A COMPARATIVE ANALYSIS OF THE SAND-TRAPPING POTENTIAL OF TWO NAMIB DESERT SHRUBS: A CASE-STUDY AT GOBABEB

BY

LOINI-NYANYUKWENI KATOMA

A PROJECT SUBMITTED TO THE DEPARTMENT OF GEOGRAPHY

AT THE UNIVERSITY OF FORT HARE

IN PARTIAL FULFILLMENT OF A BSC HONOURS DEGREE

SUPERVISORS : 1. DR A JACOT GUILLARDMOD

2. PROFESSOR M E MARKER

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DECLARATION

I declare that this dissertation is based on my own original work except where stated and that it has not been submitted for a degree at any other university.

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20/01/89

DATE

ACKNOWLEDGEMENTS

I hereby thank the staff of Desert Ecological Research Unit and the Division of Nature Conservation and Tourism in Namibia for instruments, access to unpublished wind data, facilities and permission to work as a research assistant at Gobabeb. Grateful thanks are due to Dr Mary Seely, Director, Desert Ecological Research Unit, Gobabeb, who provided welcome commentary on verbal presentations of these ideas. Thanks to the research assistants at Gobabeb for their advice and field support.

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I would sincerely like to thank my supervisor Dr Amy Jacot-Guillarmod for her guidance and useful comments on earlier drafts of this report.

The valuable ideas, helpful suggestions and comments from the entire staff of the Geography Department is gratefully acknowledged. A special note of indebtness to Thobeko Soga, Vuyisa Tanga and Simphiwe Mini whom without their assistance the study would not have materialised.

I gratefully acknowledge the assistance of Miss Mary Ann Swartz, who generously handled the typing of the manuscript, especially her time and Christmas leave which she sacrificed to make this study complete.

Grateful thanks are also due to my uncle Matti Gizyenda for financial support to carry out this project. My sincere gratitude to everyone who has contributed directly or indirectly towards the success of this study.

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ABSTRACT

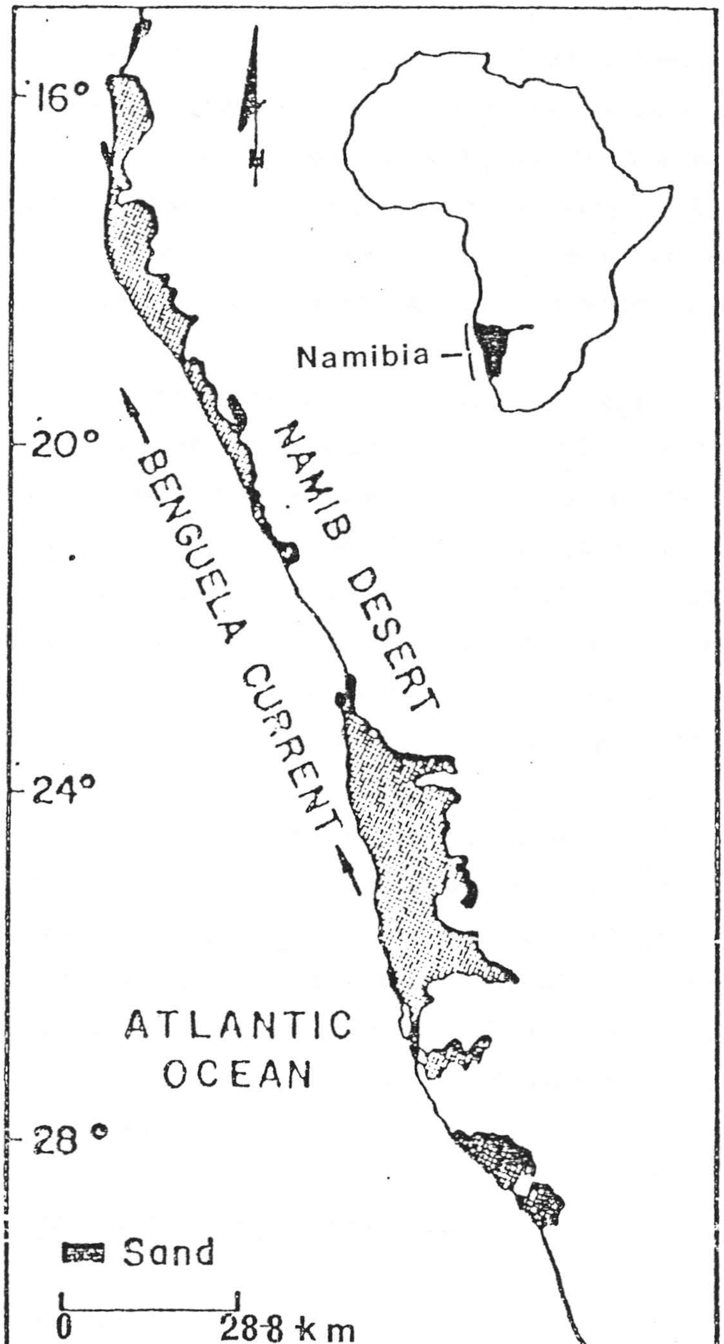
Sand intrusion from the Namib Sand Sea into the Kuiseb River poses a threat to the economical budget and ecological use of the river. This problem is associated with the mobility of sand particles by winds.

The present study reports the results that were obtained from quantitative observations of sand movement around Salvadora persica and !Nara (Acanthosicyos horrida) plant species. This case study was done at Gobabeb in the Central Namib Desert. The sand-trapping potential of the two Namib Desert shrubs were analysed and compared in terms of their effectiveness in enhancing sand accretion. Wind-, humidity-, and sand measurements demonstrate that !Nara (Acanthosicyos horrida) accretes sand more effectively than Salvadora persica.

By assuming that decreasing wind velocity causes sand accretion around the plants, a simple quantitative model of vegetated dune dynamics is postulated. Maintenance of vegetated dune dimension, height and width, is seen as a response to the pattern of the reciprocative behaviour of wind velocity and humidity change. It is recommended that a further investigation should be made to determine which of the two plant species stabilize sand more effectively. Such results may be of use in the monitoring processes of sand movement in deserts.

MAP 1

The coastal Namib Desert of southwestern Africa.



CHAPTER 1

1.0 INTRODUCTION

One of the major architects of desert landforms is sand movement which results in either accumulation as dunes or total deflation that is basically erosive in nature. Sand accretion, which is in actual fact the initial stage in the formation of dunes is normally triggered by obstacles in the way of the moving sand. Where such trigger mechanism is vegetation, usually isolated hummocks or clumps of plants are the result. The researcher was stimulated by such spectacular and intriguing effects of wind on dry desert sand.

The term sand accretion is precisely defined to the satisfaction of the purpose of this study by Bagnold (1941). He defined the term accretion as a mode of deposition. It is the result of sand movement over the growing surface. This action builds up sand aggregate having the greatest possible density. Any disturbance causes such a compact mass to increase its volume. It follows that the mass must behave as a rigid body to any force applied to it. Sand accretion in the context of this study is therefore the potential to accumulate sand.

Sand accretion appears to be enhanced by plants capable of trapping and growing through sand. !Nara shrub (hereafter referred to as Nara) and Salvadora persica are two such plants important in Central Namib. The rate at which individual plants trap sand is unknown, and the relationship between micro-climatic and sand movement is also unknown. The study has been formulated to provide information on these two aspects.

1.1 Aims and objectives of the study

This research proposes:

(a) to analyse the effect of Salvadora persica and Nara plant (Acanthosicyos horrida) in facilitating sand accretion.

(b) to investigate and determine which of the two plants accumulates sand more effectively.

(c) to determine under what micro-climatic conditions most sand accumulates around each plant.

1.2 The Nature of the problem

The researcher spent two months in the Central Namib Desert at the Scientific Research Station situated at Gobabeb. Vegetated dunes attracted the researcher's attention. Among many questions which came into mind were:

- what causes such landform formation?
- what actually happens?
- which grows first? the dune? or the plant? as the plant grows right on top of a dune! Such a behavioural relationship between sand and vegetation raised interest in this study.

This report results from an attempt to explain on a basis of experimental geomorphology some of the many strange phenomena producing, and produced by, the natural accumulation of sand over the desert surface. An additional factor rose out of the commendable efforts of the Kuiseb Environmental Monitoring Project, the Walvis Bay Town Council and other authorities, to develop a method of retarding the dune migration toward the Kuiseb River and the town of Walvis Bay.

Real concern about these matters and the desire to find a more realistic solution to the problem of sand dune migration led to the undertaking of this present study.

It is of foremost importance that this study determines the ability of, and methodology by which, plant retard sand movement. In the long run the feasibility of such plants can be used for preventative measures. Since the time-order for the dune stabilization process by plants begin with sand accretion, it is thus for the purpose of this study to concentrate on this phenomenon.

1.3 The Hypothesis

It is hypothesized that Nara plant (Acanthosicyos horrida) accretes sand more effectively than Salvadora persica. It is further hypothesized that micro-climate around the two plants have an effect on the rate of accumulation.

1.4 The Study Area

1.4.1 Location

The Namib Desert in which these two plants occur is, a relatively narrow tract of land bounded by the South Atlantic Ocean to the west and the Great Escarpment in the east. Map 1 illustrates these. The escarpment with an average plateau altitude of about 1500m above sea level rises to over 2300m at Gamsberg, at about 180km to the east of Walvis Bay. This Desert extends approximately 2000km from the north of the Olifants River in South Africa to the Carunjamba River in southern Angola. The Central Namib is drained by deeply incised Swakop and Kuiseb rivers.

The study area lies within the Central Namib along the Kuiseb River, south of the Desert Ecological Research Institute (DERU) at Gobabeb (23° 34'S, 15° 03'E). Map 2 shows the study area.

1.4.2 Topography and Geology

Gobabeb is located at the confluence of three major ecosystems of the Namib, namely:

- the dunes
- gravel plain and
- the Kuiseb River. Figure 1 illustrates this.

The Kuiseb River valley divides the Central Namib into a sandy desert to the south, and a stony desert to the north. The erg has North-south trending parallel dunes, while the reg is a relatively flat gravel-pediment with inselbergs.

From the Khomas Highland of the Great Escarpment the Kuiseb valley meanders south-west. At Gobabeb the Kuiseb valley has a southeast-northwest trend. Map 3 illustrates the Kuiseb drainage basin. The

THE STUDY AREA AT GOBABEB

MAP 2

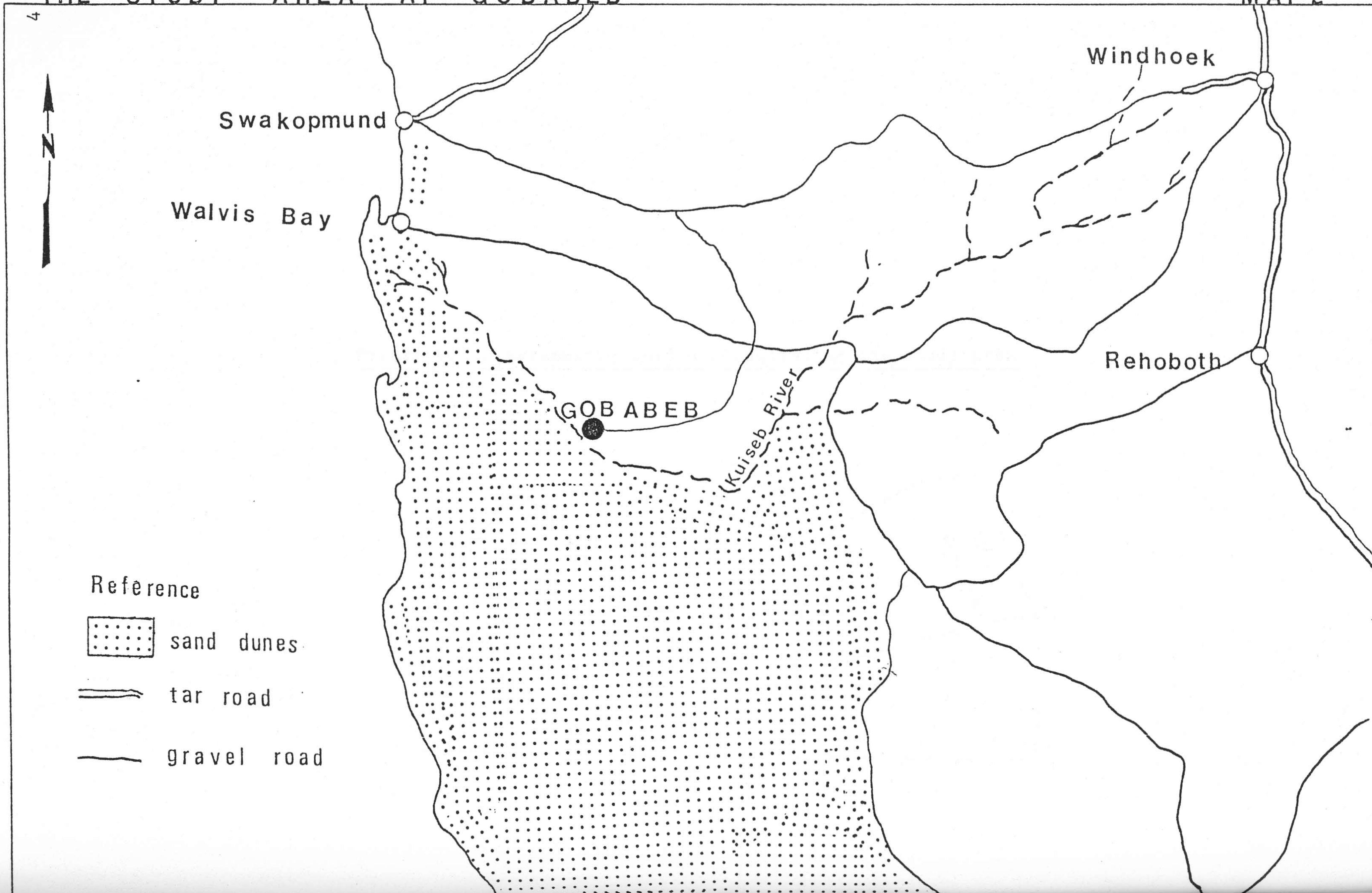
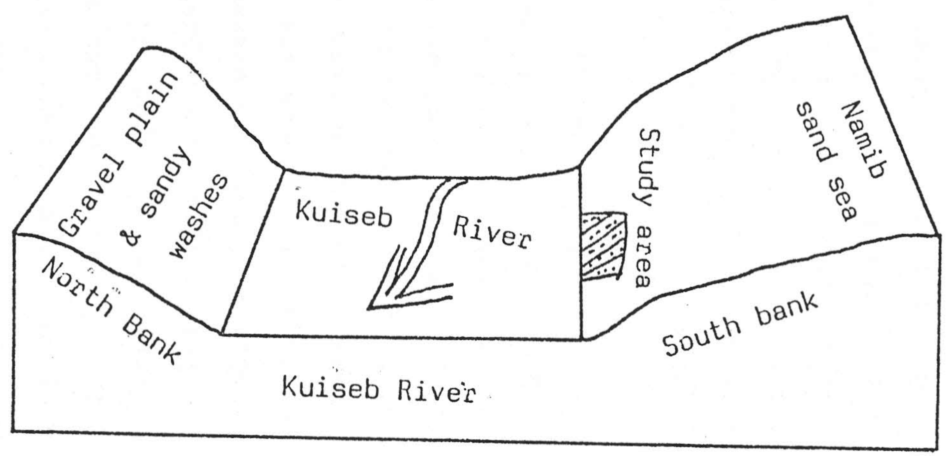


Figure I: Diagrammatic sketch illustrating the study area



increasing deflection of the river course to the north as it approaches the coast is due to sand encroachment into the drainage system.

The geology of the study area is the product of interaction between geomorphological processes and past climatic events acting on bedrock geology of the Kuiseb valley. Geological variation controls local pattern and provides load components. The Basement complex Pre-cambrian rocks are locally concealed by Calcrete sheets and other Cenozoic components. These rocks consist chiefly of the Damara System schists, marbles and salem granite containing a high proportion of quartz and pegmatite (Marker, 1977,p202).

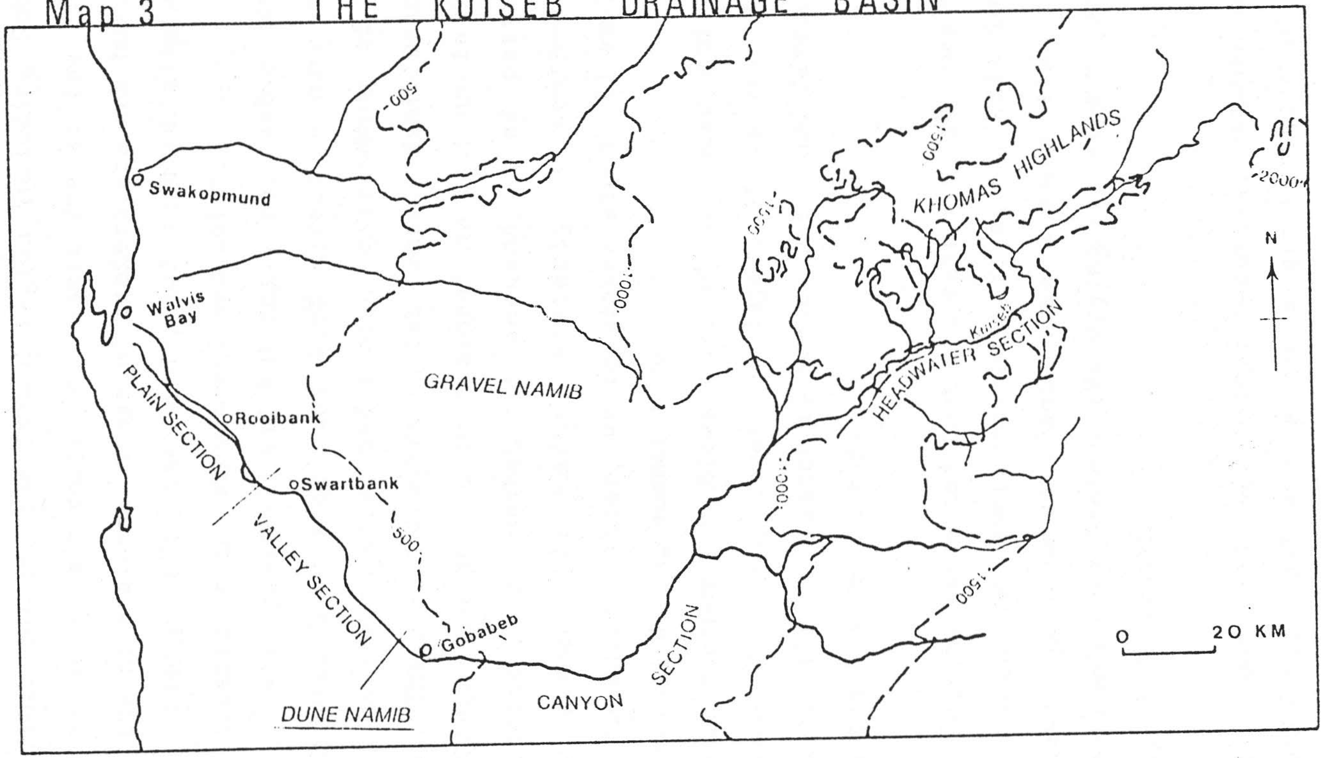
At present the bed material in the middle and lower Kuiseb consists mainly of dune sand and micaceous silts. At Gobabeb the renewed incision has stripped off the sandrock to expose basement schists. The Kuiseb river has adjusted its flow along the geological contact between sand rock and basement complex rocks, (Marker, 1977).

The Namib dune sands are younger than the Namib Formation. Near Gobabeb the dunes rest on a reddish-grey limestone crust that contains large pebbles in the upper layers (Robinson & Seely, 1980, p197). The dune sand which spills over into the Kuiseb Canyon is carried away by intermittent flow. This sand is then incorporated with micaceous materials derived from the country rocks, and from the silts as bed and over bank load (Marker, 1983, p336).

1.4.3 Climate

The Namib, a cool, coastal desert has a mild warm-temperate to subtropical climate (Schulze & McGee, 1978 as quoted by Robinson & Seely, 1980). A desert is an area where potential evaporation is at least twice as great as the average precipation. At Gobabeb it is approximately 200 times greater, as the potential evaporation averages 3500 mm while average precipitation is about 18mm per annum. Since the rainfall is minimal and irregular, fog is an alternative source of moisture. From the coast inland, the average humidity drops sharply while temperature increases rapidly. The maximum air temperature recorded at Gobabeb is 43^{o}C, while surface temperatures

Map 3 THE KUISEB DRAINAGE BASIN



can reach more than 70^{o}C.

Gobabeb is 56 km inland and the coastal influence is obvious and goes still further inland. The inland region including Gobabeb, is also referred to as an alternate fog desert due to the frequent morning fogs and the high diurnal range of temperature and humidity (Robinson & Seely, 1980,p 187). The ecological climate diagram for Gobabeb (Fig.2) illustrates the abovementioned points.
Wind is a very important and extremely noticeable component of the Namib climate. Wind speed and wind direction have thus a strong influence on the physical and biotic environments of the Namib dune ecosystem. The dominant winds in the Central Namib Desert are:
W-SSW, NW-NNE and NE-E with seasonal variations in wind speed and wind direction. At Gobabeb the seasonal wind patterns are also varied. Strong (21 km/hr) easterly to south-easterly winds predominate during winter, while weaker winds (13 km/hr) from N, NW and SW prevail during summer time.
The strong southwester blows most of the year and results in the maintenance of a cool inversion layer. It is this inversion layer that reduces the turbulence necessary for cloud development and rain is prevented from occurring.

Seely (1988,p15) has noted that the east wind follows very soon after any rain which the desert may have received. This implies that the small newly germinated plants have a short time to grow and to establish themselves, before the drying out effects of the east wind terminate their growth.

Wind-blown dead plant and animal material, organic detritus, is an important nutritional source for a great number of Namib-animals. Wind blows fog onshore and transports the detrital material. The position and strength of the anticyclone, the South Atlantic High Pressure System, are the most important determinants of the Namib climate. The Benguela Current and its associated cold water upwelling system are directly influenced by the anticyclonic winds. It is these

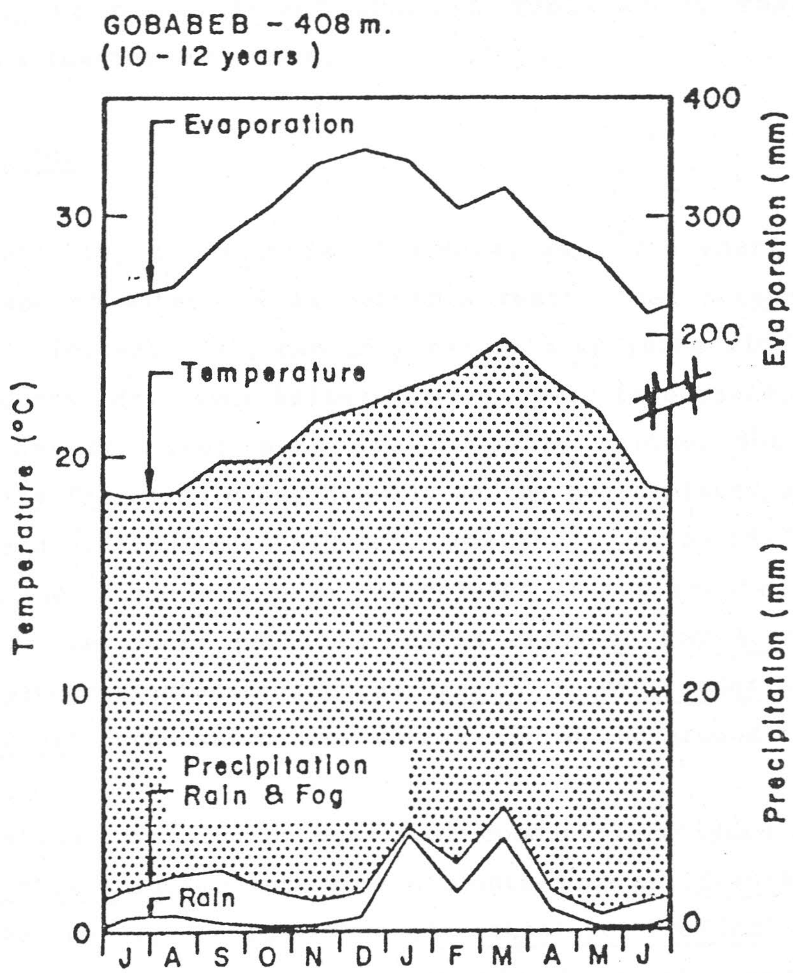


Figure 2. The ecological climate-diagram of Gobabeb (modified from Walter *et al.*, 1975). Months with maximum evaporation and maximum temperature do not coincide. Stippled area indicates the 'relatively droughty season'. Data from Seely & Stuart (1976) and unpublished DERU data.

winds which are responsible for the maintenance of cool water near the coast, the fog, the high humidity and the steep climatic gradient from the coast to the interior (Seely, 1988, p16).

In the Central Namib, the influence of the steep climatic gradient on the diversity of vegetation can be observed between Usakos and Swakopmund. Here trees disappear from the landscape of endless variety of plants inland and are replaced by small shrubs and lichens towards the coast.

1.4.4 Vegetation

Ecologically, a desert is considered as a low energy system due to the lack of water. It is for this reason that perennial and annual plants, (especially), can only flourish in years with adequate rain. In deserts, dry river valleys are the most favourable plant habitats. Most desert river beds are slightly saline. But the degree of salinity is variable and depends on the geochemistry of the catchment area and other geomorphological features, (White, 1983, p145).
The Kuiseb river - community includes taller shrubs and small trees such as *Salvadora persica*, *Acacia erioloba* and *Acacia albida*. The hard perennial grasses such as *Eragrostis cyperiodes* and *Stipagrostis sabulicola* form part of the riverine woodland ground cover.

Vegetation cover in the dune base community includes grasses such as *Eragrostis spinosa*, lilies, succulents such as *Trianthema hereroensis* and the thorny, leafless Nara (*Acanthosicyos horrida*).
This study derives from a theory which holds that vegetation has the potential for trapping and stabilizing sand. Among the vegetation of the Central Namib Desert, the Nara plant and *Salvadora persica* have been selected by the researcher as examples of plants capable of trapping sand. Since these plant species are adapted to dry environmental conditions, they are thus xerophytes. As they grow in sandy areas, the wind causes sand to heap up around the Salvadora persica and the Nara plant. After a few years, the two shrubs appear

to be growing out from the top and sides of their own small dune and form dense stands of woodland vegetation.

Fog dripping off the Nara branches and moisture and shade around the Salvadora persica, each serve to compact the sand beneath. In such partially stabilized sand at the base of the Nara and Salvadora persica dune, small animals use plants for shelter, e.g. gerbils and geckos are able to construct their burrows. Other animals, such as lizards, legless ligards, side-winding adders and beetles that do not construct burrows but "swim" directly through the unconsolidated wind blown sand, are able to do so higher up in less well consolidated sand of the dune beneath the two shrubs, (Pfeifer, 1979).

1.4.4.1 Salvadora persica : Plate 1

The shrub Salvadora persica has a more dense growth pattern than Nara. This plant is not confined to the Namib Desert. It occurs also in Etosha Pan areas, and in the far Nothern part of Namibia (Owambo) where it grows on termite hills (termitaria). As indicated by the species name, its distribution extends throughout Africa into Asia, inhabiting arid and saline areas.

Saline soils are frequently found in arid and semi-arid regions where rainfall is insufficient to transport salts formed during weathering, to the sea. Salvadora persica is one of the prominent halophytes in the flat valleys of the drier parts of Tanzania. The headwater from the Pangani River which rises from the volcanic deposits of mountains Meru and Kilimandjaro releases large amounts of salt into the drainage water. Salvadora persica is also a well-represented species in the Somalia-Masai Region, in the southern part of the coastal Sahara, in Mauritania and in Sahel (White, 1983).

In the Central Namib Desert, Salvadora persica communities occur mostly on the steep dunes between Natab and Gobabeb; and mainly on the southern side of the Kuiseb valley; and in masses along the

Kuiseb at Nara valley 20km downstream of Gobabeb, and in isolated patches down to Swartbank. This shrub is also found on the flood plains, outcrops and occasionally on the hummock dunes of the northern side of the river (Robinson, 1976). Salvadora persica is seldom present as extensive stands, but the individual plant is widespread and each plant usually forms a large clump with numerous stems.

1.4.4.2 The !Nara plant (Acanthosicyos horrida): Plate 2

!Nara, a Topnaar Hottentot's name for the thorny, leafless Acanthosicyos horrida. This cucurbit, a member of the cucumber family is an endemic plant. Like the very well-known Welwitchia mirabilis, the !Nara is, equally interesting but less well-known.

Soutrivier is a small village of the Topnaar Hottentots, 5km downstream from DERU. One can get information about the !Nara plant and its use from the people of Soutrivier. The research station was built on the site of an abandoned village called /Nomabeb, "The place of the fig-tree" (Dentlinger, 1977, p8). Europeans at the station probably had trouble pronouncing this correctly. /Nomabeb is now known as Gobabeb, while the cucurbit plant !Nara is better known as Nara.

Nara plants live on undeveloped sand dunes and sandy washes e.g. in dry streams on the gravel plain N, NW and NE of Gobabeb. This plant is most commonly found growing along river beds with underground water. When it grows in the dunes, it is often located where underground water is not far beneath the surface, which it obtains by using an extensive taproot system.

The Nara plant has no true leaves and thus limits water loss. Such a reduction of surface area is a common adaptation for some types of desert plants of which leaflessness is an extreme example of leaf

PLATE 1

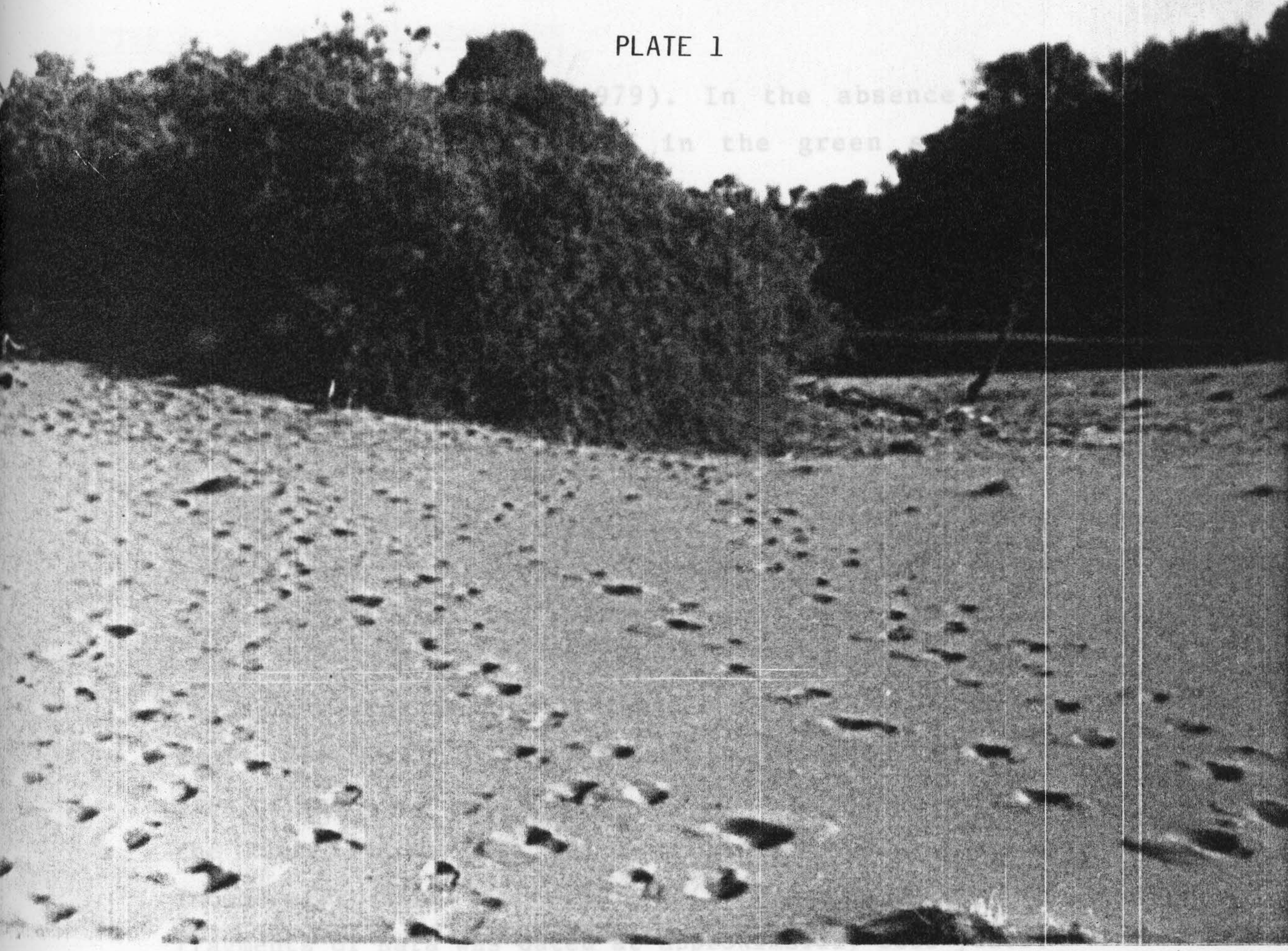


PLATE 2

modification (Pfeifer, 1979). In the absence of true leaves, photosynthesis takes place in the green stems which contain chlorophyll.

The flowers of the Nara are also green. The lack of tasty leaves prevents animals from feeding on the Nara. The soft growing tips of the otherwise stiff stems are the only part regularly consumed by ostriches, (Seely, 1988, p43). Because of the plant's ability to use underground water, combined with its ability to conserve that water through reduction of its leaves, the Nara plant is almost never under water stress. It does not suffer from the extremes of the environment as do less well-adapted species.

The Nara melons grow to a diameter of at least 145cm. When ripe, the fruits are food for jackals, gerbils, crickets, beetles and man. Nara pips or kernels contain up to 46% oil and 32% protein. Topnaars along the Kuiseb valley use the Nara pips to supplement their monetary income. According to Dentlinger (1977, p3), the oldest of seed-coat fragments of Nara was dated at approximately 8000 years.

Besides the shelter, the food source and the economical function the Nara provides for Namib animals and its people, this shrub is also an important sand binder in the Namib ecology.

Gobabeb was chosen as the study area, as the vegetation has not yet been disturbed by human action.

2.1 Introduction

In this study one finds stimulation in the spectacular and intriguing effect of wind on dry sand and vegetation in deserts. The knowledge of the fundamental relations between wind and sand movement, especially wind velocity, and particle size and sand movement is very scanty and rests on the theoretical basis and contributions by theorists to be referred to in the present study. Since there has been some little work done on sand accretion in recent literature, there is a need to introduce the discussion of aeolian forms with a short review of their extent.

2.2 Winds

Wind, which is air in motion, has been noted by Cooke and Warren (1973) to cause large areas of aeolian sand to have the most distinctive desert landforms. These striking, if not so widespread, landforms led many geomorphologists to over emphasize the role of the wind in deserts.

Wind may further be regarded as of potential effect in plant geography in three ways, namely:

(a) wind's physical influence on the growth-form of plants, as in restricting or preventing the growth of plants.
(b) wind's effect in determining other climatic values such as temperature and rainfall.
(c) landwind's effect on dispersal, such as in plant detritus, seeds etc.

Most deserts experience wind regimes that have some degree of variation in direction, and the Central Namib Desert, particularly Gobabeb, is no exception Cooke and Warren (1973) in considering relevant characteristics of the wind have noted three main causes of wind variability, namely:- speed; - direction, and -turbulence.

2.2.1 Erosional and depositional action of wind

Deflation of sand is one of the wind effects most easily observed in the Central Namib Desert. Soil removal by wind has been studied very extensively because of its importance in the context of soil erosion of agricultural lands. But less attention has been given to this important subject by desert geomorphologists as was also noted by Cooke and Warren (1973). It is for this reason that winds in the Central Namib Desert have been observed and are shown to have a distinct topographic expression. The intensification or increase in wind strength and deflection of wind around topographic obstacles results in wind-produced landforms such as vegetated dunes.

2.2.2 Geomorphologically effective winds

Bagnold (1941 and 1953) proposed that winds of a velocity exceeding 16km/hr (4,4ms^{-1}) have the potential of transporting sand; and also, that the ability of wind to transport sand increases by the cube of the wind speed. On the threshold velocity which is 16km/hr, Dury (1966) commented that, desert sand is constantly stirred by uneasy winds which are highly abrasive. He further explains that a wind reaching a speed of 11 mile per hour (18km/hr) at a height of four inches (10cm) above the ground, sets ordinary desert sand in motion. He continued saying that a wind of 22 miles per hour (35km/hr) exerts a force equivalent to more than 40 times their weight upon grains, which bounce up from solid obstacles.

2.2.3 Winds on desert dunes

Recent observations by Lancaster (1985) and Tsar (1985) on the variation in wind velocity over desert sand dunes, showed that the increase in wind speed toward dune crests has significant influence on sand transport rates, and hence, dune morphology.

According to Watson (1987, p514), wind velocity near the surface decreases in response to the change in surface conditions, but the potential for sand deposition consequent upon this is offset by the increase in shear stress as the surface gradient becomes steeper. There will be no potential lag effect as sand movement on the dune begins, if the terrain upwind of the dune is sandy. The balance between the input of sand from further upwind and the inevitable loss downwind determines whether the dune accretes or abates.

Windflow is strongly influenced by the inclination of the dune surface. Fluctuations in the turbulence of the airflow, rate of sand supply and variations in the grain-size characteristics of sand on the dune surface further complicate the relationship between airflow and dune morphology as Watson (1987) quoted from Howard et al (1978).

2.3 Sand movement by wind

Before the early seventies, sand accretion by wind had been given less attention in the context of desert geomorphology. The work on sand movement by wind in the Libyan Desert by Bagnold (1941) awakened the interest of the early seventy geomorphologists. Much of their work is directly relevant to the study of sand accretion by wind in deserts. Sand or dune accretion has been used here in its broadest sense to include "sedimentation, accretion and encroachment", (Bagnold, 1941, p127). Dune movement, (Plate 7) as it will follow in this discussion, is evident in considering trends in dune sand accretion.

The understanding of processes involved in the movement of sand in response to windshear, is basic to the understanding of dune forms. This section is a brief treatment of the argument of various authorities, notably those by Bagnold (1941).

When sand moves, the pattern of wind movement over the surface bed is altered (Cooke and Warren, 1973). Sand is moved by

PLATE 7: Sand intrusion into the Kuiseb River

- suspension which is the floating of small sized particles in the airstream,
- saltation which is a bouncing or jumping of particles, and by
- surface creep, meaning the rolling or sliding of larger particles along the surface.

The coarser grains move as creep, and their movement depends largely on the bombardment by the saltating grains.

Sand movement mechanism as outlined by Chepil and Milne (1939), (quoted by Cooke and Warren (1973, p260) is that: - most trajectories start with an almost vertical movement. As the grain enters the faster winds above the surface its path is modified, and it is pushed forward. When its initial upward movement is dissipated, it is pulled down by gravity; and its path is determined by the balance of this force with the forward force of the wind. This movement according to Cooke and Warren (1973) has been powered by the wind, and momentum has been extracted from the wind.

A measure of discrepancy is apparent in some of the earlier work between potential dune movement predicted from the wind data only and various field observations in the Central Namib Desert.

Ward (1983) quoted several workers including Breed et al (1979), Harmse (1980, 1982) and Lancaster (1982) who calculated the sand drift potential from present wind data collected along the Lower Kuiseb River. The result was, that the potential dune sand movement is in a south-westward direction, that is, away from the Kuiseb, in the Gobabeb-Rooibank sector. But in contrast, Harmse's (1982, p45) work confirmed the north-ward trend as was noted by Goudie (1972, Marker (1977), Blom (1979) and Besler (1975, 1980) as quoted by Ward (1983), and Ward himself (1983).

2.4 Grain-size particles

Sands are sorted in aeolian transport. The wind selects certain size particles from a mixture of sand grain, those which it is capable of transporting. Grains of the same calibre are carried in the three ways mentioned above and are likely to fall to the ground when the wind velocity drops. Harmse (1985) in his study in aeolian sand movement on the Namibian Coast, investigated and determined the net direction of sand movement in his three sites. The study revealed the following information:

- that most of Sandveld, an area between Port Nolloth and Saldanha Bay, dunes are fixed by vegetation although intermittent sand sheets and patches of unvegetated dunes do occur.
- the Richtersveld, an area south of the Orange River, has vegetation less dense than in the sandveld, resulting in broad areas of unvegetated sand dunes, although these become more vegetated eastwards from the coast.
- the analysis of average sand grain size showed a tendency to decrease from the sandveld, via the Richtersveld, to the Namib.
- the samples collected from the three sites, were analysed in the laboratory. Mechanical sieving was used, followed by calculations of statistical measures of average grain size.

Ward (1983, p22) describes the sands in the Kuiseb River bedload and in the adjacent dunes of the main Namib sand sea as comprising predominantly 90-95% quartz grains with 5-10% amounts of heavy minerals, micas and feldspar.

2.5 The influence of vegetation on sand movement

It is a well known fact that where the sand is colonized by plants, most of the sand appears to be fixed. This simply implies that when moving sand comes into contact with plants, or when sandy surface is itself colonized by plants, a distinctive dune form develops.

Sand dunes are greatly modified in form by the presence of vegetation, and by the character of the wind which blows over them. The free interplay of wind and sand is complicated by the effects of moisture and vegetation. These form a stable surface which together with friction retard the wind velocity.

Vegetation cover influences the nature of wind erosion in several ways; of which two are:-

- firstly, the quantity of vegetation as represented by the proportion of covered ground, is a reflection of the extent to which the surface is exposed to erosion; and
- secondly, vegetation increases elements of surface roughness, and hence reduces wind erosion, (Cooke and Warren, 1973). An example is, that, the taller and denser the vegetation, the more effective its protection.

2.5.1 Vegetated dunes as sand stabilizers

Avis (1988?) discusses at length the successful stabilization of dune areas in France by plants, which initiate changes and refinements to coastal dune stabilization techniques in South Africa in 1845. These techniques included:

- the introduction of Australian *Acacia* species, that is, sowing seeds of alien species,
- city refuse to complement the seeding,
- brushwood used in conjunction with wooden barriers to create a large artificial foredune,
- the planting of indigenous species which is the present technique.

Very little information on dune stabilization in Namibia has been published. But fortunately among the research reports are the work done by Huntley, (1982-1984?) Robinson and Seely (1980), Ward (1983) and Seely (1988). These mention of some plants with semi-stabilizing effects. Amongst the plants mentioned are:

- *Monsonia ignorata*, totally restricted to the dune base community. During dry periods the tubers of this geophyte persist in the stable sand, but the above-surface growth and reproduction occur only after rains (Robinson and Seely, 1980, p197).

- grass species such as Stipagrostis sabulicola, a coarse dune perennial grass. Harmse (1980) as quoted by Huntley (year not known) mentioned the potential build-up of dune sand around Stipagrostis sabulicola clumps but no measurements were made. Furthermore this grass species has the ability to exploit fog water (Low and Seely 1980) and thus has the potential to survive many years with little or no rain.

While acknowledging the effect of vegetation on stabilizing sand, Huntley (year unknown) contends that in the case of the study area, Northerly and North-easterly movement of sand dunes is hampered by the Kuiseb River floods rather than stability by vegetation.

Huntley (year not known, p65) has further noted that there is a distinct time lag between reduction of vegetation cover and the last good rains (1978) in the Central Namib Desert. Dead plants eg. Eragrostis spinosa, a grass species, were observed to be still effective in binding and trapping sand in the Swartbank area, in the riverbed and in the vicinity of Klein Klipneus.

Seely (1988) describes many Salsola (brack-bush) plants, which are hardy bushes which catch the wind-blown sand, causing hummocks to form.

2.6 Conclusions

Sand-built features in the desert are marked by distinctive kinds of response to variations in wind velocity, wind frequency, wind direction, sand particle size, abundance of sand and local surface conditions. These will also determine the volume of erosion, sand transport and deposition across the dune. More details can be found in Bagnold's (1941) classic discussion of sand movement.

It is with this conceptual framework that it can be deduced that some plant species have the potential of trapping and stabilizing sand more effectively than others. For this reason a comparative analysis of two Namib shrubs in facilitating sand accretion has been designed.

CHAPTER 3: METHODOLOGY

3.1 Introduction

The term methodology as used in this study implies a description of the overall research design. The working hypothesis that Nara plant and Salvadora persica accrete sand effectively was derived directly from observations.

3.2 Observation

It was noted that although vegetation has the ability to trap sand, some plants are better at accumulating sand around them than others. Young (1964, p154) describes observation as "a systematic and deliberate study through the eye, of spontaneous occurrences at the time they occur". The purpose of observation is thus, to perceive the nature and extent of significant interrelated elements within a physical environment.

3.3 Pilot Study

The pilot study was made in December 1987, for 6 days. The purpose of a pilot study, a non-controlled observation, was to determine the direction of the research procedure. The primary objective of a pilot study is according to Lounsbury and Aldrich (1979, p130). "To obtain an overview or general perspective of the research area prior to the actual data collecting phase of the research". Young (1979) also emphasizes the point that, it is during a pilot survey that a careful scrutiny of real life situations can be made.

This research procedure serves to test the research instruments to be used, and to try out the possible data classification systems to be used under actual field conditions. It was during the pilot study that the hypothesis for this study was refined and the sampling areas were selected.

Pit-traps which are hollowed tins (i.e. open on both ends) where a small bucket can fit, were used to trap sand. The following information was recorded:

(1) Temperatures (T^o) at five different places were taken for each plant, that is

- surface T^o next to pit-trap
- surface T^o next to plant
- surface T^o in the shadow of the plant
- air T^o inside the plant
- air T^o or ambient T^o

(2) wind speed, (3) wind direction,
(4) weight of sand, (5) time when readings were taken and when pit-traps were emptied.

Readings were taken after every second hour. Two days readings were taken at 10h00 and 19h00. But since wind start becoming stronger after 14h00, other four days readings were adjusted to the time when the wind became stronger. Readings were then taken at 14h00 and 19h00.

Observation as one of the research, procedures, has been found useful by various authors. According to Nachmias (1976, p74), "the main virtue of observation is its directness. It enables the generation of first hand data that are uncontaminated by factors standing between the investigator and the object of research". The advantages with the observation method are summmarised below:

(a) Data collected by observation describe the observed phenomena as they occur in their "natural setting" (Nachmias, 1976). This means that this method is the primary source of information in a field study.

(b) Observation provides essential or relevant data that are not available from published sources (Lounsbury and Aldrich, 1979). Such information can thus be used to supplement data that may interpret or quantify findings obtained by other methods.

(c) Fieldwork in general has long been used as a research tool. The few Namib Desert researchers in particular, by using observation method, have made important contributions by adding new information to the pool of knowledge.

Bagnold (1941) used this method in his intense study on "The physics of blown sand and desert dunes". He did his quantitative measurements of sand movement and wind velocity in the Libyan Desert in 1938. His previous experiments on the same topic, were held in a small wind tunnel. Bagnold (1941) suggests that quantitative predictions concerning wind velocity and its distribution, and sand movement rate caused by it should be given support by careful measurements during desert sand storms.

(d) The spatial sampling used in this research is what Lounsbury and Aldrich (1979, p103) term the "exploratory spatial sampling", a method of much use in regions where little information concerning a particular phenomenon exists.

(e) As the problem in this research is concerned with dynamic areas which undergo changes over very short periods of time, direct observation is overemphasized as a method deeply entrenched in the history of geography. Therefore, for the researcher to understand, explain and predict what relationships exist between Salvadora persica and Nara plant, these two plants were observed.

The sampling schedule was two recordings per day with 5 hours interval. The study was conducted for 14 days, that is 7 days in January 1988 and 7 days in July 1988.

3.4 Field Techniques

The term field technique in this study refers to the actual manner in which field data were collected. In deciding on the approach adopted for this study, the quantitative analysis of the two shrubs under controlled experimental conditions was preferred for the following reasons:

(a) According to Young (1964, p156) "observation should be supplemented by experimentation which might provide clues as to causal factors of given situations".

(b) Ideas similar to those held by Young (1964) were expressed by an unknown author who stated that: "A geographer had not really won his spurs until he had gone out and gotten his boots dirty", (Anonymous).

(c) The experimental method, as strongly emphasized by various scientists, evolves fuller and richer conclusions and challenges the researcher to probe deeper than other methods.

(d) The fieldwork method makes it easier for the researcher to code, classify and interpret the data, and make unbiased deductions within a defined spatial matrix.

Selection of sampling sites and layout

In selecting sites, the variables taken into consideration were:

(i) Topography: - that the two plants should be more or less on a levelled surface, to avoid surface roughness.

(ii) The size of the two plants should be more or less the same
- that is, approximately same height and approximately same diameter. This implies that the quantity of vegetation as represented by the proportion of covered

ground has been considered to be similar for the two different plants.

Two sites A and B were chosen on the South bank of the Kuiseb River. This area is situated close to Gobabeb which the researcher could reach at any time on foot. Measurements were made by using simple and portable instruments that are already available at DERU. Gobabeb First-Order Weather Station provided micro-meteorological readings.

Two plant species Nara (abbreviated hereafter as Np) and Salvadora persica (abbreviated hereafter as Sp) were samples selected from a large population of the riverine vegetation. Since it was difficult to get both plants nearby on a flat, levelled surface, the two sites were about 1km apart.

Site A: Experimental site: (Refer to Plate 3 and 4)

Nara and Salvadora persica are on a flat surface. This is the initial state of each plant. Their diameter is approximately 3m; - at an altitude of about 6m above the river bed; - the plants are approximately 200m apart.
Four pit-traps (PTs) were put in the ground, and were fixed at the four cardinal points of each plant. Figure 3 shows this. Another pit-trap was used at each plant as a control sand collector to measure free undisturbed wind. This pit-trap was laid down at random at about 5m from the plant.

PLATE 3

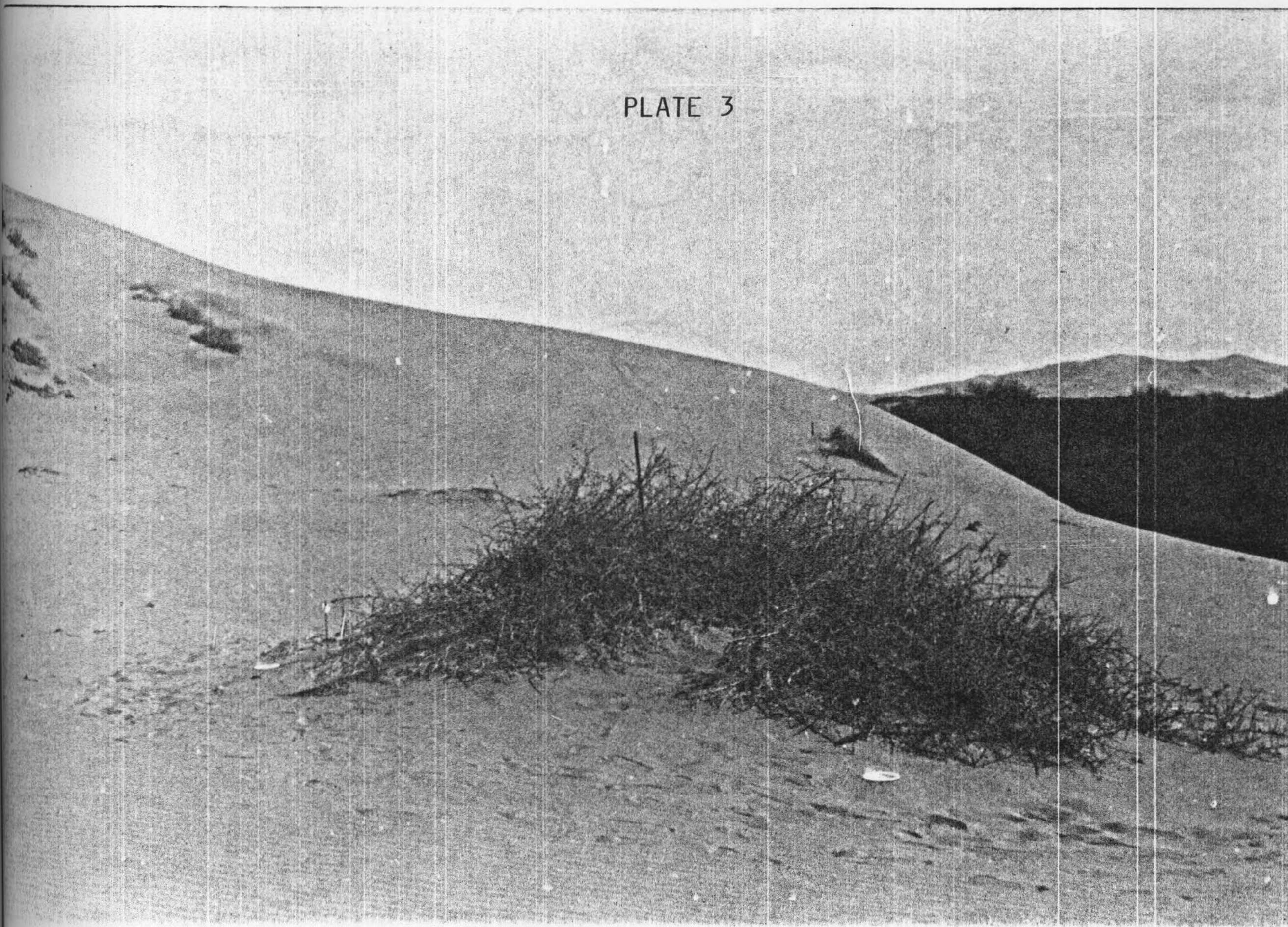


PLATE 4

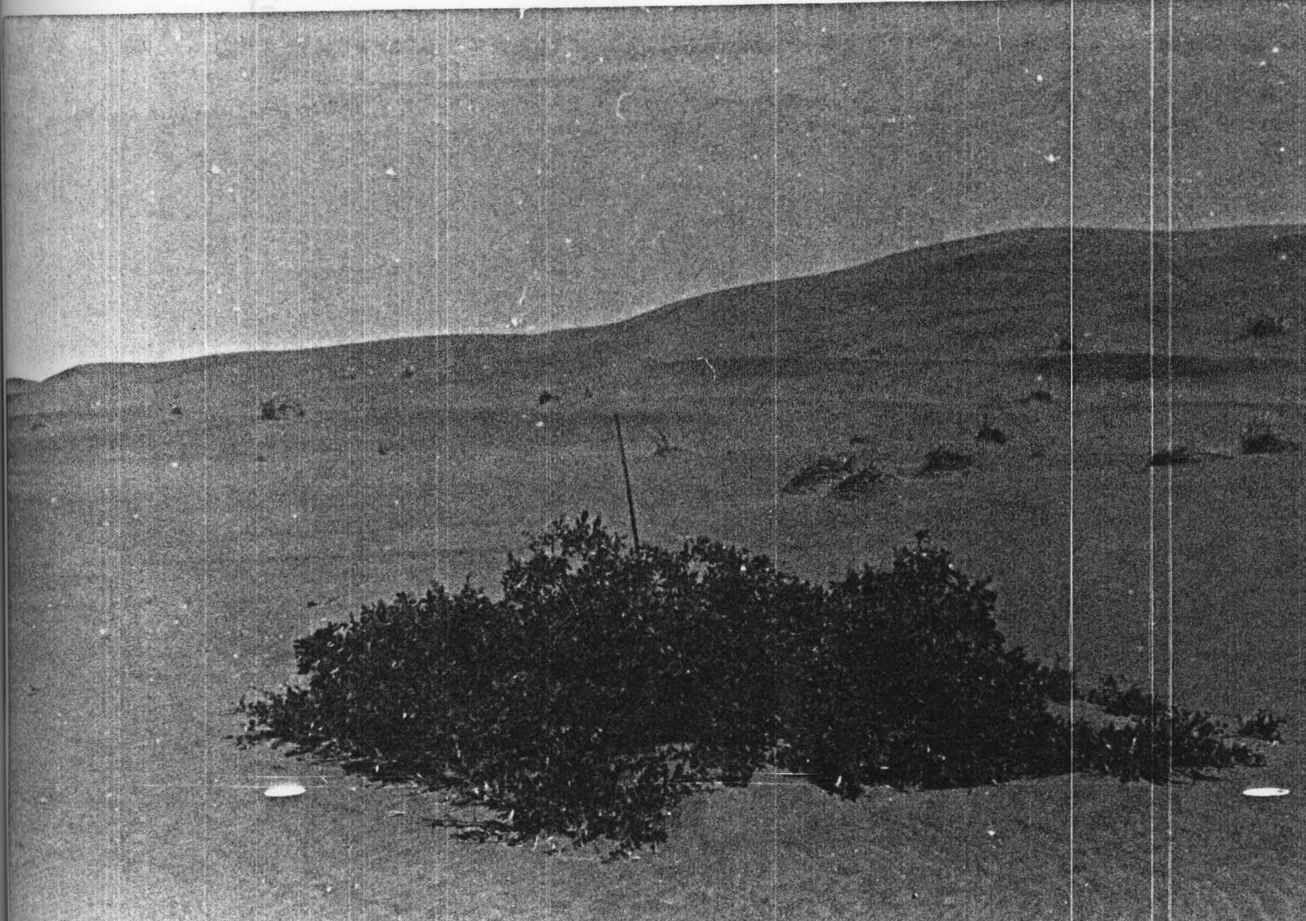
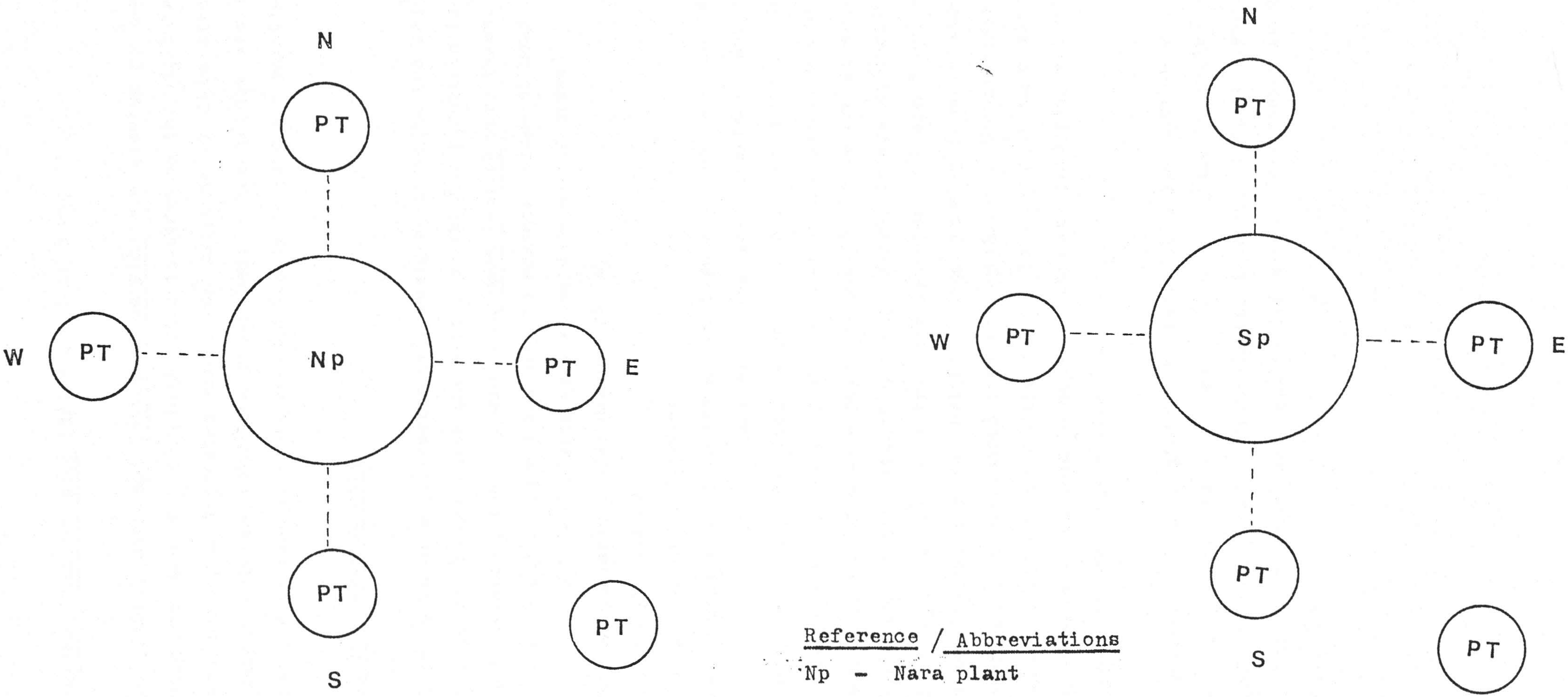


Figure 3: Layout of sites



<u>Reference</u> / <u>Abbreviations</u>

Np – Nara plant

Sp – Salvadora persica

PT – pit-trap

N – north

S – south

W – west

Site B: Control site (Refer to Plate 5 and 6)

Two plants, Nara and Salvadora persica are growing on small dunes which are about 0,5 - 1m high. This is taken as the ultimate state of each plant, a vegetated dune. The altitude of this site is also approximately 6m above the river bed; - the plants are about 50m apart. Pit-traps were placed identically to site A's positions.

Types of measurements

Three types of measurements were designed to suite the objectives of this study. To determine the effect of the two plants in facilitating sand accretion, the following sand measurements were taken.

- a cylinder (in ml) was used to measure volume of sand
- pesola balances were used to weigh sand (in grams)

Sand accumulates in two dimensions; by

(a) height and by

(b) perimeter or diameter

The wire-peg method as illustrated in Figure 4 was used to measure the increase or decrease of the sand heap. The measurements of any changes in the unconsolidated sand required reference to fixed points. These were straight wire pegs set vertically at the base of the plant, one at each pit-trap. A metal rod (a thick wire peg) was put in the centre of each plant at site A. Since the control site B has high dunes, it was difficult to put a metal rod through the centre of the plants, refer to Plate 5 and 6. The top metal rod was to measure the height of the growing dune. Changes in dune surface profiles were determined from this technique. The pit-trap wire pegs were to give an estimation of the change in volume of heap sand per unit area. Measuring tape was used to measure distances in laying out of pit-traps and the height of the exposed wire pegs.

Sand measurements included grain size records. These data were to give the researcher a general idea of what size of grain particles were being transported by wind around the two plants. A series of eight sieves were used to obtain the diameter of sand grain. The sieve sizes ranged from less than 0,063mm to 4,0mm .

PLATE 5

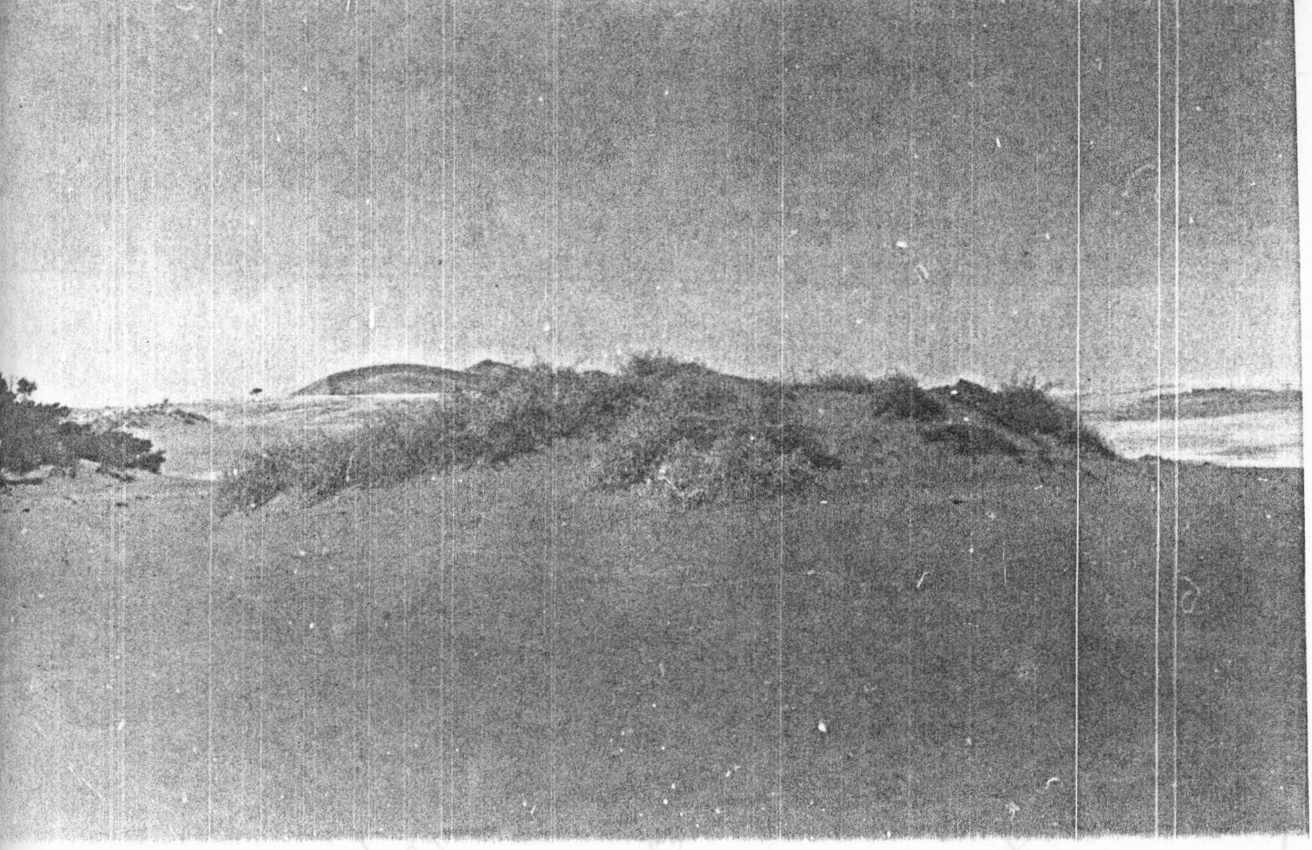


PLATE 6

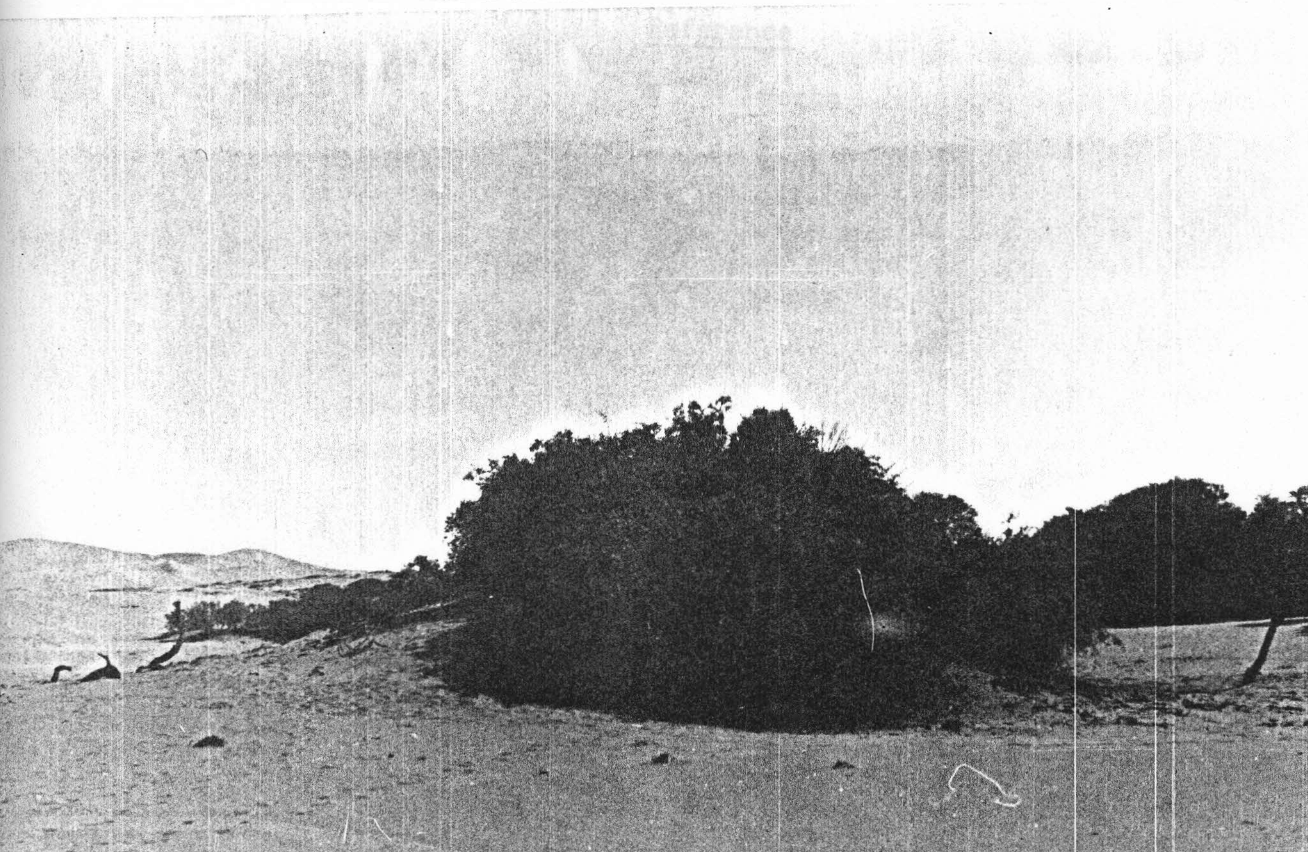
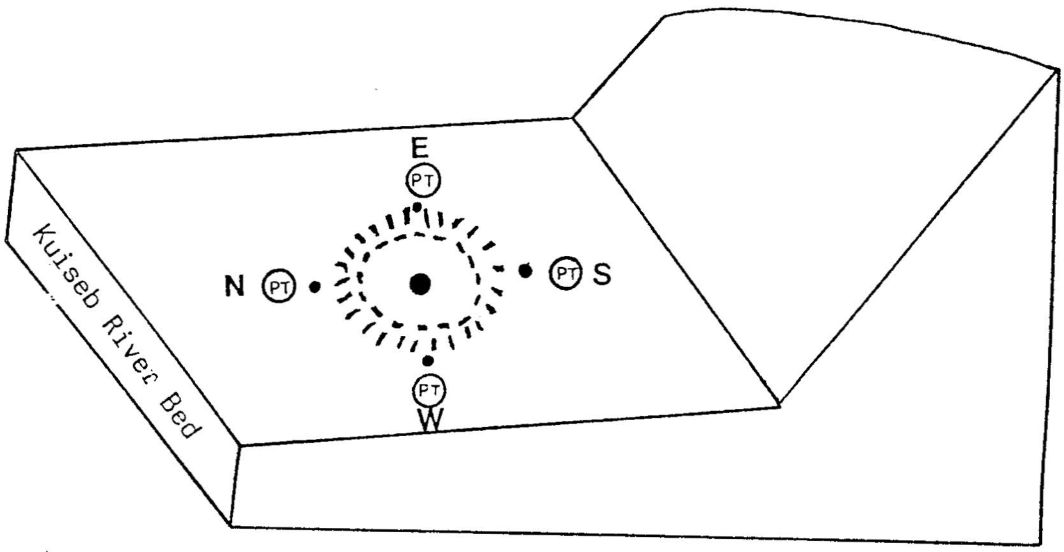


Figure 4: Schematic layout of metal rods and wire pegs at the sites.



Reference

N - north
E - east
W - west
PT - pit-trap
• wire peg
● metal rod
plant

Micro-meteorological (micro-met) measurements

To determine under what micro-climatic conditions most sand accumulates around each plant, the following data were measured.

(a) Wind, has three main aspects of variability namely:

i) wind speed (VV) - of primary importance in determining the amount of sand that is moved. Gobabeb micro-met readings, a "hand-wind totaliser" and stop watch were used.

ii) wind direction (dd) - the researcher was interested in the amount of sand blown from each direction. Wind direction was first observed or estimated and then later the readings were confirmed by using the accurate records of the Gobabeb weather station.

iii) turbulence is a property of wind which is important to the entrainment of sediment. Turbulence was not measured in this study, but it will be an important factor to be considered in the discussion.

(b) Humidity - a factor which effects compaction of sand grains. Gobabeb micro-met readings and a whirling wind hygrometer were used for measurements.

Elementary Mathematical -Statistical methods

The researcher found it appropriate to present the data in the form of averages and percentages. This eliminates complexities and a simple uniform picture results.
For analysis - sake conversions and mathematical formulae were used.

3.5 Problems encountered

Temperature measurements taken during the pilot study were found not to play a direct role in sand accretion and were replaced by humidity measurements. Unfavourable weather wherein calm weeks with no wind blowing, hampered the work, as not all readings could be taken. It is for this reason that non-continuous data are referred to as day 1,2 etc. Foggy mornings as experienced almost every day contributed to the decrease in the frequency of measurements taken.

It was extremely difficult to get relevant sources of information regarding work done on Nara and Salvadora persica. Fort Hare and Rhodes University Libraries were of little use in helping with this problem. Fortunately references made in this study were mostly from Seely MK, Director of DERU. The poor communication between the researcher at Fort Hare and the Director of DERU at Gobabeb was due to the problem of distance.

It has not been possible to use common periods of observation. This limitation was due to the distance between the two sites and thus the recording periods varied from plant to plant. But since average readings for 10 days were taken for each plant, fairly comparable results were assumed.

3.6 Conclusions

Much of the information needed for this study is not available from published sources. The demand for primary data such as those relevant to the effectiveness of Nara plant and Salvadora persica in facilitating sand accretion, could only be obtained through the method of field research.

DATA PRESENTATION, ANALYSIS AND RESULTS

4.1 Introduction

This chapter presents the raw data, analyses it and gives the results obtained. The aim is to test the sand accretion hypothesis and the climatic hypothesis associated with it. It should be noted that this study is reporting non-continuously recorded data for 10 days. Calm days have been excluded from the data. Most of site B data were discarded as a result of insufficient data except where references have been made.

A Mathematical technique has been adopted to show relationships by comparing parameters used in the present study. Such a Mathematical analysis was used to verify the classification of data and refine it and includes the use of averages, percentages, etc.

The ability of each plant to trap sand has been considered in the form of the amount of sand collected in each Pit-trap (PT). For simplicity's sake the amount of sand in grams per hour has been converted to percentage as the big range in numbers makes the plotting of graphs and histograms very difficult. The percentages as used in various figures have been defined and calculated as follows:

i) Percentage (Fig. 4.1 (a-t)

$$= \frac{\text{Amount of sand collected in a PT during a 5 hourly period per plant} \times 100}{\text{Total amount of 5 hourly sand collection per day per plant.}}$$

100% is an indication that a single PT has collected a very small amount of sand.

ii) Percentage (Fig. 4.3 a&b)

$$= \frac{\text{Amount of daily sand collection per plant during 5 hourly period} \times 100}{\text{Total amount of sand collected per plant in 10 days during a 5 hourly period}}$$

iii) Percentage (Fig. 4.4)

$$= \frac{\text{Amount of daily sand collection per day per plant} \times 100}{\text{Total amount of sand collected in 10 days per plant}}$$

iv) Percentage (Fig. 4.5)

$$= \frac{\text{Amount of sand accretion per day per plant} \times 100}{\text{Total amount of sand accretion in 10 days per plant}}$$

The total amount of sand accretion per plant = 100%

4.2 Data presentation

Details of data collected at sites, pit-trap locations and times or periods of measurements are given in Table 1 and 2. Table 1 shows the sand measurements by weight in grams per hour.

Table 2 illustrates the micro-meteorological measurements, where wind velocity (VV) is in metres per second and humidity (RH) in percentages.

4.3 Data Analysis and Results

The raw data in Tables 1 and 2 have been rounded off to whole numbers during calculations. In figure 4.1 (a-t), the histograms and their respective wind vector components illustrate sand collection of each pit-trap per day.

Results from Figure 4.1 (a-t) are summarised in a tabulated form. The results use the highest amount of sand collected in grams per hour and not percentages.

ABLE 1: SUMMARY OF THE RATE OF WEIGHT OF SAND TRAPPED (G/HR)

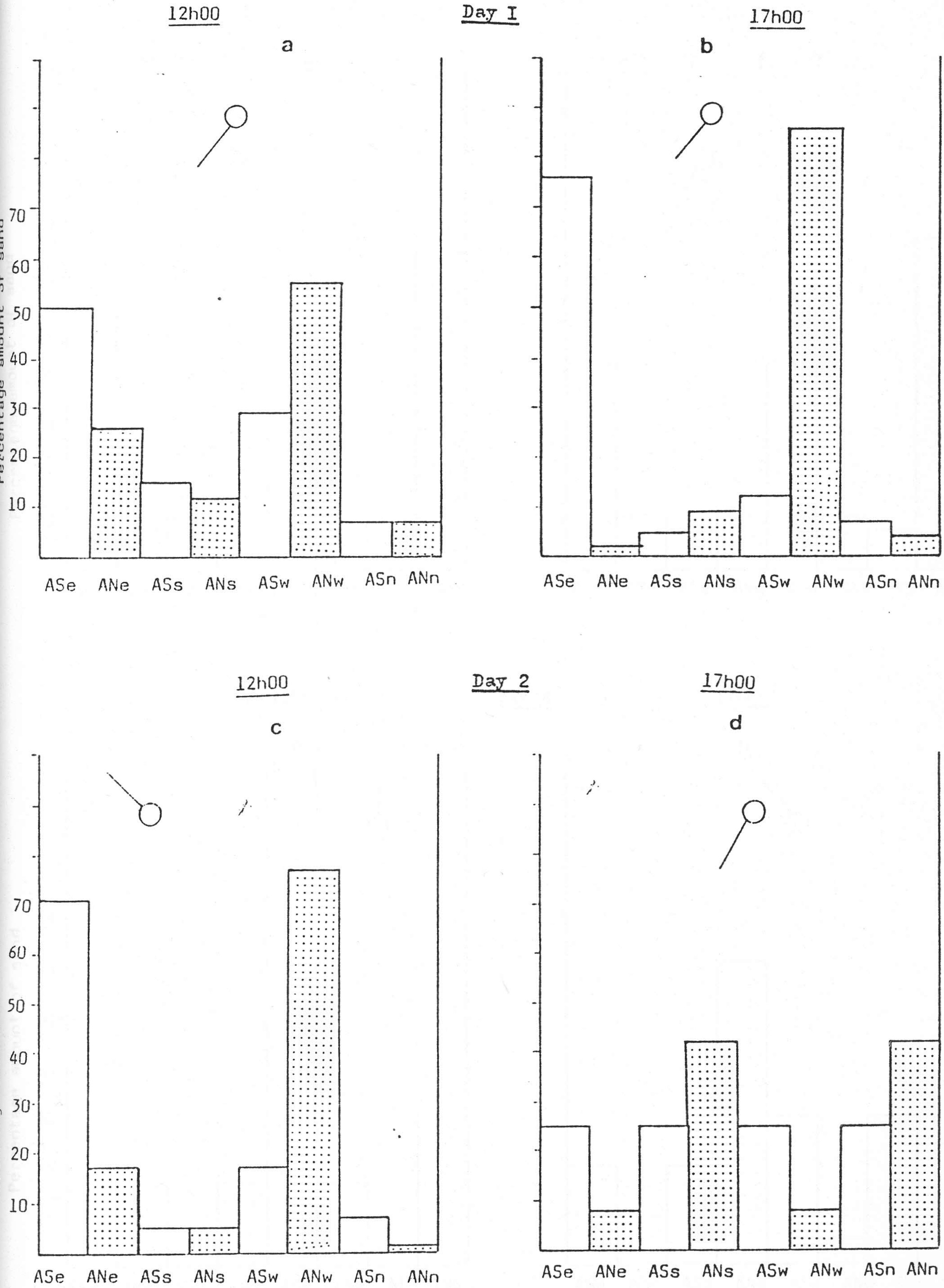
ay	Time	dd	AS_E	AS_S	AS_W	AS_N	RH(%)	Total 5 hourly	Total per day
	12h00	SW	100,8	30,0	59,0	13,6	21	204	834
	17h00	SW	480,0	30,0	75,0	45,0	15	630	
	12h00	NW	200,0	15,4	47,4	20,7	16	283	295
	17h00	SW	2,9	2,7	2,6	2,5	30	12	
	12h00	NW	15,4	3,2	8,1	3,3	36	29	65
	17h00	SW	15,0	3,0	15,0	3,0	35	36	
	12h00	N	0	0	1,0	0	40	1	11
	17h00	NW	1,5	1,5	2,5	3,1	38	10	
	12h00	NW	3,0	3,1	1,5	3,1	33	11	102
	17h00	NW	67,5	5,9	5,7	11,2	26	91	
	12h00	SW	37,5	1,5	4,7	4,9	29	50	60
	17h00	SW	2,9	2,8	1,4	2,6	33	10	
	12h00	NW	0	2,0	0	0	56	2	8
	17h00	NW	1,2	2,0	1,2	2,1	27	6	
	12h00	SW	5,0	1,7	2,4	1,5	32	11	52
	17h00	NW	22,3	2,5	1,9	14,0	22	41	
	12h00	NE	3,0	3,0	1,5	3,1	31	11	17
	17h00	NE	3,0	1,4	1,4	1,4	37	6	
	12h00	SE	35,0	5,3	42,6	11,6	32	95	127
	17h00	SE	1,8	2,8	2,0	25,0	35	32	
n Total			999	121	278	173	5 hourly	697	1571
erages			50,0	6,1	13,9	8,7	Sum Total	874	

AN_E	AN_S	AN_W	AN_N	RH(%)	Total 5 hourly	Total per day
160,0	69,6	333,8	44,8	21	609	1878
30,8	113,5	1076,9	47,4	15	1269	
210,8	64,9	951,7	16,2	16	1244	1268
2,0	9,8	2,4	10,2	20	24	
4,6	4,6	3,4	23,1	36	36	63
3,0	3,0	3,0	18,0	35	27	
1,2	1,0	1,0	2,5	38	6	68
5,9	37,5	2,5	15,0	31	62	
4,7	100,0	1,6	23,1	30	130	452
17,6	150,6	2,8	150,0	25	322	
4,1	2,1	1,6	20,0	34	28	88
3,8	49,0	1,3	6,4	33	60	
0	2	0	3,3	52	5	19
1,1	7,2	3,1	3,0	29	14	
4,4	50,4	2,3	36,5	30	93	211
2,9	54,9	1,2	59,4	20	118	
4,6	30,8	1,5	1,5	30	40	43
1,4	1,4	0	1,4	37	3	
14,2	24,6	3,3	9,4	30	51	84
2,0	6,1	3,0	21,6	37	33	
480	785	2397	512	5 hourly Sum Total	2242	4174
24	39,1	119,9	25,6		1932	

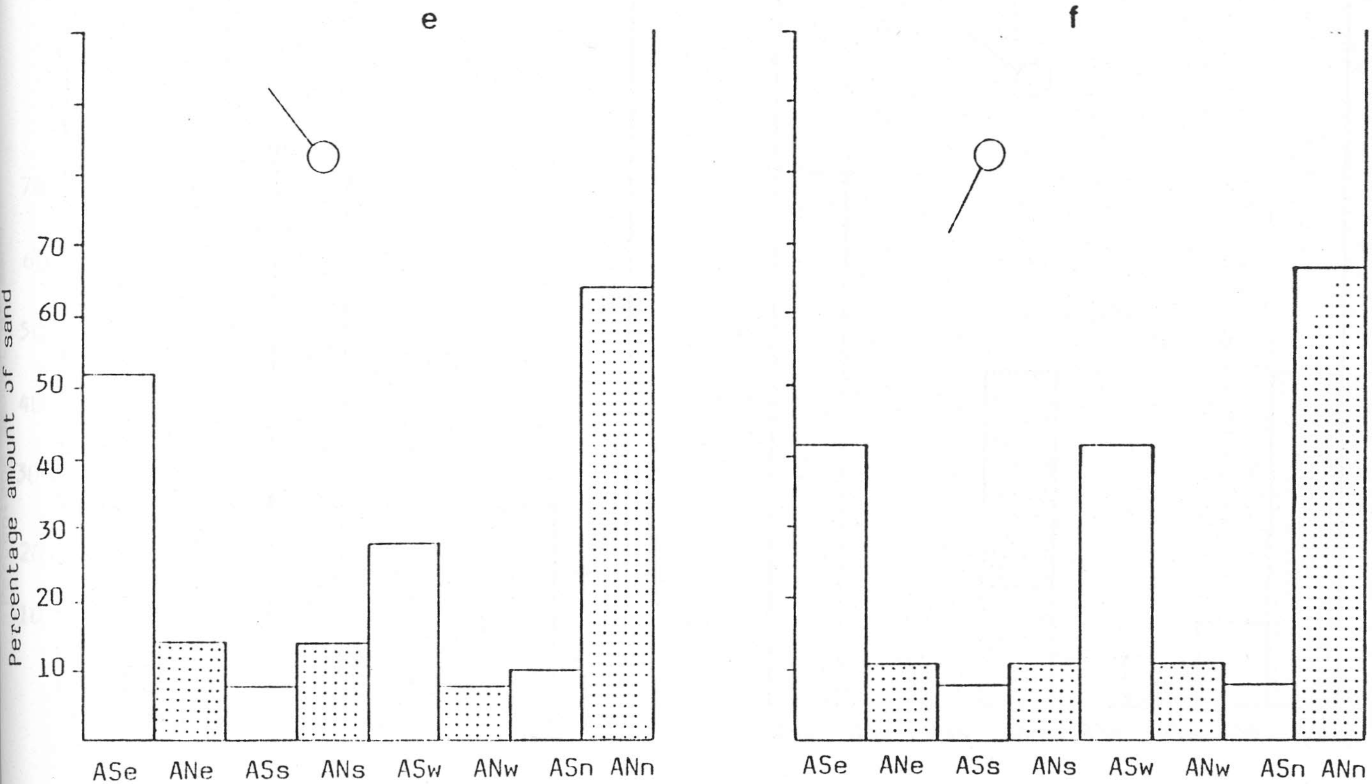
TABLE 2: SUMMARY OF WIND VELOCITIES (ms^{-1})

Day	Time	dd	AS_E	AS_S	AS_W	AS_N	AVERAGE VV	AN_E	AN_S	AN_W	AN_N	AVERAGE VV
1	12h00	SW	0,6	0,5	0,6	0,3	0,5	0,7	0,6	0,8	0,2	0,6
	17h00	SW	0,5	0,4	0,6	0,2	0,4	0,8	0,7	0,7	0,2	0,6
2	12h00	NW	0,6	0,3	0,7	0	0,8	0,7	0,5	0,3	0	0,4
	17h00	SW	0,2	0,5	0,2	0,3	0,3	0,2	0,5	0,5	0,5	0,4
3.	12h00	NW	0,5	0,4	0,3	0,2	0,4	0,7	0,5	0,3	0,3	0,5
	17h00	SW	0,3	0,3	0,4	0,2	0,3	0,7	0,5	0,7	0,4	0,6
4.	12h00	N	0,2	0,2	0	0,2	0,2	0	0,2	0,2	0	0,1
	17h00	NW	0,3	0,3	0,2	0,4	0,3	0,2	0,4	0,4	0,4	0,4
5.	12h00	NW	0,2	0,4	0,3	0,3	0,3	0,3	0,3	0,4	0,2	0,3
	17h00	NW	0,5	0,5	0,6	0,3	0,5	0,5	0,6	0,6	0,5	0,6
6.	12h00	SW	0,5	0,3	0,6	0	0,4	0,5	0,5	0,5	0,4	0,5
	17h00	SW	0,3	0,4	0,3	0,4	0,4	0,3	0,4	0,3	0,2	0,3
7	12h00	NW	0,3	0	0	0	0.1	0,2	0,3	0,3	0,5	0,3
	17h00	NW	0,3	0,3	0	0,3	0,2	0,3	0,4	0,3	0,4	0,4
8	12h00	SW	0,2	0,4	0,3	0,3	0,3	0,3	0,5	0,4	0,6	0,5
	17h00	NW	0,5	0,6	0,3	0,4	0,5	0,3	0,5	0,4	0,3	0,4
9	12h00	NE	0,4	0,3	0,3	0,3	0,3	0,1	0,4	0,5	0,4	0,4
	17h00	NE	0,2	0,4	0,2	0,3	0,3	0,1	0,4	0,3	0,3	0,3
10	12h00	SE	1,5	1,8	1,5	1,8	1,7	1,8	0,5	2,2	0,5	1,3
	17h00	SE	0,5	1,4	0,5	0,8	0,8	0,6	0,7	0,8	0,4	2,5

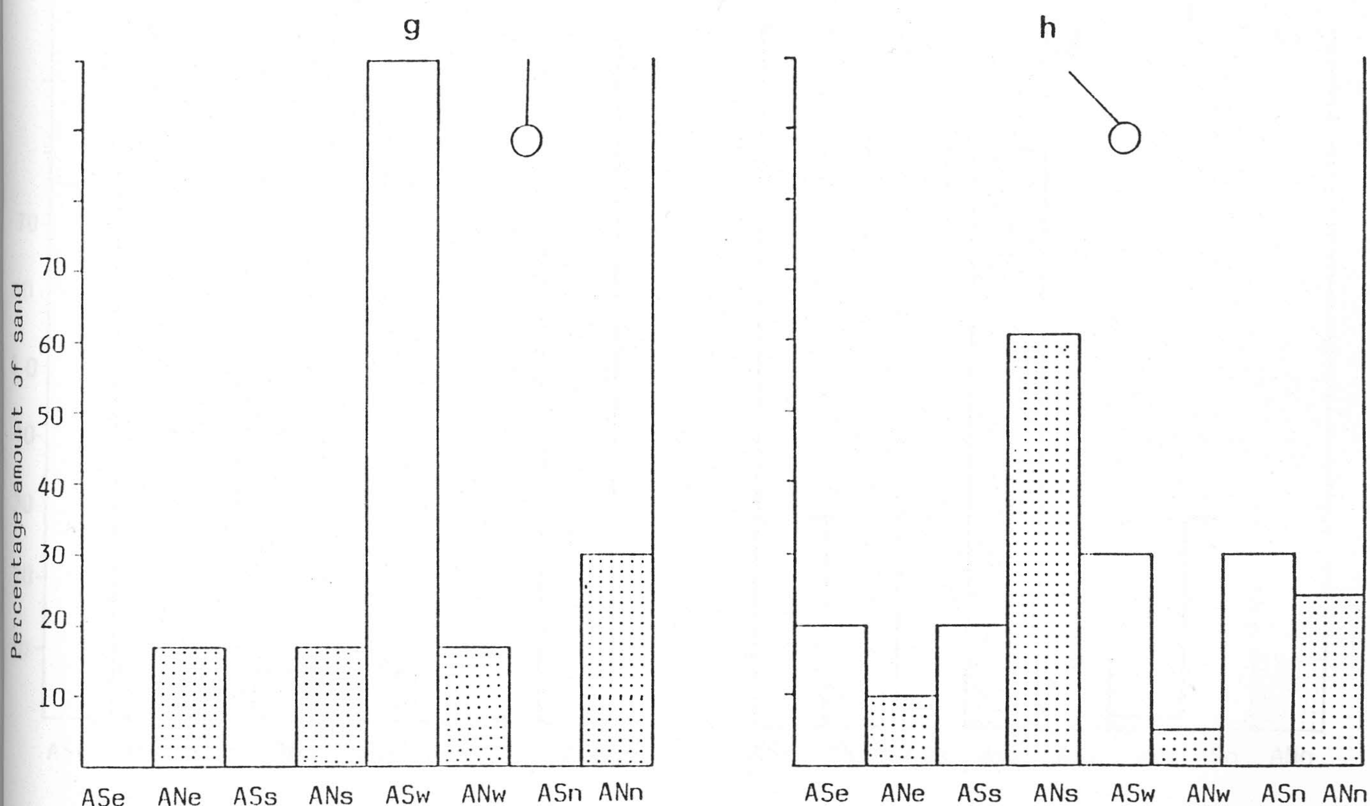
Figure 4.1 (a - t): Percentage sand collected per pit-trap as shown by 5 hourly wind vector (O—) components.



12h00 **Day 3** 17h00

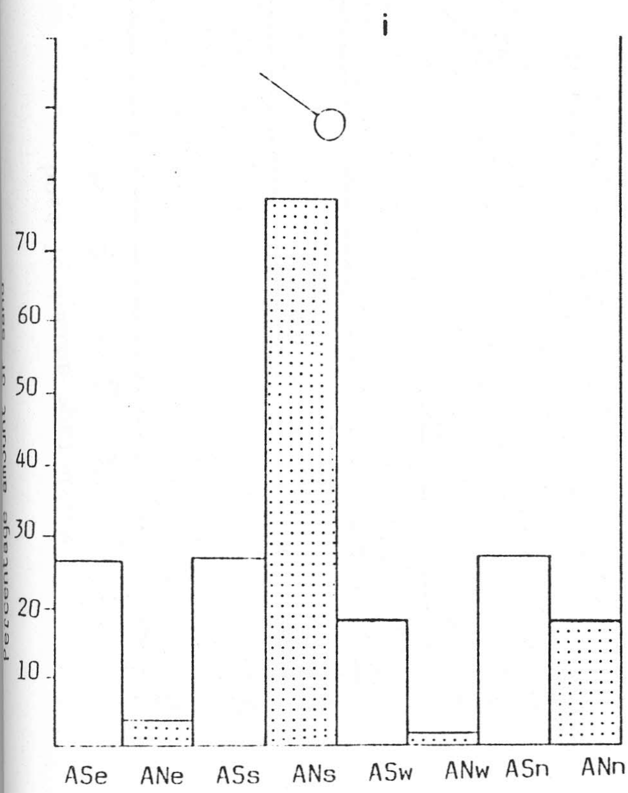


12h00 **Day 4** 17h00

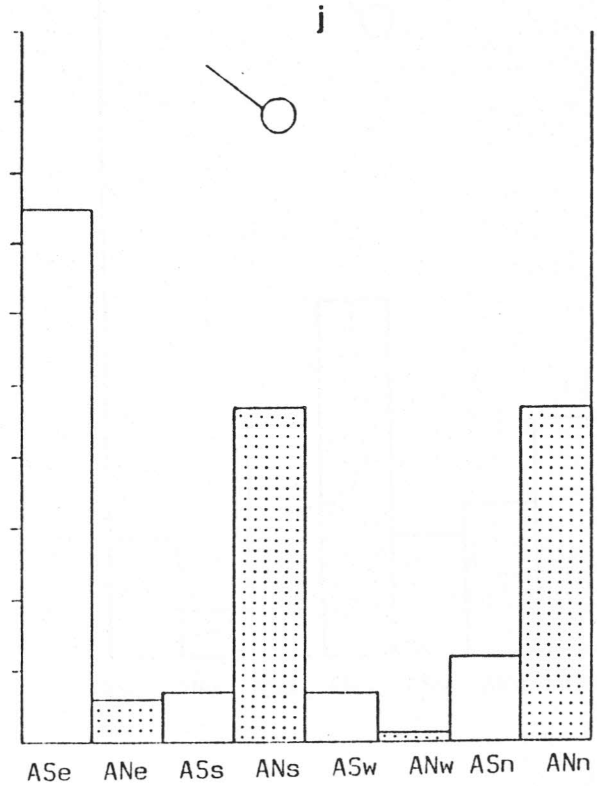


Day 5

12h00

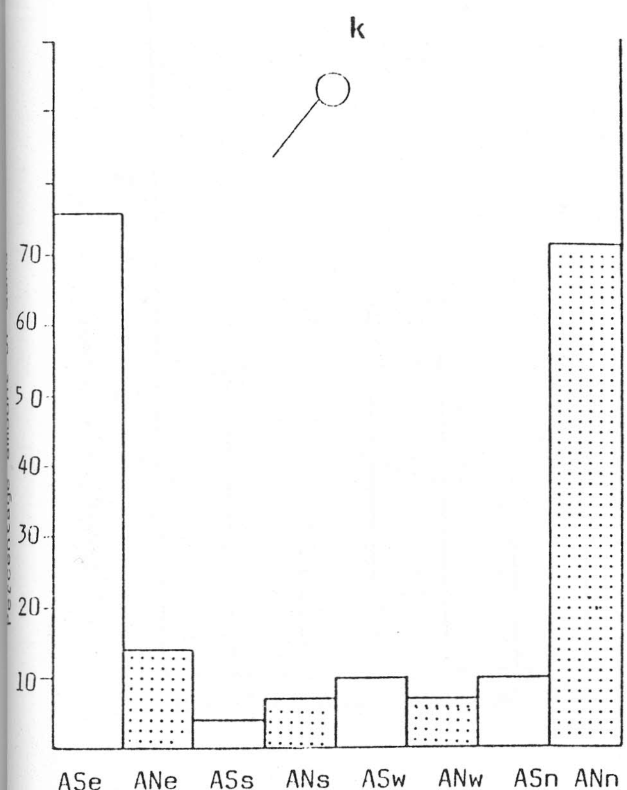


17h00

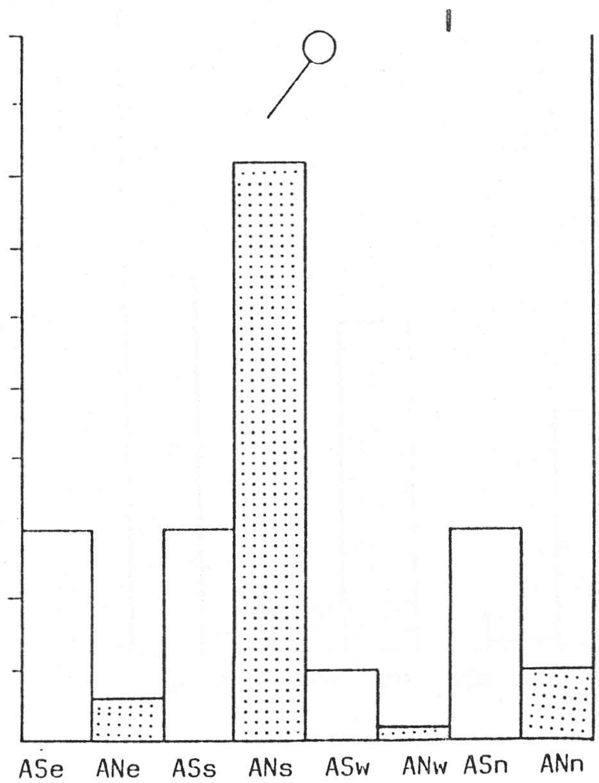


Day 6

12h00



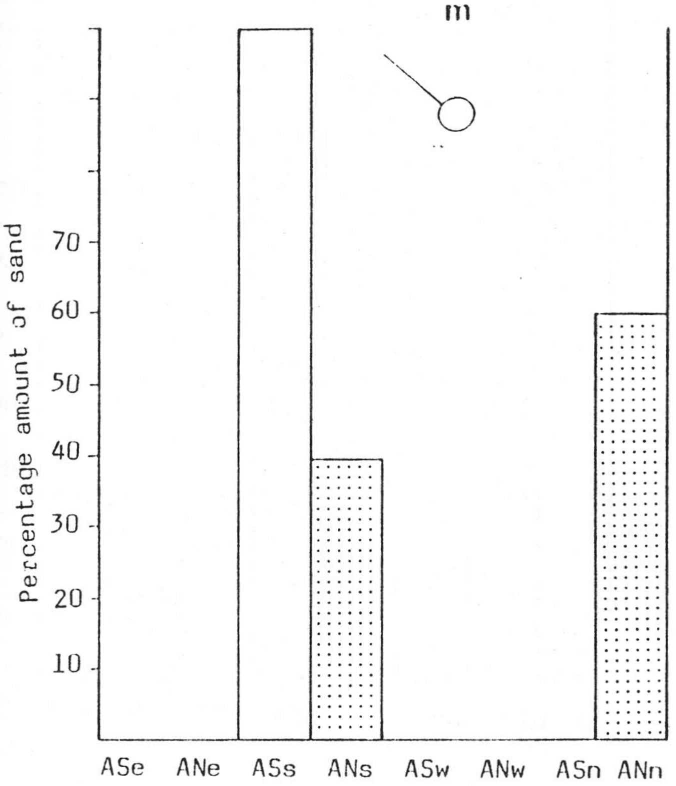
17h00



Day 7

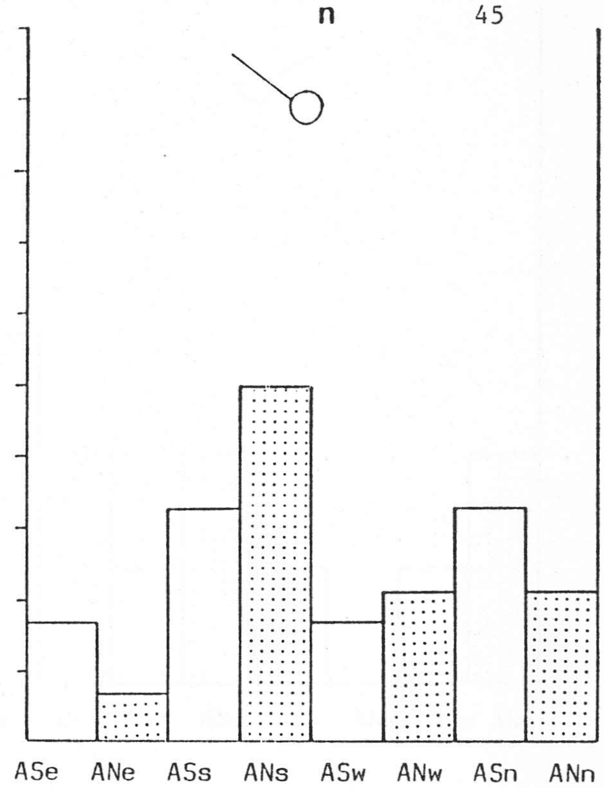
12h00

m



17h00

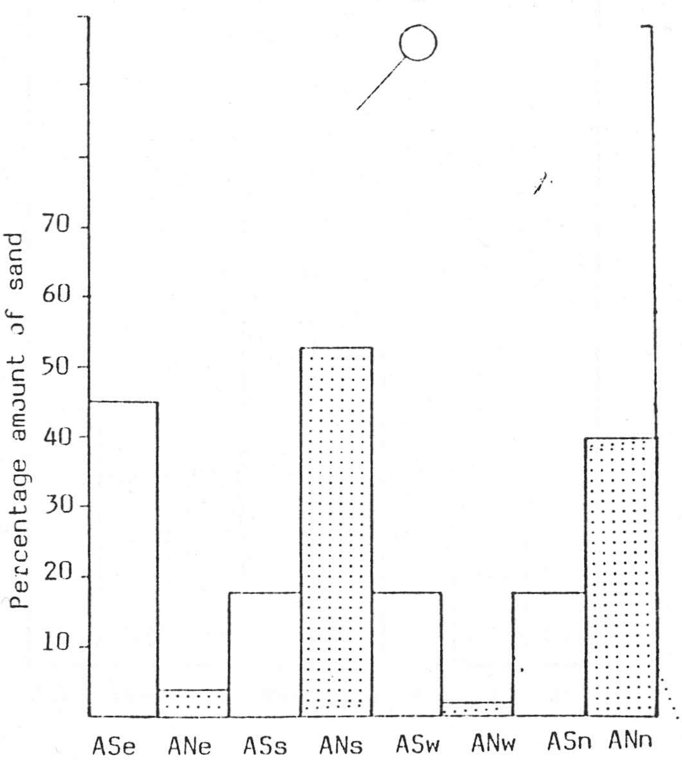
n



Day 8

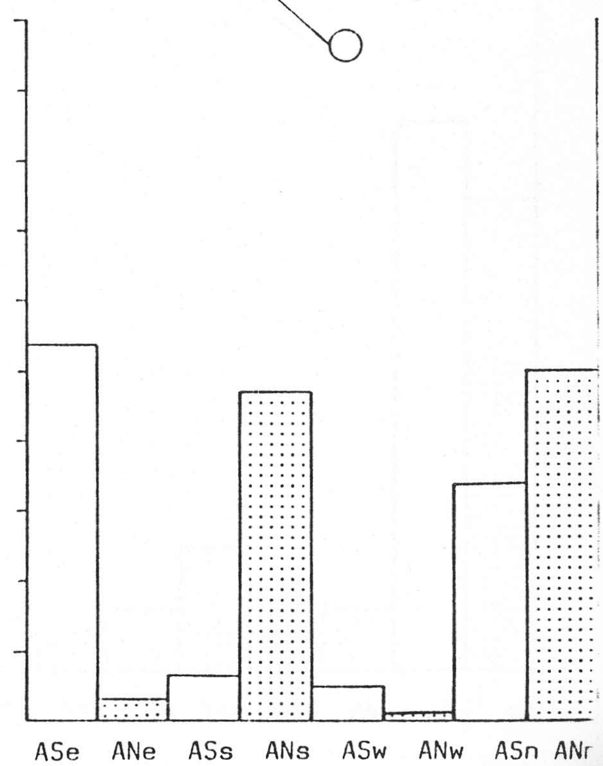
12h00

o

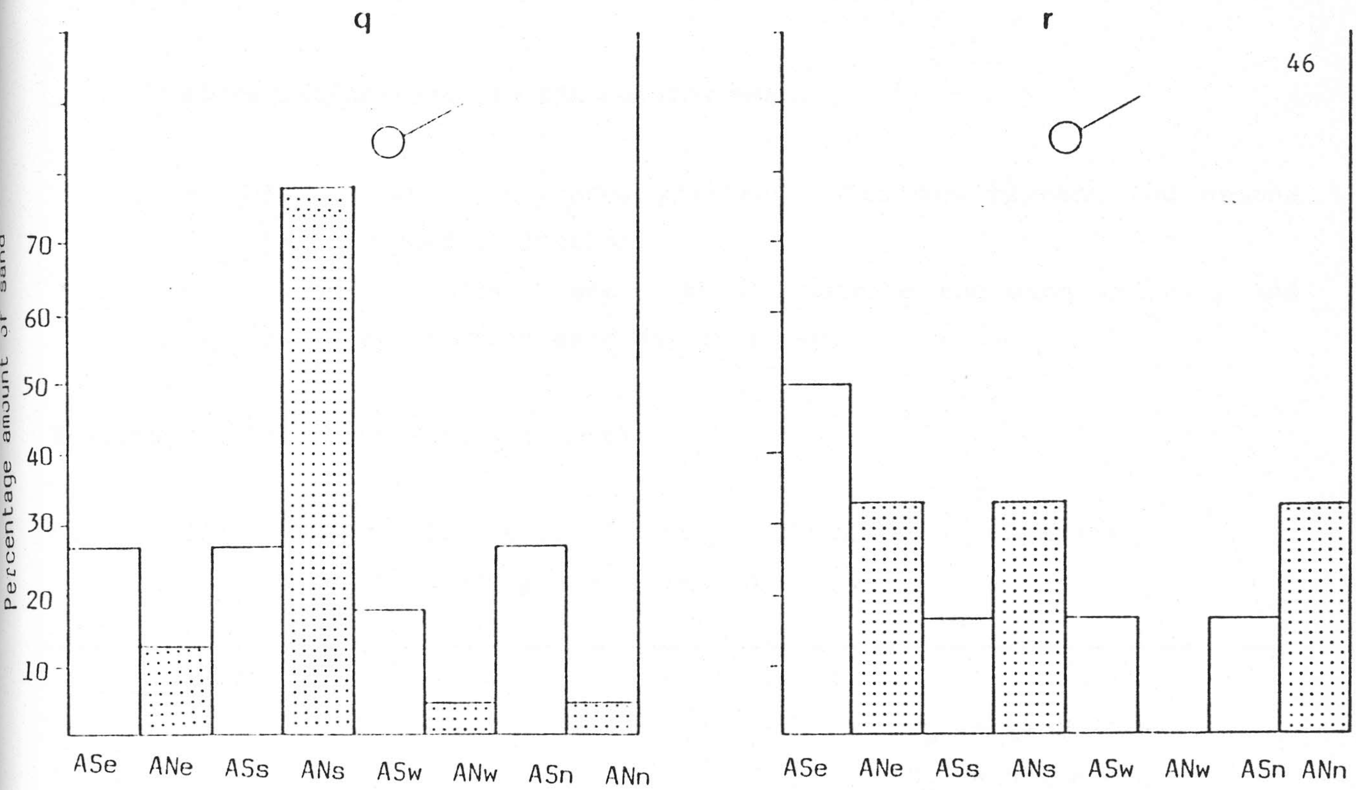


17h00

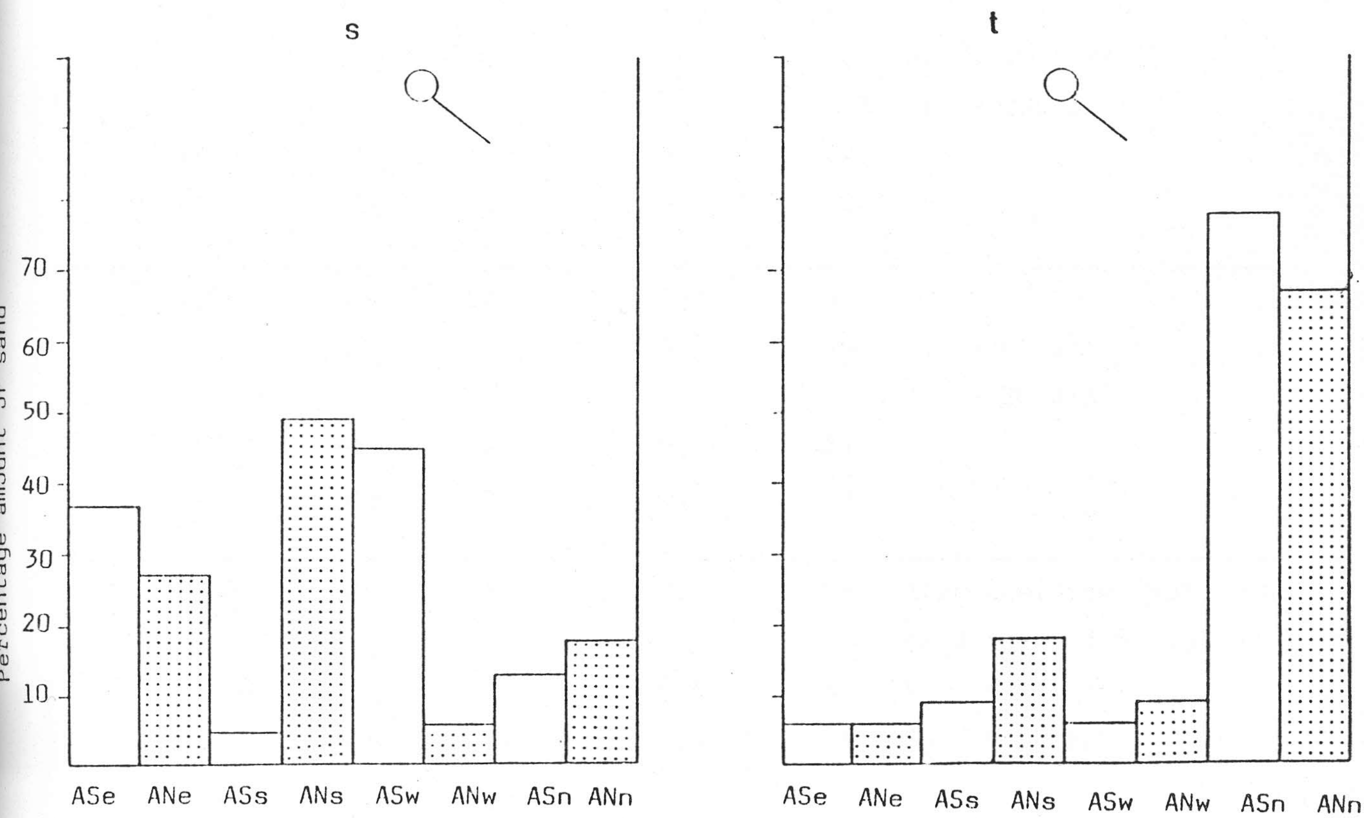
p



12h00 **Day 9** 17h00



12h00 **Day IO** 17h00



Abbreviations used in the columns mean:

- PT column - indicates pit-traps with the highest and second highest sand collection.
- $VV(ms^{-1})$ column - and - RH(%) indicate the wind velocity and humidity at which sand was measured.

Results obtained from Fig. 4.1 (a-t)

Day	Time	PT	Amount of sand (g/hr)	VV (ms^{-1})	RH (%)	Comments
I	12H00	AN_W	334	0,6	21	
		AS_E	101	0,5	21	N_p = 1411 g/hr
						S_p = 581 g/hr
	17H00	AN_W	1077	0,6	15	
		AS_E	480	0,4	15	
II	12H00	AN_W	952	0,4	16	
		AS_E	200	0,8	16	N_p = 1072 g/hr
						Sp = 200 g/hr
	17H00	AN_N	10	0,5	20	
		AN_S	9,2	0,5	20	
III	12H00	AN_N	23	0,3	36	
		AS_E	15	0,5	36	N_p = 41 g/hr
						S_p = 30 g/hr
	17H00	AN_N	18	0,4	35	
		AS_E	15	0,3	35	
IV	12H00	AN_N	3	0,1	38	High humidity (40%) no sand trapped by Sp
	17H00	AN_S	38	0,4	31	N_p = 41 g/hr
		AN_N	15	0,4	31	S_p = 15 g/hr

Day	Time	PT	Amount of sand (g/hr)	VV (ms^{-1})	RH (%)	Comments
V		12H00	AN_S 100	0,3	30	N_p =424 g/hr
			AN_N 23	0,2	30	
		17H00	AN_S 151	0,6	25	
			AN_N 150	0,5	25	
	VI	12H00	AS_E 38	0,5	29	N_p = 75 g/hr S_p = 38 g/hr
			AN_N 20	0,2	34	
		17H00	AN_S 49	0,6	33	
			AN_N 6	0,2	33	
	VII	12H00	AN_N 3	0,4	52	The highest humidity recording (52%) ∴less sand
		17H00	AN_S 7	0,3	29	N_p = 13 g/hr
			AN_W 3	0,3	29	
	VIII	12H00	AN_S 50	0,5	30	N_p = 201 g/hr
			AN_N 37	0,6	30	
		17H00	AN_N 59	0,3	20	
			AN_S 55	0,5	20	
	IX	12H00	AN_S 31	0,4	30	N_p = 36 g/hr S_p = 3 g/hr
			AN_E 5	0,1	30	
		17H00	AS_E 3	0,2	37	High humidity (37%) ∴ less sand

	12H00	AS_W	43	1,8	32	highest wind velocity with moderate humidity
		AS_E	35	1,5	32	N_p = 22 g/hr
X						S_p = 103 g/hr
	17H00	AS_N	25	0,8	35	
		AN_N	22	0,4	37	

Briefly the totals of the highest amount of sand collected for each plant as tabulated above are given below. n=frequency of occurrence.

PT	n	Total grams of sand
ANw	4	2366
ANn	13	392
ANs	9	490
ANe	1	5
ASw	2	58
ASn	1	25
ASs	0	0
ASe	8	887

Tables 1 & 2 have further been condensed to Tables 3,4 & 5. In these tables pit-traps are considered with respect to the summation of daily cycles of wind direction.

The relationship between sand accretion and micro-climatic conditions for individual plants is reflected in Figures 4.2 a&b, and 4.3 a&b. Figure 4.2 a&b should therefore be used in conjunction with Figure 4.3 a&b.

Table 3 a&b

Sp = Salvadora persica

Np = Nara plant

AMOUNT OF SAND TRAPPED

Table 3 a

Sp	45° NE	135° SE	225° SW	315° NW	360° N	Total
AS_E	6	37	645	311	0	999
AS_S	4	8	73	36	0	121
AS_W	3	45	160	69	1	278
AS_N	4	37	75	57	0	173
Total	17	127	953	473	1	1571

Table 3 b

N_p	45° NE	135° SE	225° SW	315° NW	360° N	Total
AN_E	6	16	208	249	1	480
AN_S	32	31	298	423	1	785
AN_W	2	6	1421	967	1	2397
AN_N	3	31	183	292	3	512
Total	43	84	2110	1931	6	4174

Table 4 a&b

TOTAL WIND VELOCITY RECORDED IN PIT-TRAPS DURING LOCAL PREVAILING WINDS (IN DEGREESS)

Table 4 a

SP	NE	SE	SW	NW	N	Total	Average
AS_E	0,6	2,0	2,6	3,0	0,2	8,4	1,7
AS_S	0,7	3,2	2,8	2,8	0,2	9,7	1,9
AS_W	0,5	2,0	3,0	2,4	0	7,9	1,6
AS_N	0,6	2,6	1,7	1,9	0,2	7,0	1,4
Total	2,4	9,8	10,1	10,1	0,6		
Average	0,6	2,5	2,5	2,5	0,2		

Table 4 b

NP	NE	SE	SW	NW	N	Total	Average
AN_E	0,2	2,4	3,5	3,2	0	9,3	1,9
AN_S	0,8	1,2	3,7	3,5	0,2	9,4	1,9
AN_W	0,8	3,0	4,2	3,0	0,2	11,2	2,2
AN_N	0,7	0,9	2,5	2,6	0	6,7	1,3
Total	2,5	7,5	13,9	12,3	0,4		
Average	0,6	1,9	3,5	3,1	0,1		

Table 5a&b

HUMIDITY (RH) OF SP W.R.T. WIND DIRECTION (DD)

Table 5 a

SP	NE	SE	SW	NW	N
Total	68	67	195	254	40
Frequency	2	2	7	8	1
Average	34	34	28	32	40

HUMIDITY (RH) MEASUREMENT W.R.T. WIND DIRECTION (DD)

Table 5 b

NP	NE	SE	SW	NW	N
Total	67	67	188	239	38
Frequency	2	2	7	8	1
Average	34	34	27	30	38

Figure 4.2 a & b: The diurnal variation of wind direction (in degrees) and average wind velocity (in m/s), during data collection period.

Fig 4.2 a: *Salvadora persica*

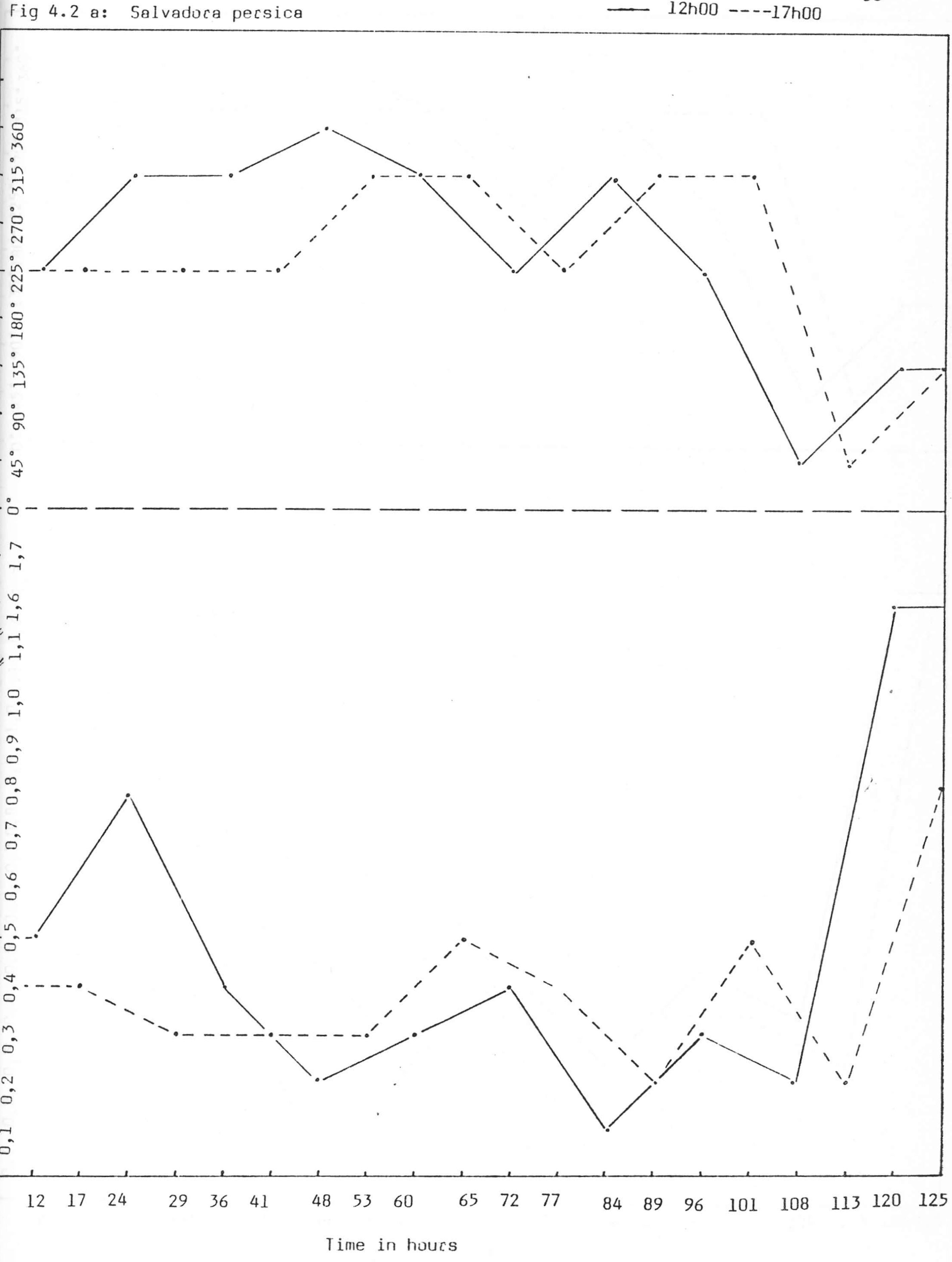


Fig 4.2 b: Naca plant

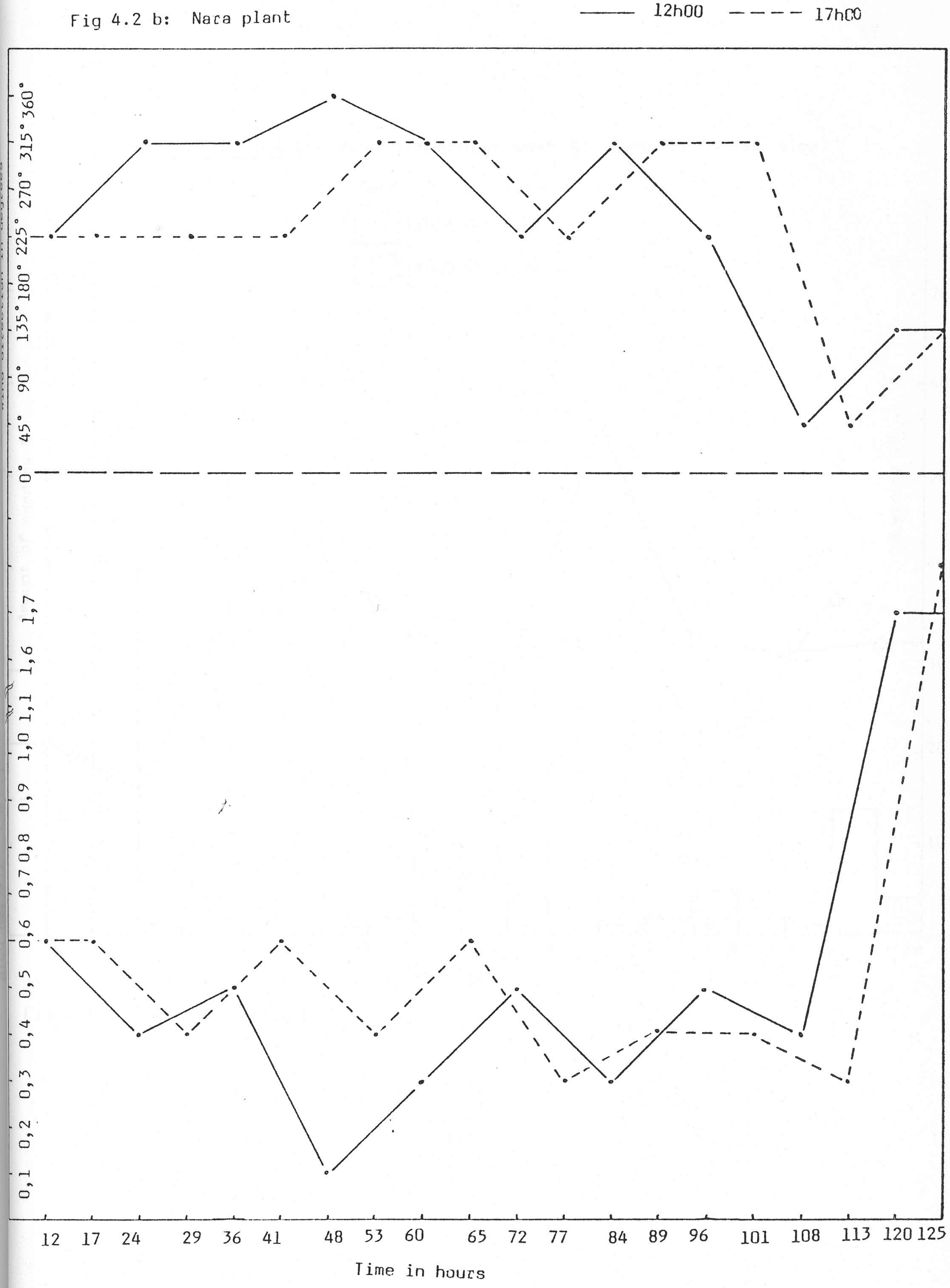


Figure 4.3 a & b: Showing amount of sand (%), humidity (as %), time.

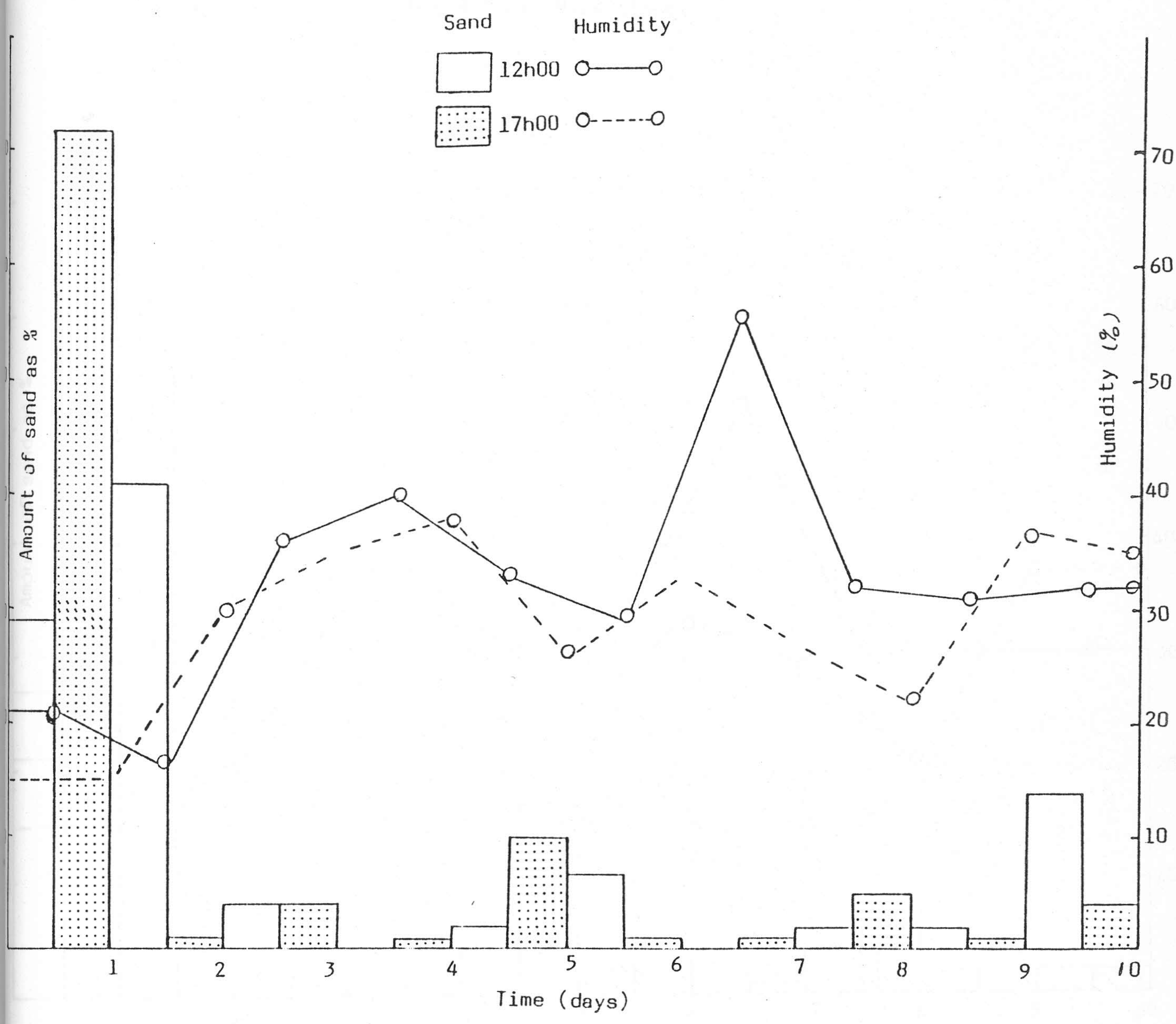


Fig 4.3 a: Salvadora persica

Fig 4.3 b: Naca plant

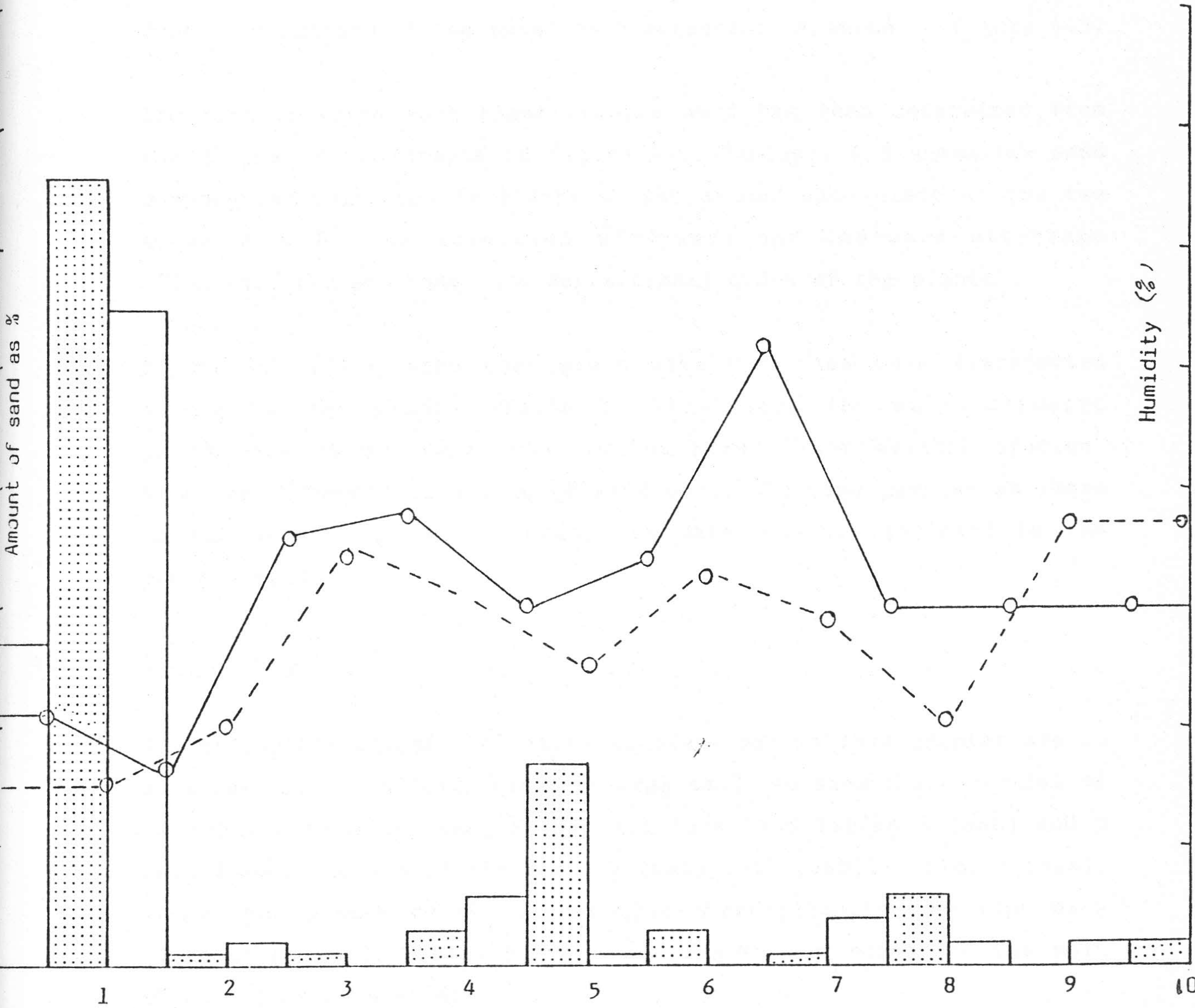


Figure 4.4 illustrates the daily sand collection of the 2 plants, when considering the fact that pit-traps were emptied after every measurement.
Table 6 shows the amount of sand accumulated per plant per day. In this case it is assumed that the pit-traps were not emptied during the data collection period. This gives a better picture of sand accretion rate, and thus the formation and growing of the vegetated dune. The pattern of the total sand accretion is shown in figure 4.5.

The rate at which each plant trapped sand has been determined from the slopes of the graphs in Figure 4.6. Tables 7 & 8 summarize sand movement as collected in pit-traps set around each plant at the two sites A & B. The tabulated wind-ward and lee-ward pit-traps illustrate the erosional and depositional sides of the plants.

Figure 4.7 illustrates what grain size particles were transported around the two plants. Table 9 illustrates the micro-climatic parameters as recorded from Gobabeb First Order Weather Station. Since measurements of volume of sand serve the same purpose as those of the weight of sand records, its data are not included in the present study.

4.4 Conclusions

All graphs histograms and tables as presented in this chapter are to show the ability of each plant to trap sand. To show the potential of each plant to trap sand, Figure 4.1 (a-t) and Tables 3 (a&b) and 6 were drawn. The aim of Figures 4.2 (a&b); 4.3 (a&b); Tables 3 (a&b), 4(a&b) and 9 were to show under what micro-climatic condition each plant traps sand. Tables 6,7 & 8 and Figure 4.6 summarize the main objective of this study.

Figure 4.4: Histograms of amount of sand (%) collected per day per plant.

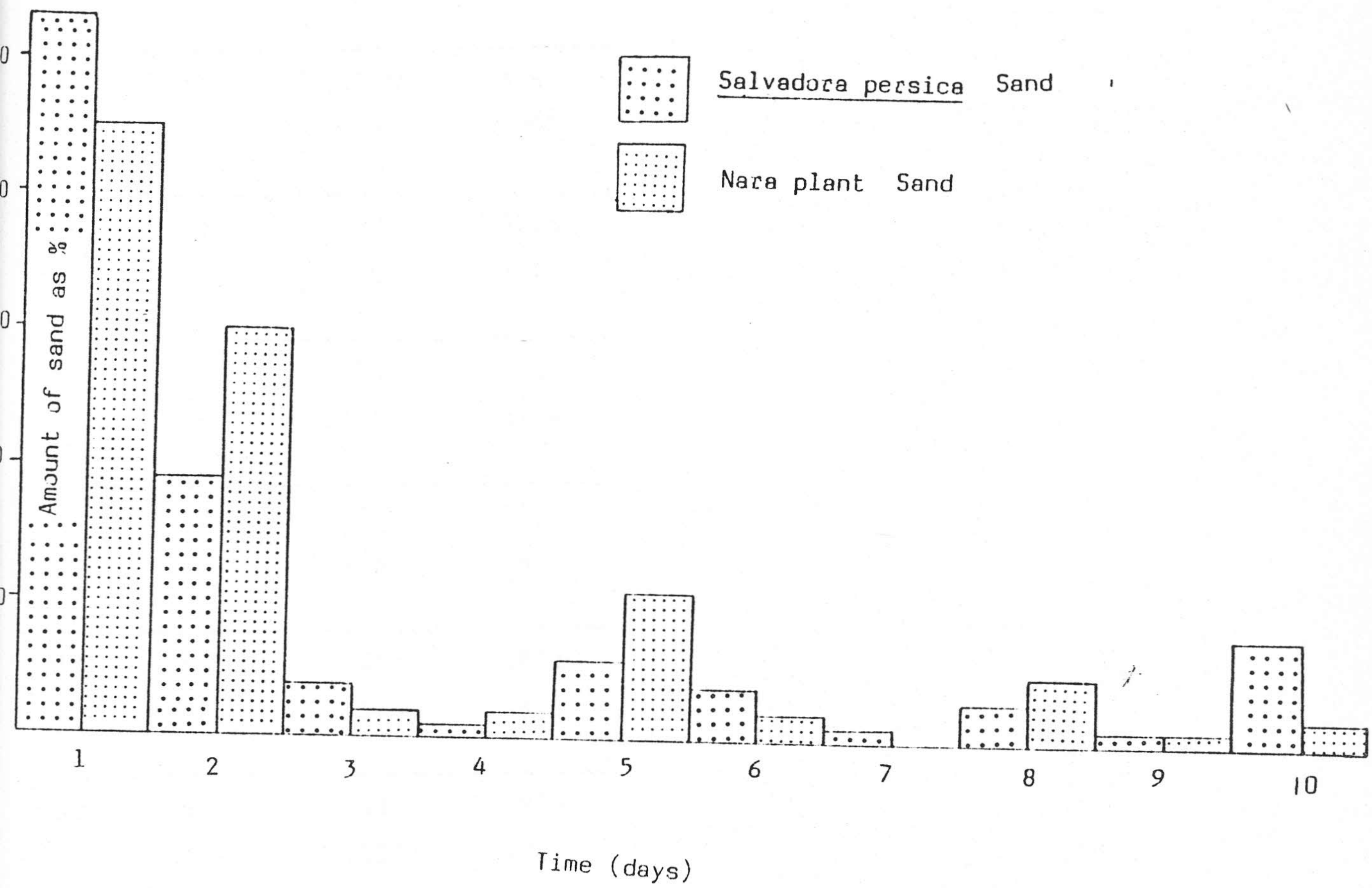


Table 6

SAND ACCRETION AROUND SP & NP

Day	Time	S_p	N_p
1	12	204	609
	17	834	1878
2	24	1117	3122
	29	1129	3146
3	36	1158	3182
	41	1194	3209
4	48	1195	3215
	53	1205	3277
5	60	1216	3407
	65	1307	3729
6	72	1357	3757
	77	1367	3817
7	84	1369	3822
	89	1375	3836
8	96	1386	3929
	101	1427	4047
9	108	1438	4087
	113	1444	4090
10	120	1539	4146
	125	1571	4174

Figure 4.5: Sand accretion (as %) per day per plant.

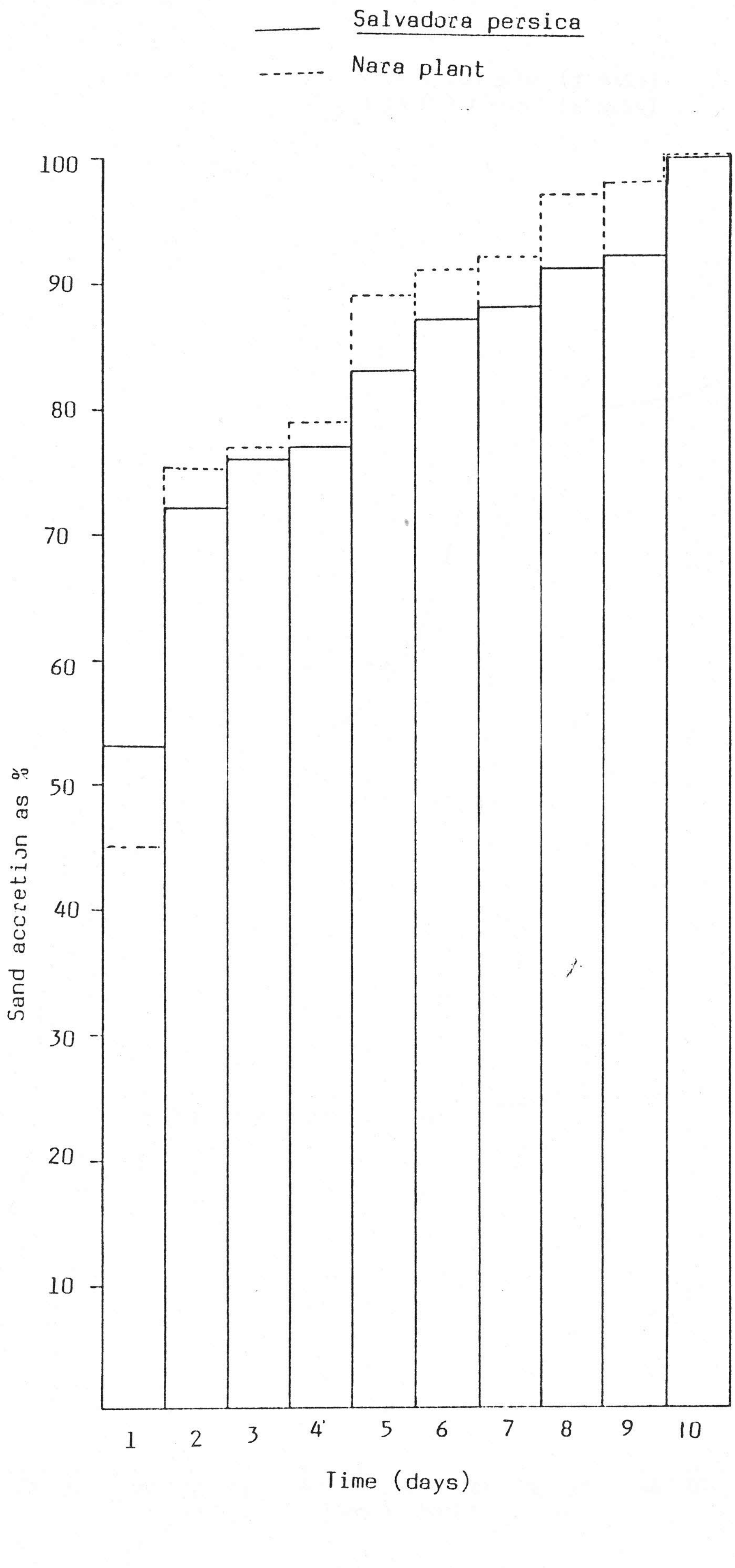


Figure 4.6: Sand accretion rate of Salvadora persica and Nara plant.

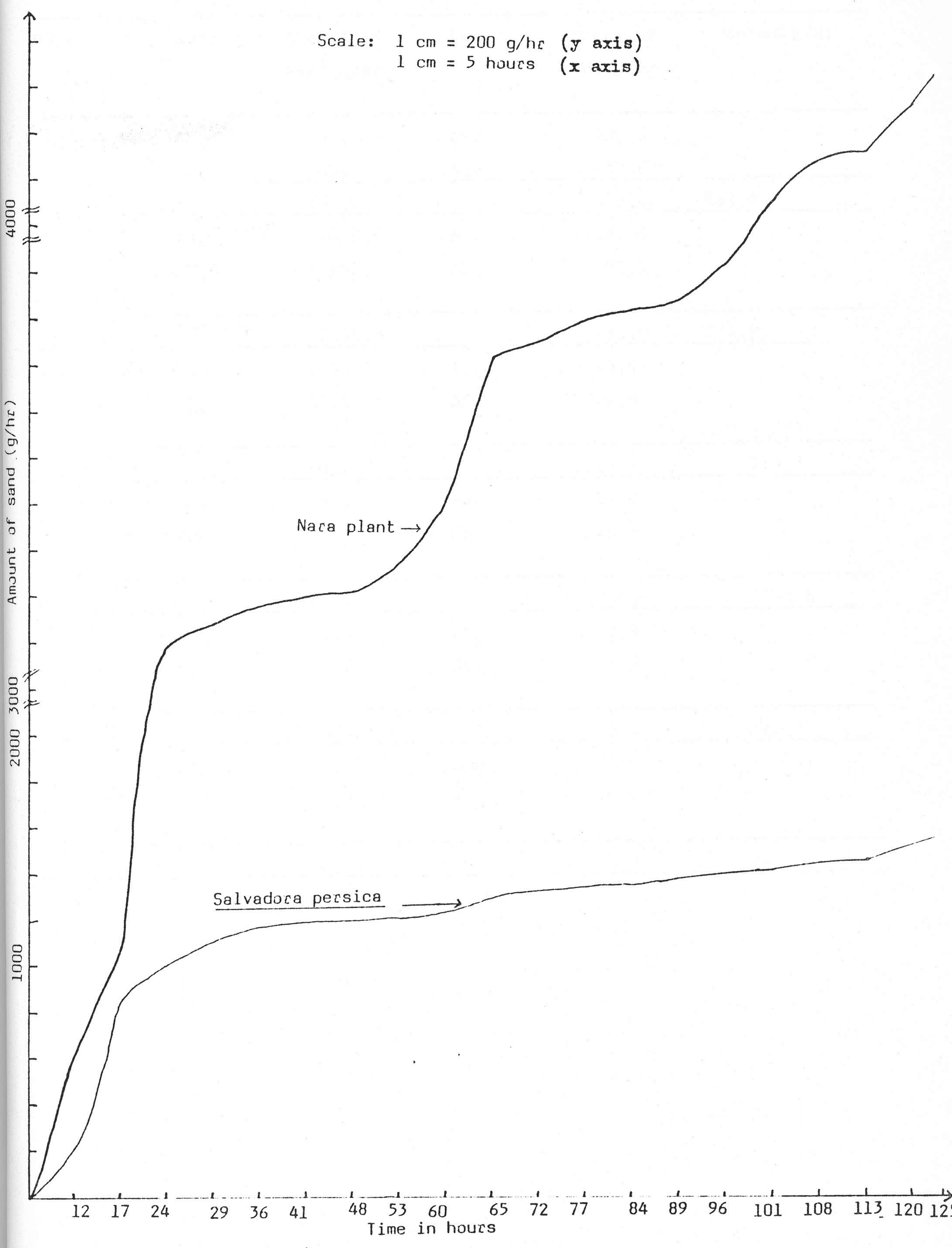


Table 7 **SUMMARY OF SAND MOVEMENT AT SITE A**

Days	dd	WwdPTs	Amount of sand g/hr	LwdPTs	Amount of sand g/hr	Total g/hr
	SW	AS_W	134,0	AS_E	580,8	
		AS_S	60,0	AS_N	58,6	
I			194,0		639,4	833,4
	SW	AN_W	1410,7	AN_E	190,8	
		AN_S	183,1	AN_N	92,2	
			1593,8		283,0	1876,8
	NW	AS_N	20,7	AS_S	15,4	
		AS_w	47,4	AS_E	200,0	
			68,1		215,4	283,5
		AN_N	16,2	AN_S	64,9	
		AN_W	951,7	AN_E	210,8	
II			967,9		275,7	1243,6
	SW	AS_W	2,6	AS_E	2,9	
		AS_S	2,7	AS_N	2,5	
			5,3		5,4	10,7
		AN_W	2,4	AN_E	2,0	
		AN_S	9,8	AN_N	10,2	
			12,2		12,2	24,4

	NW	AS_N	3,3	AS_S	3,2	
		AS_W	8,1	AS_E	15,4	
			11,4		18,6	30,0
		AN_N	23,1	AN_S	4,6	
		AN_W	3,4	AN_E	4,6	
			26,5		9,2	35,7
	SW	AS_W	15,0	AS_E	15,0	
		AS_S	3,0	AS_N	3,0	
III			18,0		18,0	36,0
		AN_W	3,0	AN_E	3,0	
		AN_S	3,0	AN_N	18,0	
			6,0		21,0	27,0
	N	AS_N	0	AS_S	0	
		AN_N	2,5	AN_S	1,0	
			2,5		1,0	3,5
IV	NW	AS_N	3,1	AS_S	1,5	
		AS_W	2,5	AS_E	1,5	
			5,6		3,0	8,6
		AN_N	15,0	AN_S	37,5	
		AN_W	2,5	AN_E	5,9	
			17,5		44,4	61,9

	NW	AS_N	14,3	AS_S	9,0	
		AS_W	7,2	AS_E	70,5	
V						
			21,5		79,5	101,0
		AN_N	173,1	AN_S	250,6	
		AN_W	4,4	AN_E	22,3	
			177,5		272,9	450,4
	SW	AS_S	4,3	AS_N	7,5	
		AS_W	6,1	AS_E	40,4	
VI			10,4		47,9	58,3
		AN_S	51,1	AN_N	26,4	
		AN_W	2,9	AN_E	7,9	
			54,0		34,3	88,3
	NW	AS_N	2,1	AS_S	4.0	
		AS_W	1,2	AS_E	1,2	
VII			3,3		5,2	8,5
		AN_W	6,3	AN_S	9,2	
		AN_N	3,1	AN_E	1,1	
			9,4		10,3	19,7

	SW	AS_S	1,7	AS_N	1,5	
		AS_W	2,4	AS_E	5,0	
			4,1		6,5	10,6
		AN_S	50,4	AN_N	36,5	
		AN_W	2,3	AN_E	4,4	
VIII			52,7		40,9	93,6
	NW	AS_N	14,0	AS_S	2,5	
		AS_W	1,9	AS^E	22,3	
			15,9		24,8	40,7
		AN_N	59,4	AN_S	54,9	
		AN_W	1,2	AN_E	2,9	
			60,6		57,8	118,4
	NE	AS_N	4,5	AS_S	4,4	
		AS^E	6,0	AS_W	2,9	
IX			10,5		7,3	17,8
		AN_N	2,9	AN_S	32,2	
		AN_E	6,0	AN_W	1,5	
			8,9		33,7	42,6
	SE	AS_S	8,1	AS_N	36,6	
		ASE	36,8	AS_W	44,6	
X			44,9		81,2	126,1
		AN_S	30,7	AN_N	31,0	
		ANE	16,2	AN_W	6,3	
			46,9		37,3	84,2

Table 8 **SUMMARY OF SAND MOVEMENT AS COLLECTED IN PIT-TRAPS SET AROUND SALVADORA PERSICA AND NARA PLANT**

Site B

Days	dd	WwdPTs	Amount of sand in g/hr	LwdPTs	Amount of sand in g/hr	Total g/hr
	SW	BS_W	181,4	BSe	780,8	
		BS_S	75,4	BSn	79,3	
			256,8		860,1	1116,9
Day 1	SW	BN_W	2362,4	BNe	401,6	
		BN_S	248,0	BNn	108,4	
			2610,4		510,0	3120,4 Np>Sp
	NW	BSn	8,8	BSs	8,9	
		BSw	25,7	BSe	33,3	
			34,5		42,2	76,7
Day 2	NW	BNn	51,3	BNs	17,4	
		BNw	8,8	BNe	9,6	
			60,1		27,0	87,1 Np>Sp
	Nw	BSn	22,3	BSn	12,0	
		BSw	13,4	BSe	109,5	
			35,7		121,5	157,2
Day 3	Nw	BNn	210,6	BNs	291,2	
		BNw	7,5	BNe	33,5	
			218,1		324,7	542,8 Np>Sp
	Nw	BSN	7,1	BSs	7,2	
		BSw	4,3	BSe	8,9	
Day 4			11,4		16,1	27,5

BNn	9,3	BNs	81,2	
BNw	2,8	BNe	9,8	
	12,1		91,0	103,1 Np>Sp

Figure 4.7: Histograms of the average grain size particles recorded around Salvadora persica and Nara plant.

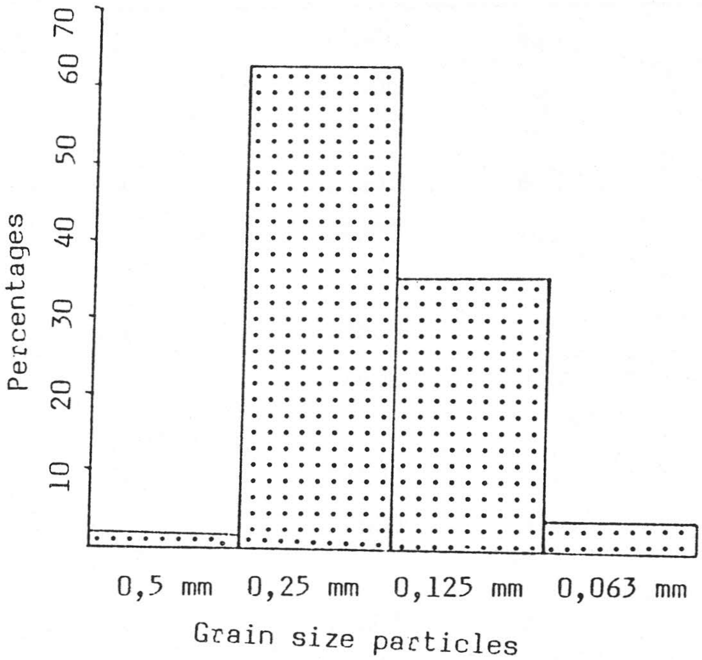


Table. 9 **WIND VELOCITIES (VV) AND HUMIDITY (RH) READINGS, AS RECORDED FROM GOBABEB WEATHER STATION**

Day	Time	VV (ms^{-1})	RH (%)
1	12h00	6,5	20
	17h00	7,0	16
2	12h00	6,0	21
	17h00	7,5	21
3	12h00	2,0	26
	17h00	3,5	30
4	12h00	4,0	40
	17h00	5,0	38
5	12h00	5,0	36
	17h00	6,0	35
6	12h00	2,5	29
	17h00	3,5	27
7	12h00	2,5	32
	17h00	0,5	20
8	12h00	4,5	31
	17h00	2,4	20
9	12h00	1,5	37
	17h00	2,5	31
10	12h00	6,0	22
	17h00	8,0	17

Figure 4.8 a & b: For comparison; using Gobabeb humidity and wind velocity records.

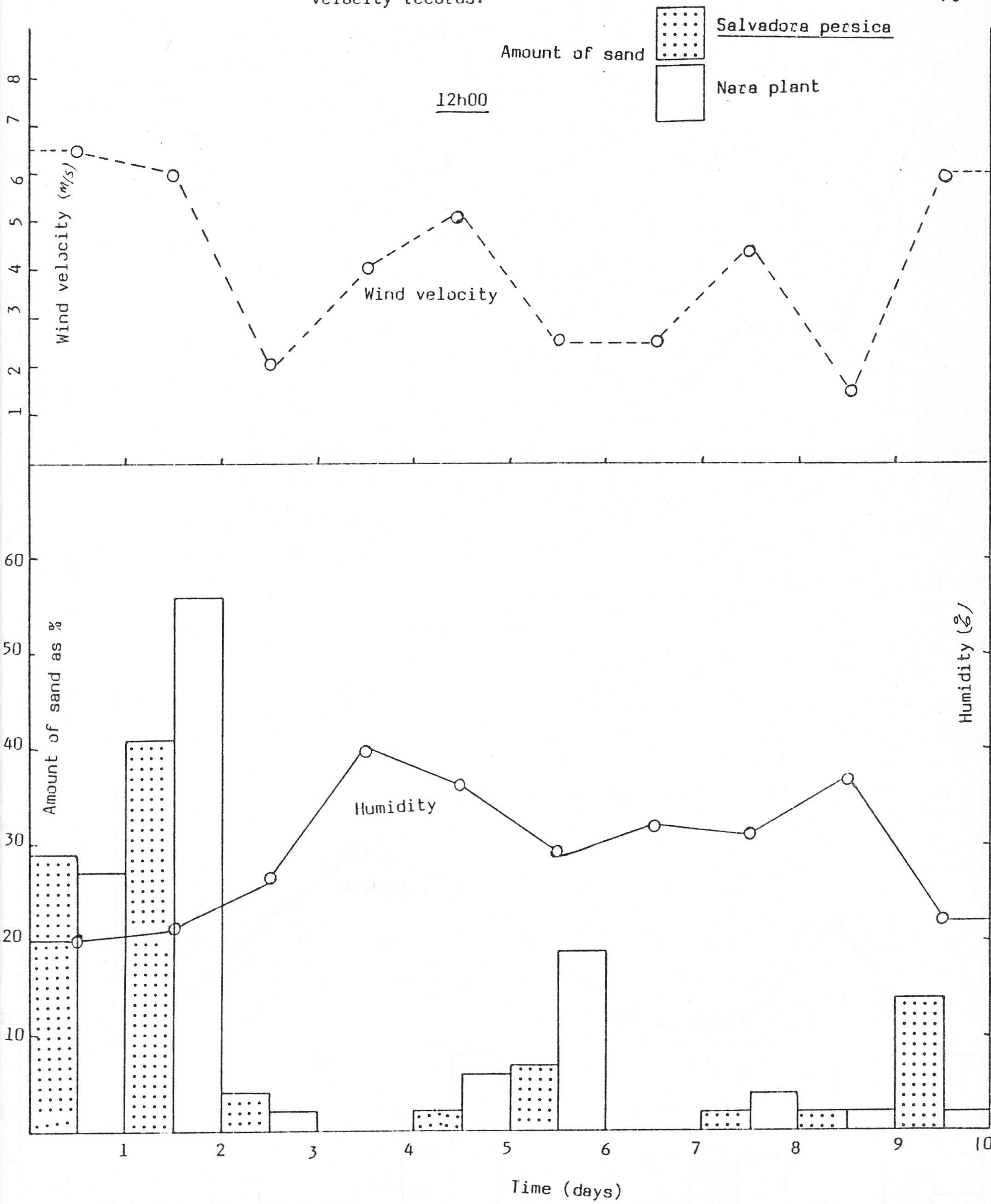
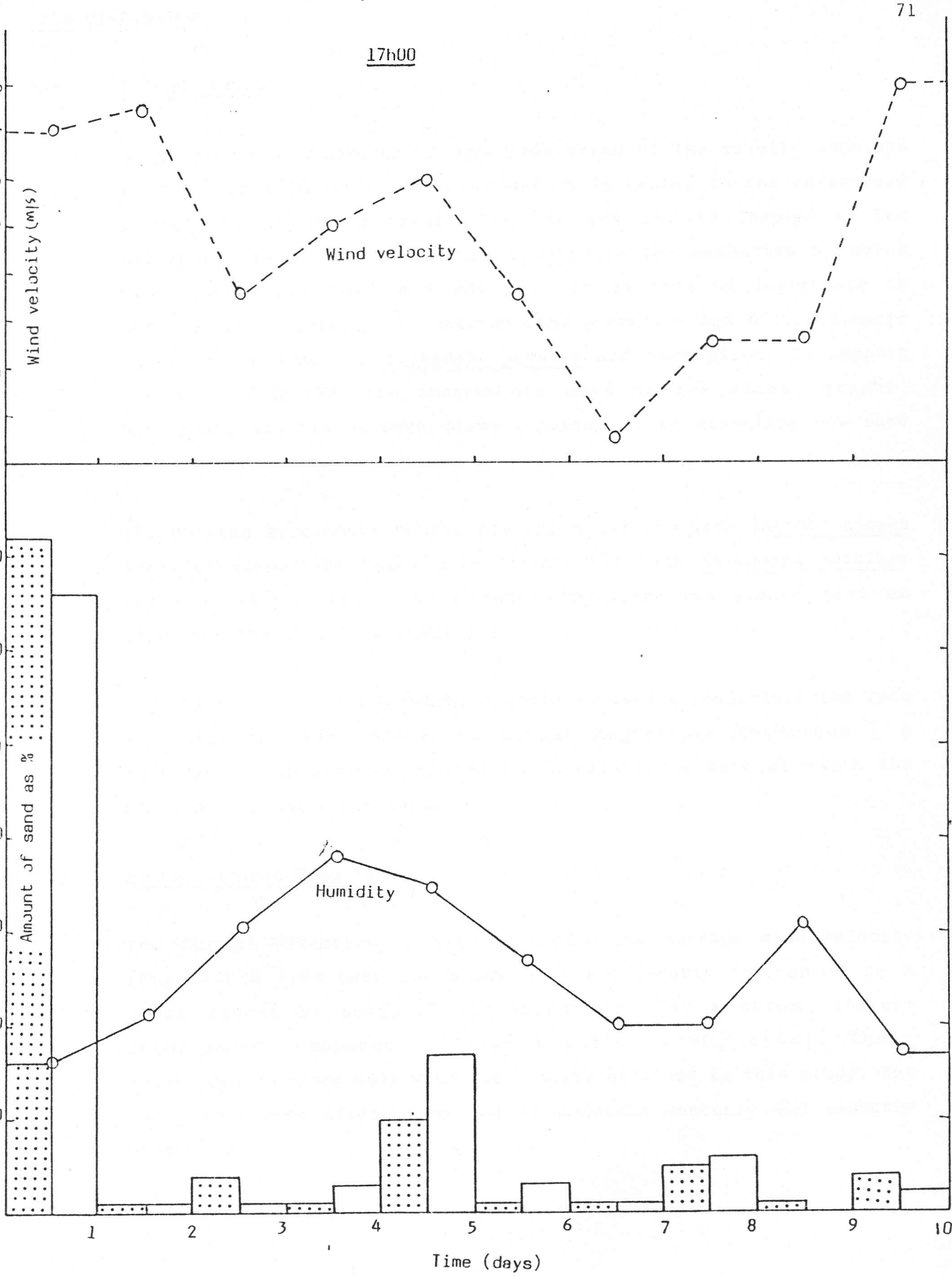


Figure 4.8 b : For comparison; using Gobabeb humidity and wind velocity records.



CHAPTER 5

DATA DISCUSSION

5.1 Introduction

In showing the relevance or appropriateness of the results obtained from the data analysed, data discussion is geared to the three-fold objectives of the present study as set out in Chapter 1. The discussion is a further attempt to explain the mechanism by which vegetated dunes form and advance. It is thus of importance to consider the relationships between sand accretion and micro-climatic conditions around the Salvadora persica and Nara plant. To support the data collected from instruments used at the sites, graphs, histograms and tables were drawn (chapter 4) to visualize how sand accumulated.

The working hypothesis of the present study is: Nara (Acanthosicyos horrida) accumulates sand more effectively than Salvadora persica; and that micro-climatic conditions around the two plants have an effect on the rate of accumulation.

Bagnold's (1941) sand movement formula is used to calculate the rate of potential sand movement. Linear Regression technique (a mathematical technique) is used to calculate the rate at which the individual plant traps sand.

5.2 Micro-climatic Results

The diurnal variation of wind direction and average wind velocity (Fig. 4.2 & 4.8) over the study area are clearly influenced to a great extent by seasonal variations and "by a strong thermo-topographic component", (Tyson & Seely, 1980, p148). Their observations accord well with the results obtained in this study. The two plants were affected by low to moderate westerly and easterly winds.

The surprisingly low wind velocity (1,5 ms^{-1}) recorded in Table 9 yielded sand which was able to be weighed on a pesola balance; - a point which seems to contradict Bagnold's (1941) threshold wind velocity of 4,4 ms^{-1}. The other factor considered in this study is the fact of the position of pit-traps. These sand collectors were placed such that the wind-effect affects both plants equally. It is for this reason that Bagnold's (1941) threshold velocity theory should be looked for among the data presented in Table 9 and Figure 4.8.

Watson's (1987, p511) contribution is a probable answer to the question why sand was trapped when wind velocity was very very low (1,5 ms^{-1}). According to him sand movement is not a "response solely to wind velocity, but to wind shear over the dune surface, and that the rate of sand transport on a sloping surface is influenced by the gradient". The best evidence Watson (1987) has observed was that dunes do increase in height despite high wind velocity. Although the present study is limited in scope, the wind velocity measurements provide a new insight into the dynamics of vegetated dunes. According to Lancaster (1986, p518) wind velocity measurements can be used to develop more sophisticated and reliable models of dune morphology. Therefore, to him, the variation of surface shear stress with the overall wind velocity suggests that sediment transport in strong and gentle winds may be very different, but it will still support his arguments. Lancaster (1986) maintains that wind velocity does have an important effect on dune morphology. His arguments clarify the purpose of the present study of considering wind velocity and its important effect on vegetated dunes.

Wind velocity data (Table 9) recorded at Gobabeb First Order Weather Station reveals that 10 out of 20 readings were, in Mabutt's (1977) terms, geomorphologically effective winds. The presence of sand trapped when wind velocity was greater than 4,4 ms^{-1} is therefore not in doubt. But then Livingstone (1986) gives an account of sand

trapped when wind velocity was less than 4,4ms^{-1}.
Figures 4.1(a-t) and 4.2, and Tables 4 a&b, 5 a&b show that at each site around each plant wind velocity and humidity change. Livingstone (1986) explains that such changes are caused by effects at two scales superimposed on one another. The first scale is the macro-scale of an erg where the regional wind changes speed and direction in response to the regional pressure gradient. But for a dune study covering a relatively small area, he assumes a constant regional wind velocity. It is for this reason that Table 9 and Figure 4.8 were drawn using Gobabeb weather data.

The second scale is more important for the results for individual plants, (Figure 4.1; 4.2; Tables 4 and 5). There is a pattern of wind velocity change across the vegetated dune profile. According to Livingstone (1986), wind velocity varies as a response to the convergence and divergence of streamlines caused by the intrusion of the dune sand into the wind flow. This may possibly give an account of recording velocity which enables sand to be trapped around an obstacle.

It should further be noted that wind velocity is not only altered by roughness of the surface and height of the plant, but also by pit-traps which are forms of depressions.

Table 9 further illustrates that eight out of ten day's readings show that 12h00 humidity measurements are higher as compared to the 17h00 records. This is without doubt attributed or influenced by foggy mornings as experienced almost every day (Personal observation).

On the other hand Table 9 also reveals that in eight out of 10 day's measurements, the 17h00 wind velocity readings are higher than the 12h00 records. That is, wind velocity generally intensifies in the afternoon. Such winds cause evaporation and sand surface dries out to give low humidity measurements of the air and thus of sand. Therefore wind velocity and humidity show an inversely proportional wind velocity and humidity show an inversely proportional relationship.

5.3 Sand measurement results

The results of day 4 and day 7 on the histograms read that the southern and western pit-traps of Salvadora persica had 100% sand collection. But these results are an indication that those were the only pit-traps which collected a very small amount of sand, almost nil.

The Nara western pit-trap collected most sand during the present study (Table 3a&b), - a point which may point to a North-westward sand movement towards the Kuiseb River as the meander bend is North-west at Site A.

Salvadora persica eastern pit-trap collected the second highest sand amount (Table 3 a&b). The reason might be the dune which is about 100m east of the plant, while east of the Nara plant there is a gravel plain. Perhaps were it not for the dune, Nara plant would have collect even the second highest sand as the analysis shows clearly that even eddies add their small amount of sand to the shrub.

Table 8 is the only summarized data compiled from site B. Its data give similar results as obtained from site A. One can conclude with certainty that the two plants, when considered individually, behave in a similar way in spite of being in another location. The control site has therefore achieved the purpose it was designed for, despite incomplete records.
In order to understand how vegetated dunes undergo morphological evolution, the factors which influence erosion, sand transport and deposition must be elucidated.

Tables 7 & 8 summarize the sand measurement data as collected from site A and B respectively. The data have been added into 38 groups, with the aim of recording the behaviour of wind-ward and lee-ward greater sand amounts than the wind-ward pit-traps; 12 records of the wind-ward pit-traps showed greater sand amounts than those of the lee-ward; and 3 groups showed equal amounts of sand on the lee-ward and wind-ward pit-traps. These simply mean that the lee-ward pit-traps were on the depositional side and that the wind-ward pit-traps were on the erosional side. These results fit well into the findings of Robinson and Seely (1980), Lancaster (1985), calculations by Lai & Wu (1978) as quoted by Watson (1987), and Watson himself (1987). They maintain the point that erosion would be on the steepest wind-ward sides, and deposition would be in the lee of the dune crest. Therefore, more sand accumulates on the lee-ward side.

In the present study the equation for computing potential sand transport rate from meteorological observations was used. The formula which comes from Bagnold's (1941) equation, states:

$$Q = \frac{1.0 \times 10.0^{-4}.\ t.\ (v-v_t)^3}{(\log 100z)^3}$$ (after Lancaster, 1985,p608)

where Q = the rate of potential sand movement,

z = the height of the wind recorder

t = the number of hours which a wind of given velocity (v) blows, and

v_t= the threshold velocity for sand movement, (4.4 ms^{-1}).

In the context of the present study, z = 3m (Gobabeb wind recorder, above a gravel surface), t = 5 hours; for v substitute wind velocities in Table 9. In all calculations for Q, the answer was nil. This proves that no potential wind transporting sand was blowing.

According to Lancaster (1985, p608), Q formula gives a reliable index of the rate of potential sand movement. He further maintains that in the Central Namib Desert areas, the total and resultant sand transport rates are low. These areas he considers as areas of net sand accumulation.

Sand is also deposited where the plants have some binding effect and

possibly where increased rainfall and floods add to the moisture content of the soil.
Answers to questions posed in Chapter 1 are summarised by Lancaster (1985) as follows: vegetated dunes (large dunes) develop in areas where the rate of sand transport is low relative to sand supply. This implies that throughput of sand is slow and accumulation will result.

Grain size particles

Investigations of grain size composition in this study indicate that the diameters were 0,5mm; 0,25mm; 0,125mm and 0,06mm (Figure 4.7). Similar results by Harmse's (1982) Namib sample analysis, and Lancaster (1981) show that dunes are composed of sand in the medium to fine sections with mean grain sizes in the range 0,149 - 0,27mm.

Cooke and Warren (1973, p30) report that: In the Tenere Desert in the Republic of Niger, most coarser sands of dunes have a bimodal grain-size distribution with an important coarser mode at about 0,6mm. Since sandflow is a power function of windspeed, wind records of that area show that winds which are capable of moving such sands (0,6mm) do not occur more than about 10 times in the year, and are much rarer than this.

Further accounts by Seely et al (1981), and Ward (1983) show that the sands in the dune hummocks in the central Namib were derived by the aeolian reworking of mixed dune and river sand assemblage which characterises the Kuiseb bed load. Such observations by Seely et al (1981) confirms that dune hummocks form in response to the lack of strong regular flooding of the Kuiseb River in its lower reaches.

Sand grains trapped at the base of vegetated dunes are somewhat coarser. Bagnold (1941) noted that since the larger grains are heavier they are more likely to roll down further or not jump (saltate) so high. According to Robinson and Seely (1980, p186) vegetation and other micro-relief anomalies may locally alter grain size distributions, but the overall trend is for coarser sand to occur towards the lower dune and finer sands upslope.

5.4 Comparison

When Salvadora persica and Nara plant data were analysed, the following comparable results were obtained:

The rate at which sand accumulate was calculated from the slope of the graph in Figure 4.6. These curves look awkward, but useful information was derived from these. To obtain a mathematically best-fitting curve through the data points, the curve denoted as $y = y(t)$ is considered. The rate of sand accumulation was then obtained by computing the slope of the curve which is:

$$\text{rate} = \frac{dy}{dt}$$

The wind which rose appreciably above the threshold velocity, and also low humidity caused the curves in Figure 4.6 to increase rapidly within the first 24 hours. When these points are omitted the remaining data points are consistent and almost linear. Using the method of linear regression one obtains the best fitting straight lines. For Salvadora persica the line is expressed as:

hour

24 - 125 : $y_1(t) = 1006 + 4{,}24t$

The rate at which Salvadora persica accumulates sand is:

$$\text{rate} = \frac{dy_1}{dt} = 4{,}24 \text{ g/hr}$$

For Nara plant proceed as above. But a high sand increment can also be seen between the 60th hour and 65th hour. The wind factor causes such and increment. The best fitting straight lines obtained by the method of linear regression are as follows:

hour

24 - 53 : $y_2(t) = 3005 + 4{,}84\ t$

65 - 96 : $y_3(t) = 3345 + 5{,}83\ t$

The rate of sand accumulation is the average of the rates of the two curves y_2 and y_3 ie:

$$\text{rate} = \frac{4.84 + 5.83}{2} = 5{,}335 \text{ g/hr}$$

From the above calculations it is determined that Salvadora persica has a lower rate of sand accumulation than Nara plant. This analysis presents solutions to the problem statements in Chapter 1 (section 1.1) and thus answers the first and second objectives of the present study.

From the foregoing solution it is clear that over a surface of loose sand where humidity is low, a wind of given strength will derive sand at a certain rate depending on the character of the sand. Bagnold (1941, p70) maintains that "the rate of sand movement increases with increasing diversity of grain size. The intensity of sand movement adjusts itself to the strength of the wind". The results of the present study emphasize the fundamental property possessed by wind-blown sand accumulating around plants and other obstacles, which is :"A given wind can transport sand over a hard immobile surface (eg. wind-ward side of dunes) at a considerably greater rate than over a loose sand surface" (eg lee-ward side of dunes), (Bagnold, 1941, p72). Gentle winds ranging between 1,5 - 8,0 ms^{-1} were effective winds depending on the air and sand particle humidity. Therefore the reciprocal behaviour of wind velocity and humidity is an important factor in determining the geomorphological significance of wind flow. In the context of the present study the most effective winds will be winds of high velocity with very low humidity (less than 15%). Since there was sand recorded in pit-traps when wind velocity was below 4,4ms^{-1} and that less sand was recorded when wind velocity was 8,0 ms^{-1} with 17% humidity, this study finds it difficult to equate Bagnold's threshold velocity to these results. However, this study reports that sand can be transported even if wind velocity is below Bagnold's (1941) threshold velocity (4,4ms^{-1}).

Similar results by Cooke & Warren (1973, p30) show that:

sands with a grain-size of about 0,25mm can be distributed by much more frequent wind and the magnitude-frequency relationship means that winds of a lower magnitude move the greater proportion of the finer sands.

The measurements of the total sand accumulated by the two plants as shown in Table 6 and Figure 4.5, and together with the summary in Tables 7 & 8 clearly illustrate that Nara (Acanthosicyos horrida) accumulates sand more effectively than Salvadora persica. These results together with the calculated rates of sand accretion enable the present study to accept the hypothesis.

The wire peg technique was intended to illustrate the degree of change in the dimensions of vegetated dunes, or lack thereof. The full potential of this method was not realised.
This means that the data were not significant enough to draw strong conclusions. However, the June 1988 observations indicated that Nara dune had grown higher (approximately 35cm) and bigger in width than was the case in January 1988, (Personal observation). But the Nara's leaflessness can be another factor which makes throughput of sand easy and thus account for more sand trapped by the plant.

The behaviour of the two plants can be attributed to a combination of factors, such as age of plant, temperature, moisture, source of sand, gradient especially the fact that the Namib Desert possess a steep west-east climatic gradient, according to Besler (1972) as quoted by Ward (1983, p22). The formation of vegetated dunes is probably boosted by the ready source of sands of the Namib Sand Sea. (Ward, 1983).

5.5 Conclusions and Recommendations

Wind velocities as recorded at the Nara plant do not decrease much as compared to wind velocities recorded at Salvadora persica. This implies that Nara plant does not retard wind velocity as Salvadora persica does. This may result to more sand passing through the Nara plant.

The comparatively low rates of sand accretion were reflected by low wind velocity of, often, less than 4,0 ms^{-1}. If wind energy is of sufficient magnitude to promote sand movement across and past the plant, the development of a vegetated dune will result. Sand movement in the study area was facilitated by the infrequent rainfall. Wind and humidity are by no means the only processes enhancing sand accretion, but a combination of factors is accountable for that.

Recommendations

In this report it is recommended that:

1. A further long term programme is necessary to examine the growth or the increase in dimensions (height and width) of the Salvadora persica and Nara dunes.

2. Since Nara and Salvadora persica have both a spreading growth pattern, it is thus necessary to further investigate their growth rate. This may enable the two shrubs to be used and utilized more intensively for future sand stabilization of sites.

3. A study should be made to find out what grain size particles are transported by wind velocities greater than 4,4 ms^{-1} and less than 4,4 ms^{-1}.

According to Holmes Rolston III "destroying species is like tearing pages out of an unread book, written in a language humans hardly know how to read". It is with these words in mind that the need exists to preserve and conserve plants for ecological and economical use, such as the two shrubs discussed in the present study.

CHAPTER 6

CONCLUSIONS

The principal aim of the present study was to provide information concerning Salvadora persica and Nara (Acanthosicyos horrida) on their effectiveness in sand accretion.

Salvadora persica traps less sand and lets a small amount of sand pass through. Therefore, the result given in this report is: Nara (Acanthosicyos horrida) accumulates sand more effectively than Salvadora persica. The study also acknowledges the fact that the trapping potential of a plant does not automatically imply stabilization.

The study showed that sand movement is affected by micro-climatic conditions around the plant.

The present study along with those by Ward (1983) and others, has shown that much can be discovered from process studies of vegetated dunes. There exists still considerable scope for more information to be gleaned from careful field investigations of the relationship between wind regime, sand movement and vegetated dune.

There is therefore an urgent need for preserving and conserving the present desert vegetations which during the anti-desertification process act as stabilizing tools.

Vegetation under certain micro climatic conditions will continue to enhance sand trapping potential. The Namib Sand Sea is advancing towards the town of Walvis Bay. This drift sand is also encroaching on the Kuiseb River. It will ultimately alter the river course, or block it. The sand intrusion in town will make life undesirable for the inhabitants. The two Namib plant species as considered in the present study are thus representatives of the sand accretion potential of desert vegetation of the world. They could prove valuable allies in the struggle to keep back the desert sand from the Kuiseb River and the town. The Nara, on these results, appears far more efficient than Salvadora persica, at high relative humidities; Salvadora persica appears more efficient at high wind velocities.

ABBREVIATIONS USED IN TABLES, HISTOGRAMS AND DIAGRAMS

dd -	wind direction	
VV -	wind velocity	
RH -	relative humidity	
SW -	south-west	
NW -	north-west	
NE -	north-east	
SE -	south-east	
N -	north	
AS_E-	site A	Salvadora persica east pit-trap
AS_S-	site A	Salvadora persica west pit-trap
AS_W-	site A	Salvadora persica north pit-trap
AS_N-	site A	Salvadora persica east pit-trap
AN_E-	site A	Nara east pit-trap
AN_S-	site A	Nara south pit-trap
AN_W-	site A	Nara west pit-trap
AN_N-	site A	Nara north pit-trap
BS_E-	site B	salvadora persica east pit-trap
BS_S-	site B	salvadora persica south pit-trap
BS_W-	site B	salvadora persica west pit-trap
BS_N	site B	salvadora persica north pit-trap
BN_E-	site B	Nara east pit-trap
BN_S-	site B	Nara south pit-trap
BN_W-	site B	Nara west pit-trap
BN_N-	site B	Nara north pit-trap
Sp-	Salvadora persica	
Np-	Nara plant	
PT-	pit-trap	
g/hr-	grams per hour	
ms^{-1}(m/s)-	metres per second	
Np>Sp-	Total amount of sand of Nara plant is higher than that of Salvadora persica	
n-	frequency of occurrence	

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