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2 papers:
(1) Willow-Twig screens on dunes in Netherlands
(2) Dune Mgt in Denmark
(J. Tomlinson has full proceedings)

Hedeselskabet, Denmark **July, 26-30, 1993**

Protection of Sand Dunes

The Impact of Willow-Twig Wind Screens on Sand Movement

by: P.M. van Dijk, W.A. Hollemans and W.P. Spaan.

Abstract

In coastal management willow-twig wind screens, placed in the transition zone from beach to fore dune ridge, are used to trap and retain wind borne sand. In this study the effects of such wind screens are quantified. On the island of Schiermonnikoog (The Netherlands), three plots were instrumented with erosion pins and sediment traps: (1) the beach and dune foot, (2) a seaward dune slope with wind screens and (3) a seaward dune slope without wind screens. Sediment transport and surface height changes were determined for six wind erosion events. Results show that wind screens are very efficient in trapping wind borne sand. They reduce sediment transport up slope of the wind screens to a negligible level, therewith affecting the supply of wind blown sand to backlying dune area.

Presentation

INTRODUCTION

The transition zone from sea to land, comprising the under-water shore, the beach and the dunes, is continuously subject to changes. Between the subsystems, sediment transport takes place by water and wind action (Figure 1). A seasonally determined trend can be recognized in these sediment exchange processes. High tide flows may supply sediment to the beach, but during winter storms they often remove large amounts of sand from the beach and fore dune ridge. During spring and summertime, strong landward winds carry dry beach sand towards the fore dune ridge or even further inland. In an ideal situation, sediment losses at the fore dune ridge caused by water erosion during wintertime are more or less counterbalanced by wind blown sand during drier periods.

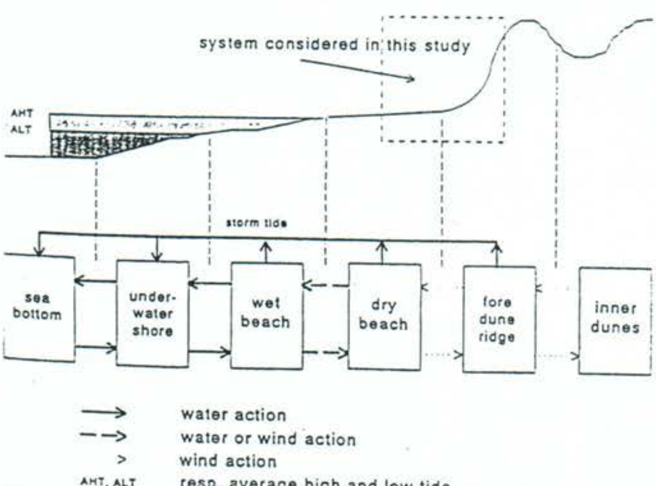

Figure 1. Schematic overview of sediment transport processes between subsystems of a sand dune coast.

Stolk (1989), however, analyzed Dutch shore line changes of the last hundred years and found that the main part of the Dutch coast is subject to erosion rather than accretion. Withdrawal of the shore line is expected to proceed and increase in the near future, depending on the rate of sea level rise (Louisse & Kuik, 1989). Therefore, coastal protection and coastal dune management are necessary to ensure safety and to protect the economically and ecologically important coastal dune area. Besides curative measures, like sand suppletion, preventive measures are taken along the Dutch coast.

Most commonly used are willow-twig wind screens, placed at the foot of the foredune ridge (Photo 1).

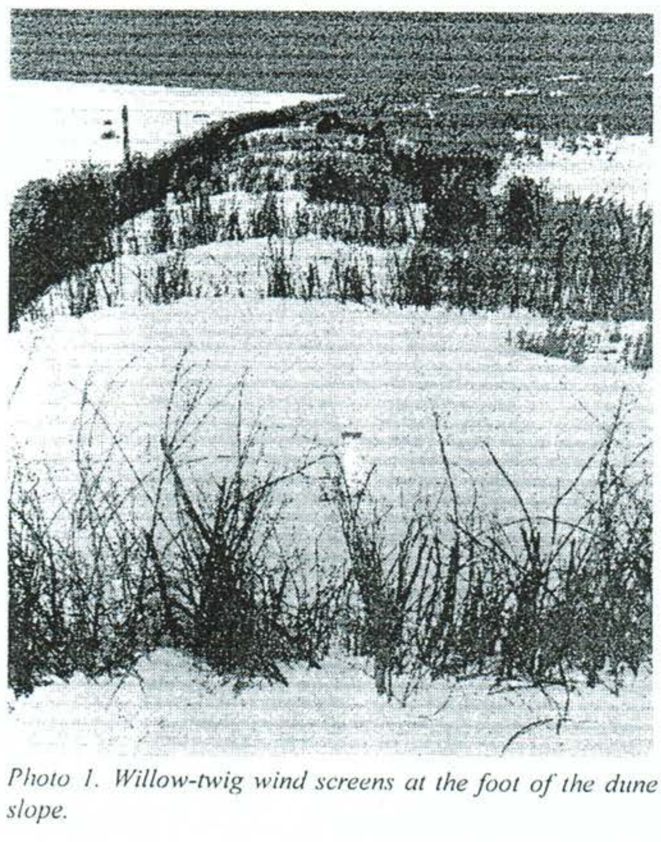

Photo 1. Willow-twig wind screens at the foot of the dune slope.

They trap and retain sand blowing from the beach to the dunes. In this way, a sand buffer develops that helps limiting damage caused by winter storms to the dunes. They consist of a main line of twigs at the dune foot, with every 6-7 m a short line of twigs perpendicular to the main line. At the up slope side of the screens, bentgrass (Ammophila arenaria) is planted for extra stabilization.

The wind screens drastically change the morphology of the seaward side of the foredune ridge. However, few quantitative information is available about their effects on erosional and depositional processes. Wind screens also affect the dynamics of the backlying dune area by changing the supply of wind blown sand into this area.

The objectives of this study are to quantify the influence of willow-twig wind screens on (1) sand transport fluxes and (2) on sediment deposition patterns on the seaward slope of the foredune ridge (Figure 1), with the remark that only sediment transport by wind action is considered.

METHODS AND MATERIALS

The measurements were carried out on the island of Schiermonnikoog in the Dutch Waddensea district (Figure 2) during Spring 1990 on the seaward dune slope in a plot with wind screens (the 'wind screen plot'), in a plot without wind screens (the 'reference plot'), and in a transect on the beach and dune foot (the 'beach plot'; Figure 3a). In both the wind screen and reference plot nine sediment traps were used. Three sediment traps were placed in front of the wind screen (at the beach side, the down slope zone), three in between (the middle slope zone) and three up slope of the wind screens (the up slope zone). The same configuration was used in the reference plot (Figure 3b). The position of the erosion pins is also indicated in Figure 3b. The sediment traps that were used are of the SOKOP-type (Spaan & Hollemans, 1991) being similar to the De Ploey vertical sand trap (de Ploey, 1980). They were described and tested by van Dijk & Hollemans (1991).

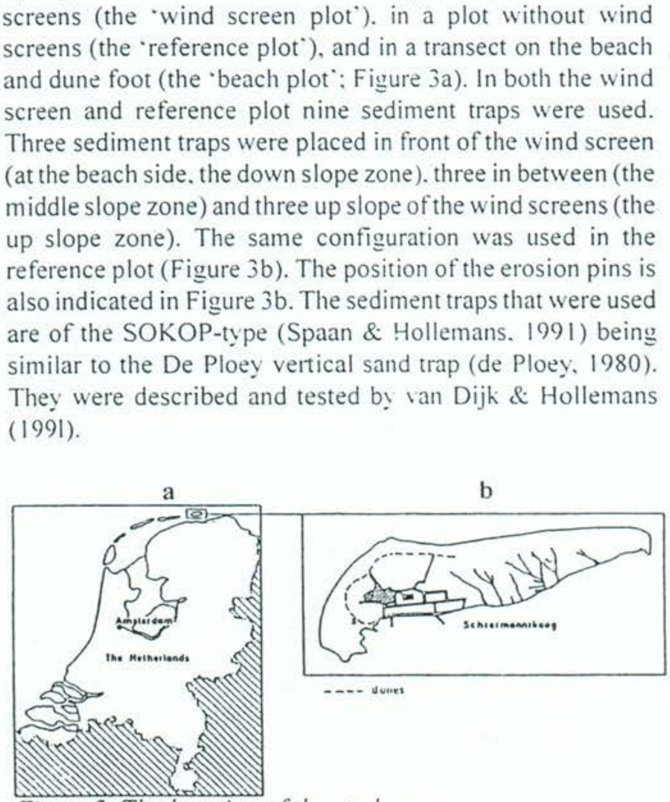

Figure 2. The location of the study area.

On the beach a transect was instrumented with pins and traps in order to identify eventual differences in sediment transport fluxes between the beach and the dune slope.

Nearby on the beach, a continuously recording wind erosion field station (Spaan & Abeele, 1991) was installed, from which the following information was obtained: the duration of the wind erosion events, wind direction and wind velocity during erosion, the threshold wind velocity for sediment transport, air humidity and precipitation.

RESULTS

During the months May and June 1990, the height of the pins above the sand surface was measured each time after a wind erosion event, i.e. nineteen times. Six of these events were sampled with the traps. For these six events Table 1 gives the results of the measurements.

Four of the six events occurred during periods with NW-NNW winds. During these periods the threshold wind velocity for erosion was higher than during the two events with winds coming from NE and W respectively. This is due to the much drier conditions of the sand surface and possibly also to the lower air humidity during the latter two events.

The effect of the wind screens can be recognized from both the sediment transport and the sediment deposition data. For three erosion events the effect of the wind screen on sediment transport is shown in Figure 4. In this figure, the direction of the arrows indicates the direction of sand movement. The length of each arrow is proportional to the amount of sediment transport at that point.

For the same events the effect of the wind screen on sediment deposition is shown in Figures 5, 6 and 7. In these figures the following information is shown for the beach plot, the wind screen plot and the reference plot:

the initial surface height on May 6 (the full line)
the surface height changes during the last event (the broken line with markers)
the new surface height (the broken line).

Below follows a short description of the six wind erosion events of Table 1.

On May 7 (Figure 4a and 5), with NW-wind, sediment transport in and behind the wind screens (the middle and up slope zone) is negligible, while in the reference plot all three zones have considerable sediment transport. So during this event the wind screen trapped most of the wind blown sand. In the up slope zone of the screened plot the planted bentgrass prevented the entrainment of sediment. On the beach, the sediment transport was much higher than on the dune slope. From Figure 5 it becomes clear that part of the sediment was deposited on the dune foot and right behind the wind screen. On the reference plot the sediment was deposited more evenly. This agrees with the rather equal values for sediment transport found here (Figure 4a).

The wind erosion event on May 16 is very similar to the event on May 7. However, the much stronger and somewhat drier wind forced sediment further into the wind screen compartments. Again sediment deposition occurred for a large part on the dune foot and in front of and behind the main wind screen line in the compartments (Table 1, down and middle slope

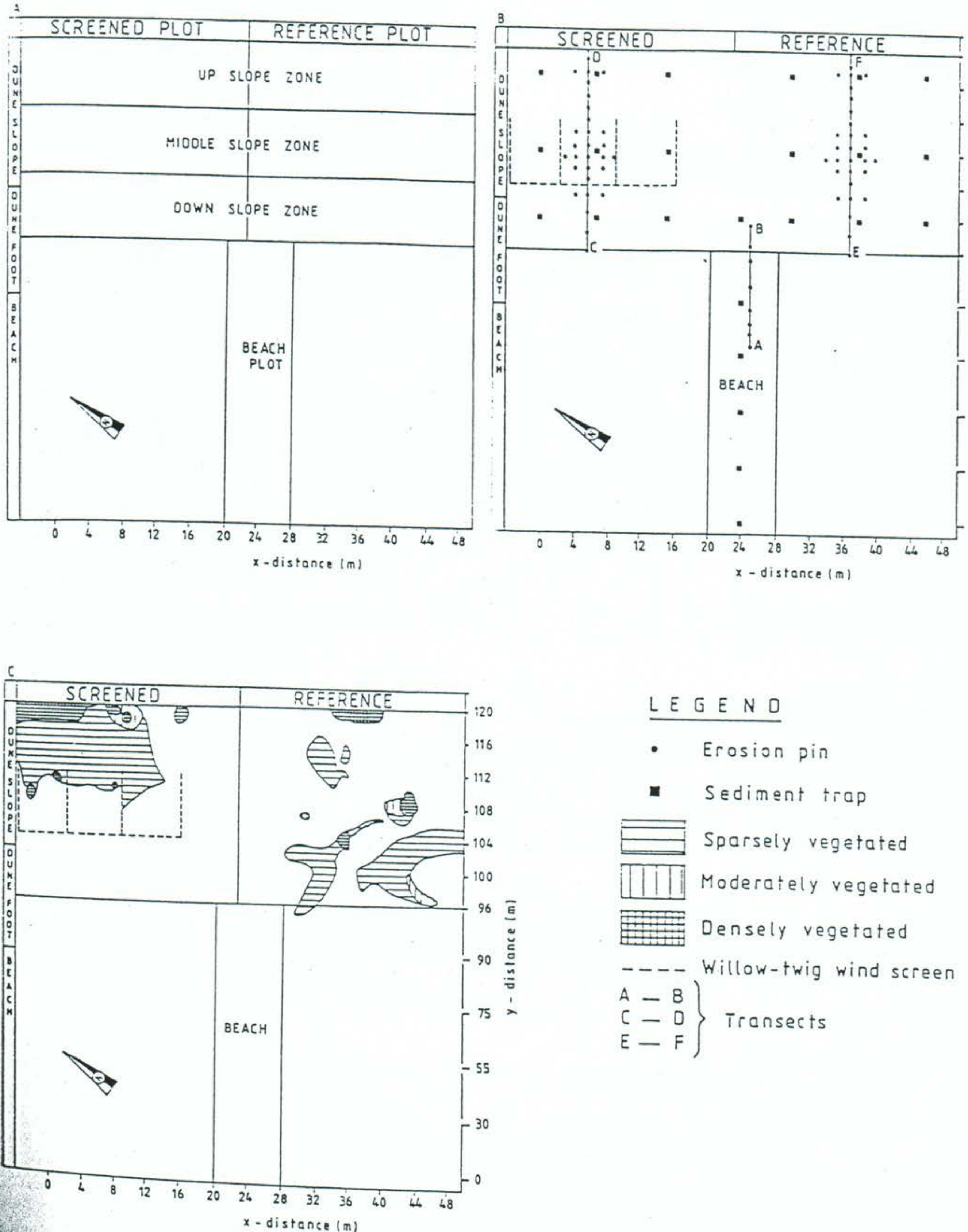

Figure 3. (a) the three plots and zones distinguished in this study; (b) the configuration of the sediment traps and the erosion pins; (c) vegetation (*Ammophila arenaria*) in the three plots.

		GENERAL INFORMATION ON THE EROSION EVENT					
Date of event (1990)		7/5	16/5	21/5	2/6	10/6	19/6
Duration (min)		270	440	540	660	740	600
Wind direction 1)		315	317	41	330	338	287
		NW	NW	NE	NNW	NNW	W
Wind velocity (m/s) 1)		8.1	9.1	9.4	10.6	8.6	7.8
Threshold wind velocity (m/s)		7.2	6.6	6	8.8	7.7	6.2
Relative air humidity (%) 1)		90	85	71	83	86	76
Precipitation (mm)		0	0	0	1.3	0	0
Surface moisture conditions		moist	moist	dry	moist	slightly moist	dry
Plot 2)	Zone 2)	SEDIMENT TRANSPORT (kg/m) 3)					
Screened	down slope	168.7	194.2	0.8	225.2	25.9	116.3
	middle slope	2.4	230	23.3	147.9	1.2	43.7
	up slope	3.4	2.9	3	2.9	3	11.1
	Average	58.1	142.4	9.1	125.3	10	57
Reference	down slope	77.7	233.5	38.8	164.8	99.4	77.3
	middle slope	56.4	189.5	27.5	198.3	8.5	51.2
	up slope	61.3	171.3	2.5	138.6	26.2	15.4
	Average	65.2	198.1	23	167.2	44.7	48
Beach	Average	112.4	241.4	92.5	208.7	202.5	122.4
Plot 2)	Zone 2)	SEDIMENT DEPOSITION (kg/m2) 4)					
Screened	down slope	11.1	15.2	0.8	17.9	9.5	14.3
	middle slope	9	11.6	-0.5	30.8	-0.3	4.6
	up slope	-0.7	-0.2	0.7	0.7	-1.5	-0.7
	Transect C-D 5)	7.8	10.3	0	15.2	3.4	1.5
Reference	down slope	1.3	-14.7	-0.3	9.8	-2	-3.6
	middle slope	3.1	-4.4	-0.7	3.6	-14	0.8
	up slope	-10.8	10.4	-1.6	20.7	3.3	3.1
	Transect E-F 5)	1.8	-8.7	-1.1	15.8	-0.8	-1.1
Beach	Transect A-B 5)	-13	-	17	13.9	-4.6	-1

1) average values during transport event; wind velocity and direction measured at 10 m height
2) see Figure 3
3) all sediment transport values are based on 3 sediment traps
4) calculated from the surface height changes using pin data and a dry bulk density of 1630 kg/m3
down slope: n=6, middle slope: n=16, up slope: n=7, Average: n=14.
5) Transect A-B: n=8, C-D: n=14, E-F: n=14.

Table 1. Results of measurements during six wind erosion events in May and June 1990 on the island of Schiermonnikoog.

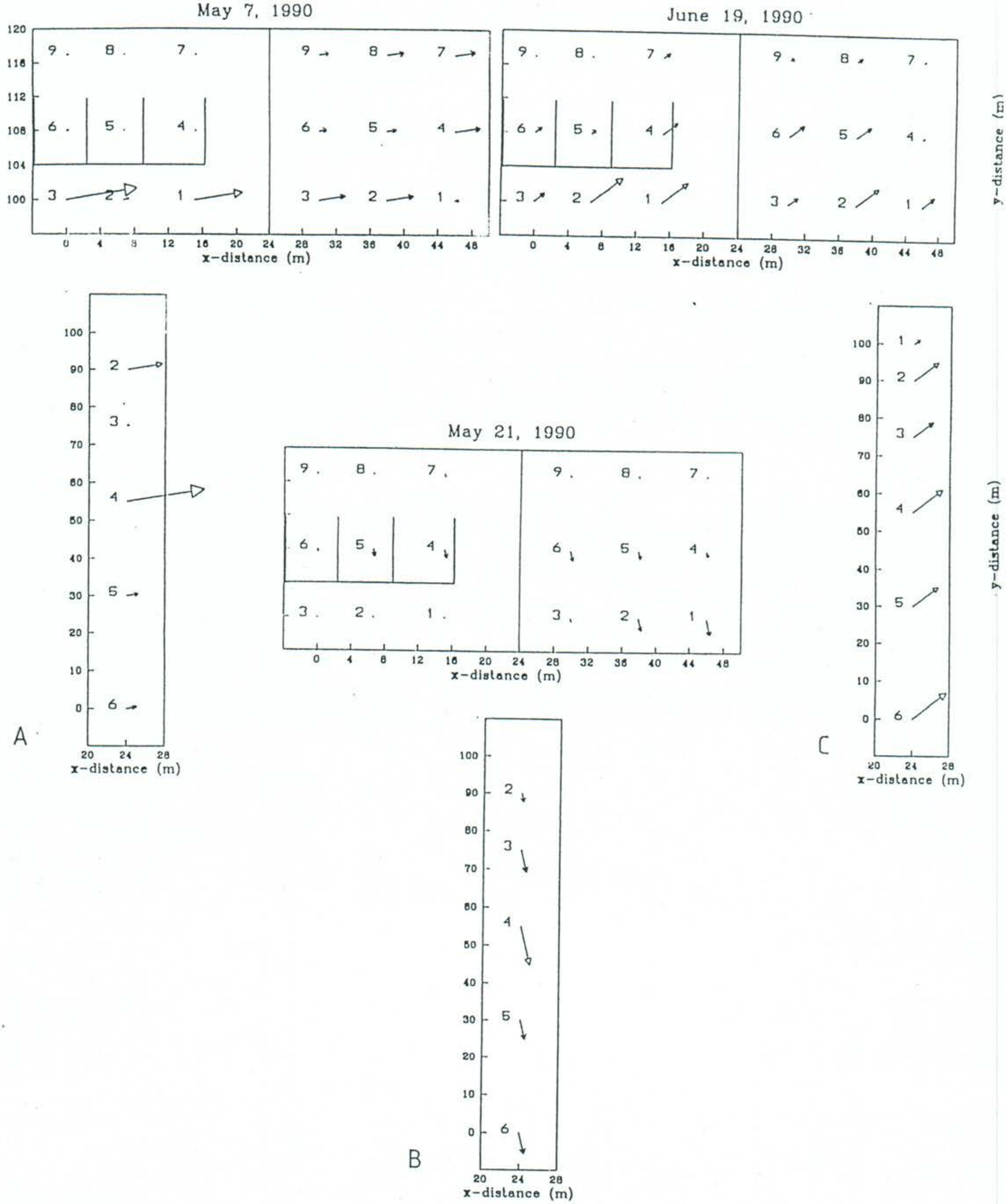

Figure 4. The distribution of sediment transport in the three plots (see Figure 3), for wind erosion events on May 7 (a), May 21 (b) and June 19 (c). The arrows indicate the direction of sand movement. The length of the each arrow is proportional to the amount of transported sand at that point.

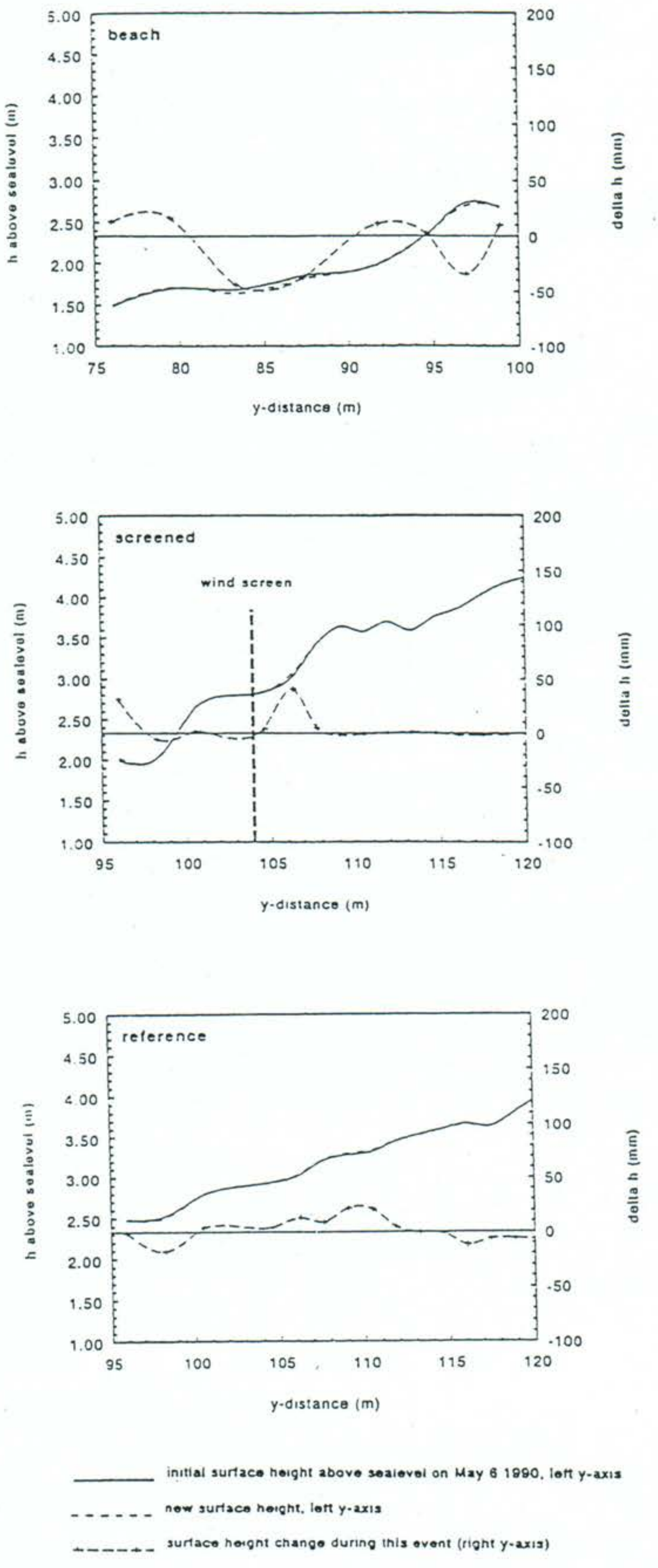

Figure 5. Surface height changes resulting from a wind erosion event on May 7 (1990) in the beach plot, the wind screen plot and the reference plot.

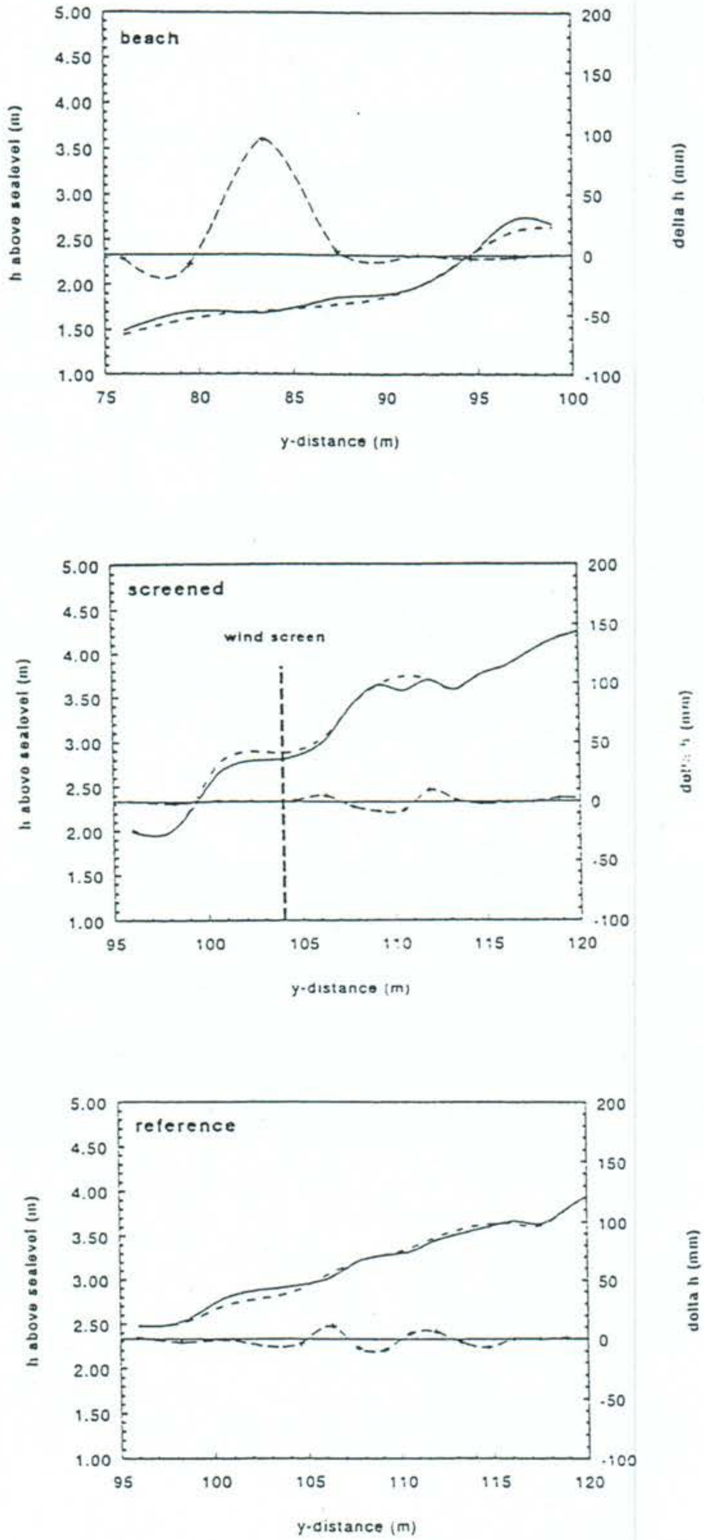

Figure 6. Surface height changes resulting from a wind erosion event on May 21 (1990) in the beach plot, the wind screen plot and the reference plot.

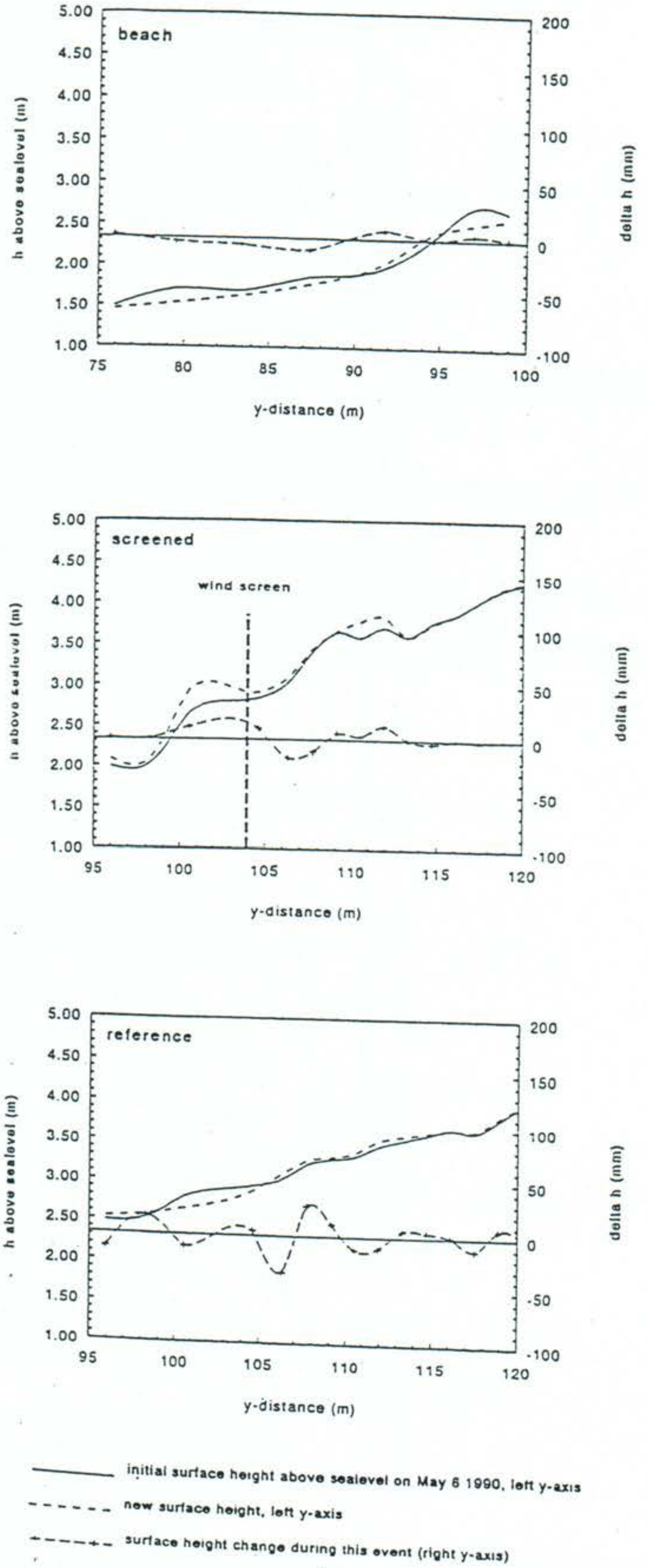

Figure 7. Surface height changes resulting from a wind erosion event on June 19 (1990) in the beach plot, the wind screen plot and the reference plot.

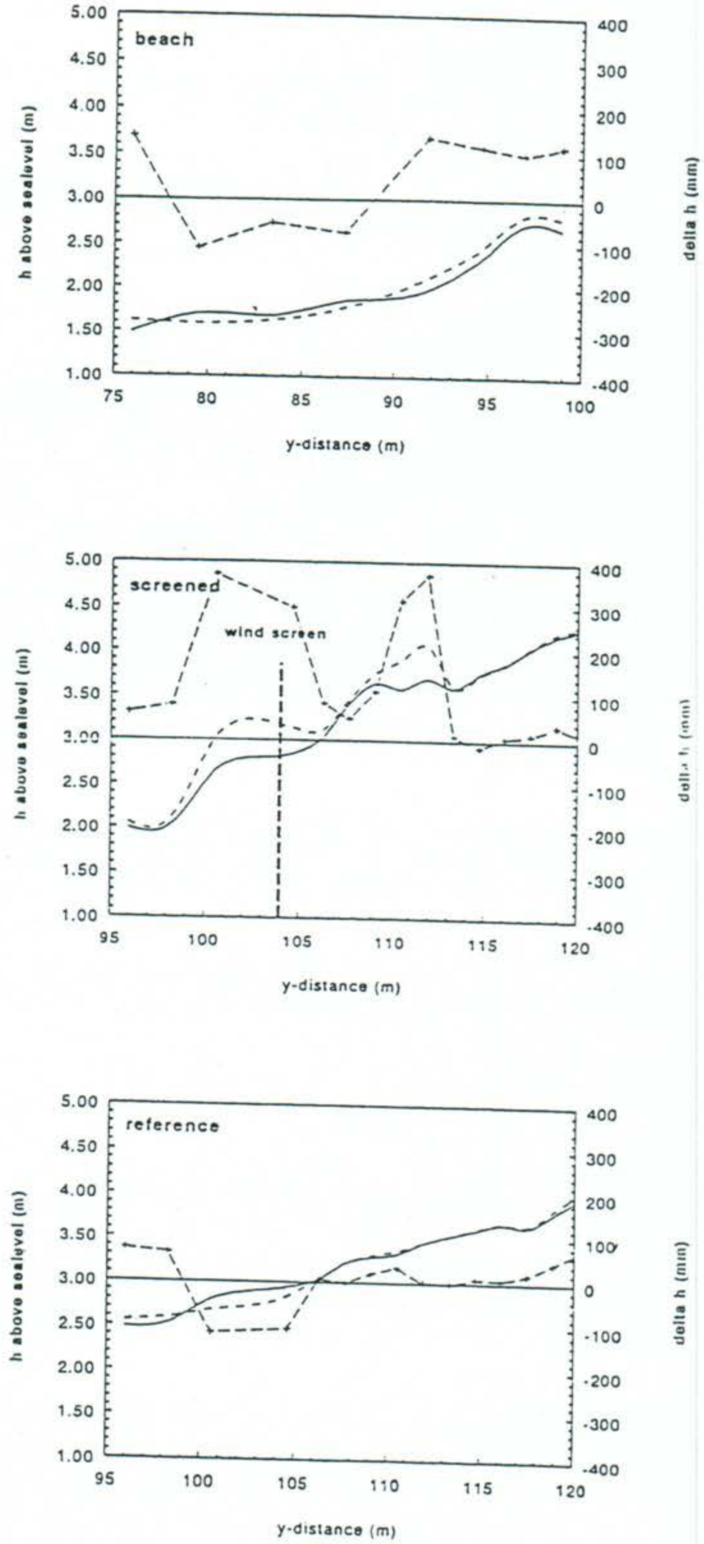

Figure 8. Overall surface height changes during the months May and June 1990 in the beach plot, the wind screen plot and the reference plot.

zone). The middle slope zone of the screened plot shows very high values for sediment transport. In this zone sediment deposition occurs as the wind velocity suddenly decreases. In such a situation the assumed efficiency of the traps (Spaan & Hollemans, 1991) in catching sand grains may be too low and the calculated sediment transport consequently too high. It should be realized that this error in the quantification of sediment transport using these traps can be important during the other events as well, especially in the screened plot.

On May 21 the slope was lying in the lee of the NE wind. Table 1 and Figure 4b clearly show the increase of sediment transport with increasing fetch in the reference plot. In the screened plot this fetch is interrupted by the screen. Sand that started to move in the middle slope zone is immediately captured by the wind screen, so that in the down slope zone transport is about zero. Figure 6 shows that surface height changes in both the screened and reference plot are small, while much sediment deposition took place on the beach.

During the event of June 2, the wind direction was almost parallel to the dune and main wind screen line. Due to the high wind velocity, much sediment was transported in all zones except for the up slope zone in the screened plot. Again the presence of the evenly planted bent-grass is the cause of this difference. It appears that the wind screen has no evident effect on transport caused by very strong parallel winds. Still, deposition in the down and middle slope zones of the screened plot was considerable.

The storm of June 10 was comparable to the latter one, but the wind velocity was much smaller. Now the wind screen does reduce the sediment transport in the middle slope zone, and extends its effect to the reference plot which lies at the leeside of the wind screens. Deposition of sediment occurred in front of the wind screen (down slope zone). In the reference plot there was nett erosion in the middle slope zone.

On June 19 the average wind velocity was quite low (Table 1). However, sediment transport was high because of the dry conditions at the sand surface. In the screened plot sediment transport was very high in front of the screen and drops behind it (Figure 4c). In the reference plot the amount of transported sediment decreases more slowly slope upward. Surface lowering occurred on the beach, while the surface at the dune foot raised (Figure 7). In the screened plot this tendency continues up to a few meters behind the screen. In the reference plot there is no clear trend in deposition and erosion.

CONCLUSIONS

In general it can be said that the presence of willow-twig wind screens greatly influence sediment transport and deposition. Figure 8 shows the surface height changes in the three plots for the whole measuring period. Sediment deposition occurred at the dune foot. In the presence of a wind screen a large sediment buffer develops on the lower half of the slope. In the reference plot, sediment is removed from the lower part of the slope, while the up slope zone shows nett deposition. So, the slope morphology in the screened plot develops entirely different from the reference plot.

During the six recorded wind erosion events, sediment transport up slope of the wind screens was negligible. This implies that in most erosion events, the backlying dune area will not receive any sediment coming from the beach.

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Dune Management in Denmark: Application of the Nature Protection Act of 1992.

by: Frede Jensen

Presentation

BACKGROUND

Most of Jutland's coastline along the North Sea consists of dunes. For centuries the main objective for all land management was maximum agricultural or forestry output. In dune areas and areas adjacent to dune areas sand drift was a major problem for agriculture and the objective of all legislation concerning the dunes was the sand drift. During the latest decades more and more focus has been placed on protection of the ecological environment. The Nature Protection Act of 1992 gives a legal framework for management balancing utilization and protection of the ecological environments.

Figure 1. The sandburied church of Skagen. The church was abandoned in 1795. The tower was left as a landmark and the rest was demolished.

THE NATURE PROTECTION ACT OF 1992

In July 1992 Denmark had its first Nature Protection Act (MILJØMINISTERIET, 1992). The act is a compilation and modernization of different previous acts, firstly the acts about nature conservation, nature management and sand drift. The aims of the act are to protect and improve nature and at the same time improve access and possibilities for outdoor activities but it is also an aim of the act to fight devastatings and drift. The act deals with a number of protected ecological environments and it is worth noting that the basis for legislation about dunes in Denmark is not a recognition of dunes as a valuable ecological environment which needs protection but protection against sand drift. Still, in the remarks to the bill it is stated that in management of dunes and sand drift, consideration should be taken to nature and landscape values.

For many years it has been reckoned that there is about 80.000 ha of dune area in Denmark. This is about 2% of the total area of the country. A survey from the 1970'ies and 80'ies by The Danish Institute of Plant and Soil Science, Department of Land Data, Vejle, shows a dune area of about 160.000 ha (Figure 2) (Jensen et al., 1985).

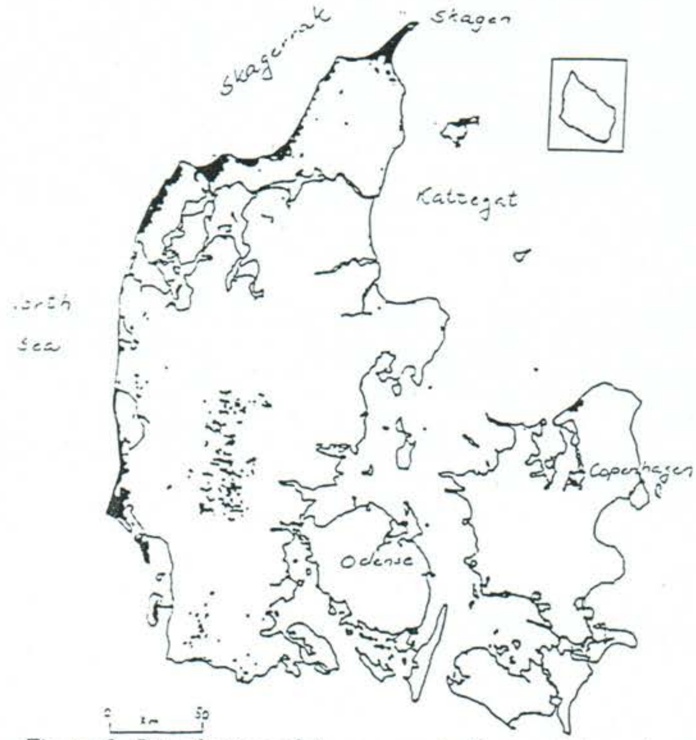

Figure 2. Distribution of dune areas in Denmark from the "Danish Institute of Plant and Soil Science, department of land data, Vejle" (JENSEN et al., 1985).

A major part of the dune area is owned by the state, the Ministry of the Environment. The National Forest and Nature Agency is managing these areas through its local forest districts. In the private areas along the North Sea, a minimum of 100 m from the foot of the dune and landward must be "preserved dune".

When a dune area has been selected for preservation, the right of use is very restricted. The public has a free access by foot to the preserved dunes. In a dune preserved area the owner has the joy of ownership. he may hunt and he may pay his taxes but otherwise he must not do anything - still. if he has a house or a summerhouse in the area. the house may stay there and he may maintain the house but he must not enlarge it. If the dune preserved area becomes narrower due to coastal erosion. the forest district must see that the dune preserved area is moved farther inland so that the preserved area always is at least 100 m wide.

The extent of the dune preserved areas is shown on special maps. and the dune preservation is registered by the authorities for each individual property. In the field the preserved areas are marked with concrete poles with a royal crown and a K for dune preserved (klitfredet in Danish) (figure 3).

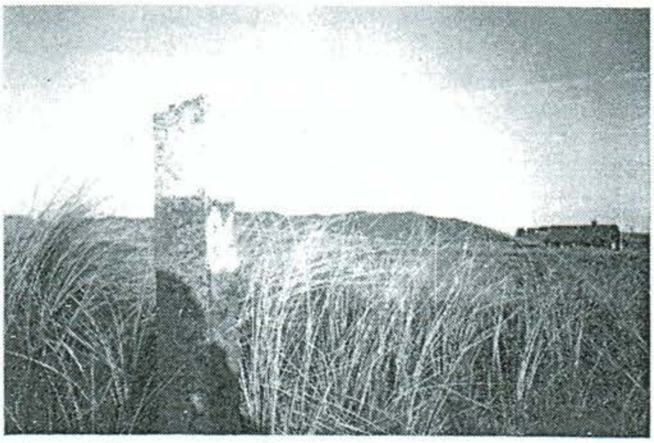

Figure 3. Dune preserved area with boundary marker.

In most cases the local state forest district performs the duty of the local dune authority and the decisions of the forest district may be appealed to the National Forest and Nature Agency. Some more vital decisions may be appealed to the Ministry of the Environment (SKOV- OG NATURSTYRELSEN. 1993).

MAJOR DUNE TYPES

In Denmark the most common dune types are (FEILBERG AND JENSEN). 1992):
The foredunes are formed on the beach sheltered by subaqueous seaweed. rubbish or any other material which gives shelter for the wind. The foredunes are extremely exposed and can easily be flushed away by the waves. At stable conditions the foredunes may develop into white dunes.

Coastal dunes are often white dunes because of the white sand seen through the vegetation. The dominating plant in the vegetation is marram grass, Ammophila arenaria, which thrives best with continuous mild accretion of sand. Marram spreads vegetatively and this ability is used when marram is planted to stabilize the drifting sand.

Fertile dunes sheltered from the sea may develop into green dunes. The green dune has a rich and vigorous flora with Ammophila arenaria, Galium verum, Salix repens, Rosa pimpinellifolia, Geranium sanguineum etc.

The grey dune consists of leached sand and the fertility is very poor. The vegetation is sparse and fragile - often crisp under dry conditions - with characteristic species as Carex arenaria, Corynephorus canescens, Cladonia spp and Cornicularia spp.

Especially in Northern Jutland we find a number of stone flats and stone deserts. The stone flat comprises stones that cover the surface densely and in some places to a depth of 15 cm. Today there is a stone flat developing near the very spit of Grenen near Skagen (HAUERBACH 1992)

Between the mentioned dune types we find a rich variety of dune heaths with Calluna vulgaris and Empetrum nigrum, dune plains with Carex arenaria. dune bogs with Erica tetralix and Eriophorum angustifolium and dune lakes, which may dry up completely during summer time.

THREATS TO THE DUNES

For centuries, Danish dune management consisted in combating sand drift. Through such a long period attitudes have found their way to the backbone of people in such a way that drifting sand by many people in sand drift areas has been considered ruinous and necessary to fight with all means. But increasingly during the latest decades untouched dunes have been considered a valuable ecological environment which should be left untouched unless there are major social reasons to interfere.

The major threats to the free development of the dunes in Denmark today are (FEILBERG AND JENSEN 1992):

1) Coastal protection works
2) Sand drift damages
3) Attrition
4) Tourism
5) Overgrowing

1) On the sandy westerly shores of Denmark. the beach and the adjacent dune systems constitute a dynamic landscape with a coastline which may move both ways. In many places a coastal erosion rate of 1-2 m a year has been normal for a long time but in the last 15 years the erosion rate has increased to 3-5 m a year due to more often and more violent gales in this period (ANDERSEN. 1993). Where infrastructure and other social assets are threatened by coastal erosion. coastal protection works may "freeze" and impoverish the dynamic landscape.

2) Damages caused by sand drift are the classic and historical problems with dynamic dunes. Today sand drift is under control but there are still sand drift problems for instance in connection with the summerhouses and recreational facilities in or near the dunes. Buildings may be endangered by the drifting sand and it is quite often necessary to stabilize the drifting sand. This supports nature's own dynamic processes to perform a natural transition to a stable situation. In a traditional situation all overhanging duneparts are cut down at a sloping angle so that the wind may pass with a minimum of erosion. A major blow-out in the dune has to be refilled with sand. This can be achieved by digging down pinetrees of about 2 metres length in the sand. The trees collect the sand the way a snowfence collects the snow. When the dune has been levelled, it is stabilized by planting of marram - Ammophila arenaria.

3) Attrition ruins the vegetation and sand drift may start. Today attrition is mostly due to the recreational usage of the dunes whereas very few people are living in the dunes the whole year and hardly any perform our ancestors' intensive use of the dunes. Attrition may be counteracted by a sensible laying out of access roads and paths and by repair of the damage by the methods mentioned earlier or by means of straw or woodchips. Besides it is considered most important to inform about the values of the

dunes and to try to convince people that dunes have to be adequately protected.

4) In many dune areas, tourism is about to become the most important trade and everyone acknowledges that tourism must have reasonable terms and room for development. At the same time there is awareness of the fact that an unhampered tourism can spoil cultural as well as natural values - the aim is a tourism which can be lived by and can be lived with. In Denmark, tourism in the dunes is very much linked to summerhouses and bathing at the beaches. Because of the strict legislation new summerhouses are almost impossible to build in dune areas but conflicts between interests are sure to come when greater investors offer big investments in tourist facilities and offer new local jobs - often in areas with high unemployment. Then it is vital that polititians stay cool and ensure that all development is evaluated with regard to the existing environment and that sustainability is ensured.

5) When the lasting stabilization of the dunes started around the middle of last century, afforestation was an effective means. From these plantations conifers - firstly Pinus mugo - have spread to adjacent dune areas, and many of these areas will, if left to themselves, develop into pine plantations or pine shrub of much less intrinsic value than the dune area. For many years now selfgrown pines have been cleared in valuable dune areas and this work has to be continued until all live residues of trees and seeds will be removed from the area. Furthermore, it is now discussed also to remove some of the established pine plantations and restore the areas. The afforestation of the dunes in Denmark has had its day - it has stopped the sand drift as it was the aim of the afforestation. Today the pine plantations occupy areas which have higher nature and landscape values as dune areas.

STRATEGY FOR DUNE MANAGEMENT

In the National Forest and Nature Agency a working group is working with a strategy for dune management in Denmark and the main points are (SKOV-OG NATURSTYRELSEN, 1991):

1. The ruling principle for dune management is "sustainable and multiple use". This means a kind of management which preserves the dunes, while at the same time, the dunes play their role in the dynamic coastal protection system against the sea, devastating sand drift is stopped, and the great landscape and recreational interests are considered.

2. An element in management is the wish to restore a zone with so called Atlantic dune moorland behind the high coastal dunes along the North Sea. This implies in many places that dune plantations must be felled and restored with the original vegetation of grasses, dwarf bushes, etc.

3. In suitable places with low recreational pressure, sample plots of reference are placed. Some of these may be part of the monitoring of European dune areas which have been proposed by EUCC (The European Union for Coastal Conservation).

4. In 1992 a Danish sand dune seminar was held near Skagen with participants dealing with dunes from different scientific and managerial positions. Contacts established in this seminar should be maintained.

5. A national survey of the Danish dune area shall be carried out during the next few years.

DISCUSSION AND CONCLUSION

During 500 years legislators in Denmark have repeatedly considered dune management. For almost the whole period the main aim was to stop the devastating sand drift that was caused by excessive use of the dunes. Sand drift was radically stopped by afforestation of major dune areas.

All over Europe huge dune areas have been lost during this century. In Denmark it has been estimated that 35% of the dune area has been lost to afforestation and recreation (DOODY 1993) and even if it is a small proportion compared to the Mediterranean area, where 75% is estimated to have been destroyed (GENU, 1975), it is still serious considering the scarcity of dune areas and the pressure on the dunes. Today the excessive pressure on the dunes in Denmark mainly comes from recreational usage especially during the summer time.

With the Nature Protection Act of 1992 the priorities concerning dune management are spelled out. The intrinsic value of the dunes is acknowledged and the public is given free access by foot to the dune areas. Thus in Denmark greater attrition must be envisaged due to the intensive recreational usage of the dunes.

To fulfil the aims of the legislators it is necessary to have an active dune management to do the necessary repair works and to make visitors understand how important adequate protection of the dunes is. In a world with growing pressure on natural resources for recreational purposes this last point is vital. If visitors do not understand and accept that the vegetation in many dune areas is extremely vulnerable and behave accordingly, the result may be that in many places it will be impossible to maintain the dune areas in an acceptable condition and an increasing demand will develop for restrictions in public access to protect the ecological environments.

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