raising them if sand has been deposited against them;
(d) their tendency to tear.

VEGETATION

GENERAL. Though it will be more expensive to stabilise dunes with vegetation than spraying them with, e.g. oil, such areas will not only be more agreeable to the community in an otherwise desolate area, but will stabilise additional dust and sand being blown onto them.

Experimental results indicate that the dune sand can be stabilised with vegetation provided the area between the plants are stabilised for about 2 years to enable the plants to become wellestablished and if the plants are irrigated with water with a low salinity. As non-hardy plants are detrimentally affected by the adverse weather and soil conditions prevailing at Walvis Bay, only hardy plants, which are also resistant to saline conditions, may thrive under these conditions.

As only 6 800 m^3 reclaimed sewage water will be availablemonthly for irrigation, only about 10 to 12 ha can be irrigated. To utilise this water economically only drought resistant species should be established on the dunes as windbreaks while the irrigation water should preferably be injected into the root zone of the plants. Due to the negligible capillary movement of water in the saline dune sand (P.J.le Roux, unpublished data) and the low rate of evaporation of water from the sand it is estimated that these plants should eventually require an irrigation at about six weekly intervals.

TRIAL PLANTINGS. Since November 1970 various trial plantings have been undertaken at Walvis Bay. All plants were raised in the nursery at Grootfontein with non-saline water.

The various experiments and results obtained are:
(a) Various species were planted at Mile 2 in saline silt with a resistance of 8 ohm. The underground water has a conductivity of 35 000$\mu\Omega$/cm.

The ATRIPLEX NUMMULARIA plants are growing exceptionally well while the following species died: ACACIA ALBIDA; ACACIA CYANOPHYLLA; CASUARINA EQUISETIFOLIA; LAGUNARIA PATERSONII and MYOPORUM SERRATUM.

(b) During August 1971 various plants were planted in 15 cm diameter holes drilled in the silt and filled with dune sand. These holes were drilled to a depth of approximately 2 m till reaching the saline underground water.

The following species are growing exceptionally well: ATRIPLEX BREWERI; A.CANESCENS; A. HALIMUS and A. LENTIFORMIS.

The following species died: ATRIPLEX SEMI-BACCATA; AGROPYRON DISTICHUM; CASUARINA EQUISETIFOLIA; DODONAEA VISCOSA; GALENIA SECUNDA; LOTUS CRETICUS; POLYGONUM EQUISETIFORME and RETAMA ROETAM.

The ATRIPLEX BREWERI and A. LENTIFORMIS seems to be the most promising plants under these conditions.

(c) A number of 45 gallon oil drums were filled with dune sand and irrigated with sea-water to field capacity. The plants were planted in this sand and each drum was irrigated with 9 liter sea-water at weekly intervals since August 1971. Except when these plants were raised in the nursery, they have only been irrigated with sea-water.

The following plants have been irrigated with sea-water and show reasonable growth. The figure in brackets denotes the percentage of the original number of plants still alive: ATRIPLEX BREWERI (100); A. CANESCENS (60); A. HALIMUS (89); A. LENTIFORMIS (100); A. NUMMULARIA (11) and A. SEMI-BACCATA (66).

The following species have shown the best growth: ATRIPLEX BREWERI and ATRIPLEX HALIMUS.

The following species died in this experiment: AGROPYRON DISTICHUM; AMMOPHILA ARENARIA; ARTEMISIA MONOSPERMA; CASUARINA EQUISETIFOLIA; DODONAEA VISCOSA; EHRHARTA VILLOSA; EUCALYPTUS CAMALDULENSIS; GALENIA SECUNDA; LOTUS CRETICUS; MYOPORUM SERRATUM; POLYGONUM EQUISETIFORME; PROSOPIS JULIFLORAE and RETAMA ROETAM.

Further experiments are being conducted with SALSOLA NOLLOTHENSIS plants to determine whether they can be grown in dune sand and irrigated with sea-water.

(d) During December 1971, 590 plants of 21 species were planted within the upper area reached by the waves during high tide. Due to the severe action of the waves during neap tide, all the plants were either washed out by the waves or covered by sand to a depth of 60 cm.

(e) During January 1972, 39 large oil drums were filled with dune sand while each drum was irrigated with 65 liter reclaimed sewage water to drain the excess salt in the sand. One hundred and seventy eight plants of 22 species were planted in this sand. The 5 plants in each drum were irrigated with 4.5 liter reclaimed sewage water at weekly intervals.

All plants which were not scorched are growing exceptionally well. As the salinity content of the sewage water is very low (conductivity = 3 000$\mu\Omega$/cm), it is anticipated that the plants which are irrigated with this water could probably resist a higher salinity content.

Apart from the plants which are shown in Table 1 to be irrigated with reclaimed sewage water, the following species are growing exceptionally well: ATRIPLEX BREWERI; A. CANESCENS; A. LENTIFORMIS; A. NUMMULARIA; A. SEMI-BACCATA; LOTUS CRETICUS; POLYGONUM EQUISETIFORME. These species can withstand a higher salinity level as shown in Table 1.

VEGETATION AND ITS RESISTANCE TO SALINE UNDERGROUND WATER

The distribution of the indigenous vegetation in the Kuiseb River and its estuary is determined by the salinity of the soil and underground water. The salinity levels (conductivity) of this underground water have been recorded and vary from 2 300 to 254 000$\mu\Omega$/cm.

Indigenous vegetation grows proliferously in this area where the conductivity of the underground water varies between 2 300 and 16 000. ARTHROCNEMUM AFFINE and SALSOLA NOLLOTHENSIS can tolerate underground water with a conductivity of 76 500 and 61 000$\mu\Omega$/cm respectively. For comparison, the conductivity of sea-water is 47 500$\mu\Omega$/cm.

The local indigenous species, and the highest recorded conductivity of the underground water which they can tolerate, are presented in Table 1. Except TAMARIX USNEOIDES which is a tree, all other plants are grasses, small succulents or shrubs. The most promising indigenous plant is SALSOLA NOLLOTHENSIS (Fig.3) which continues to grow even if partly covered by sand. This plant has been observed to grow in sand 10 m above the river bed from which it obtains its moisture. It grows to within 120 m of the sea where the saline fog and spray wets the plants and where it is regularly sandblasted.

TABLE 1. Provisional salt tolerance of indigenous and exotic vegetation Walvis Bay

Electrical conductivity recorded (max.) of underground or irrigation water

EC x 10^3	
76.5	ARTHROCNEMUM AFFINE* Moss ex Adamson
61	SALSOLA NOLLOTHENSIS* Aellen
47.5**	ATRIPLEX BREWERI, A. CANESCENS, A. HALIMUS, A. LENTIFORMIS, A. SEMI-BACCATA
35	ATRIPLEX NUMMULARIA, POLYGONUM EQUISETIFORME
30	PHRAGMITES AUSTRALIS* (Cav.) Steudel, TAMARIX USNEOIDES* E. Meyer ex Bunge
29.5	LYCIUM TETRANDUM* L. fil.
24.5	ODYSSEA PAUCINERVIS* (Nees) Stapf
18	ACANTHOSYCIOS HORRIDA* Welw., CAPPARIS HEREROENSIS* Schinz
10	CROTALARIA COLORATA* Schinz, HELIOTROPIUM CURASSAVICUM* L, SCIRPUS DIOICUS* (Kunth) Boeck.
3***	AMMOPHILA ARENARIA, ARTEMISIA MONOSPERMA, CASUARINA EQUISETIFOLIA, EHRHARTA VILLOSA, EUCALYPTUS CAMALDULENSIS, E. GOMPHOCEPHALA, GALENIA SECUNDA, LEPTOSPERMUM LAEVIGATUM, PROSOPIS JULIFLORAE, RETAMA ROETAM

*) Indigenous species (The pH of the groundwater varied between 8.1 and 8.4).
**) Irrigated with seawater.
***) Irrigated with sewage water.

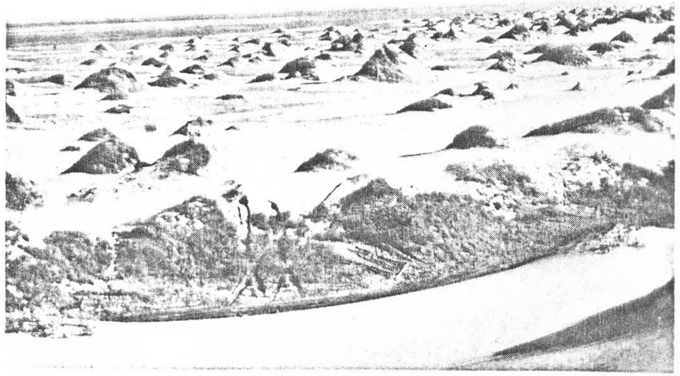

Fig. 3. SALSOLA NOLLOTHENSIS plants with deposited sand having been transported from the coast over the wet silt area in the background.

While certain plant species can resist high salinity levels (Table 1) the salinity of the underground water in extensive areas of the estuary is too high (between 80 000 and 250 000$\mu\Omega$/cm) and can probably not be reclaimed by establishing vegetation.

SUMMARY

The sand dunes of the Namib Desert cover an area of approximately 28 000 km^2. This sand was originally transported from the interior to the Sea mainly by the Orange River, from where it migrated along the shore with the aid of the Benguela current.

The main problems encountered in sand control are:
(a) the low rainfall of 11 mm per annum;
(b) the aridity of the dune sand;
(c) the prevailing strong S to SW winds;
(d) the frequent occurrence of saline fog; and
(e) the high salinity of the soil and underground water.

A few dunes have been successfully stabilised with either gravel, coal-ash or oil.

Pole barriers have been used with success to ensure that large volumes of sand are deposited in predetermined areas. The damage caused to these barriers by the wind had been mainly eliminated by spraying a plastic/water emulsion on the windward side of the barrier.

Various experiments are being conducted to determine the most suitable sand barrier and the tolerance of plant species to local saline conditions. These experiments indicate that:
(a) plastic sand barriers are unsuitable;
(b) five Atriplex species are able to grow in very saline soil (conductivity = 8 ohms) and where the underground water has an EC x 10^3 of 35;
(c) five Atriplex species planted in dune sand and irrigated with undiluted sea water show reasonable growth;
(d) more than 15 plant species will grow in dune sand which is irrigated with reclaimed sewage water with an EC x 10^3 varying between 2 and 3.

Ten indigenous plant species have been collected near Walvis Bay which can tolerate saline underground water with an EC x 10^3 varying between 10 and 67.5.

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