

Restoration of dune mobility in The Netherlands

Bas Arens¹, Luc Geelen², Rienk Slings³ and Hans Wondergem⁴

¹ Bureau for Beach and Dune Research
Iwan Kantemamplein 30, NL-1060 RM Amsterdam, The Netherlands
E-mail: Arens@duinonderzoek.nl

² Waterleidingbedrijf Amsterdam
Vogelenzangseweg 21, NL-2114 BA Vogelenzang, The Netherlands

³ nv PWN Waterleidingbedrijf Noord-Holland
PO Box 2113, NL-1990 AC Velserbroek, The Netherlands

⁴ Staatsbosbeheer
PO Box 62, NL-1800 AB Alkmaar, The Netherlands

Abstract

Pioneer stages in Dutch coastal dunes are under threat. In several areas experiments are executed to reactivate dunes. The aim is to restore aeolian processes in order to create new possibilities for the development of pioneer vegetation. How successful are these experiments? This paper compares the results of three different projects from three different areas. The results indicate that large-scale destabilisation of dunes by removal of vegetation leads to a massive increase of dynamic, aeolian processes in an area. In order to achieve durable dune mobility, the sand must stay in movement, either by regular disturbances or by the availability of high, erodible dunes.

Keywords: Dune mobility; Coastal dunes; Restoration; Geomorphology.

Introduction

Coastal dunes are important features. Although their ecological value is widely known, sometimes we tend to forget that they are also valuable from a geomorphological point of view. The distribution of vegetation types through the landscape depends on the geomorphological setting. The specific orientation of slopes determines the establishment of specific plants. Wet dune slack vegetations are subjected to the vicinity of groundwater, mostly determined by the extent of deflation of dune slacks. The presence of all kinds of highly valuable vegetation types depends on the occurrence of dynamic, aeolian processes. We believe that a good management of the landscape should form the basis for good management of ecological values.

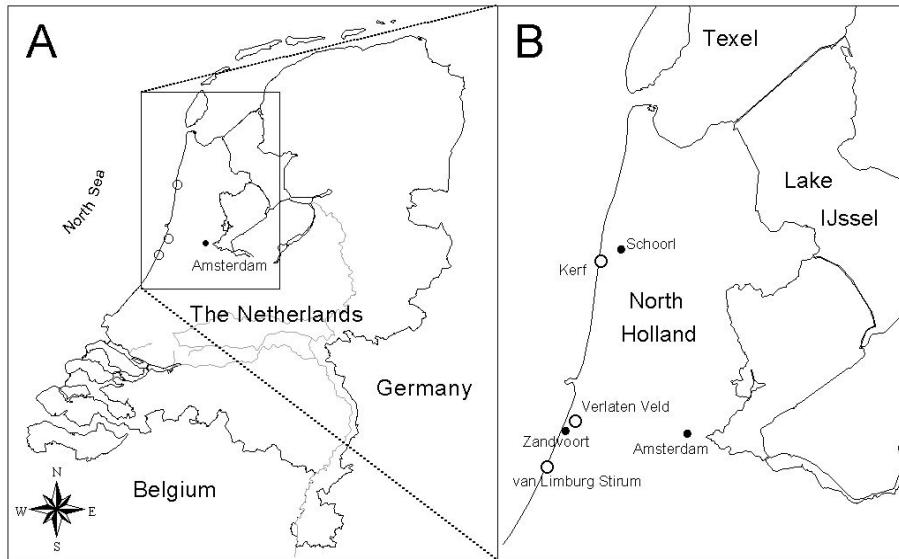


Fig. 1. Map of The Netherlands (A) with location of the sites (B).

Coastal dunes in The Netherlands are subjected to several threats. Due to stabilizing activities by man, increased nitrogen input, but possibly also climate change, all these dunes were stabilized in the past. As a result many younger and species rich vegetation types have become scarce. Managers try to reverse succession by several means. In the past, restoration of pioneer stages in dune slacks was mostly performed by removal of vegetation and topsoil in the slack. Consequently, no (sustainable) aeolian activity was restored, due to the presence of the groundwater table and the usually moist conditions at the surface, which prevent the sand from being taken up by the wind. After a number of years, the method has to be reapplied because of ongoing succession. Repeated removal of the topsoil structurally lowers the surface and finally the height of the surface will be below the average groundwater table. The landscape is modified because of steepening of slopes and lowering of the surface, and at the end, there are no further opportunities for future restoration.

Presently, more sustainable methods are developed that take account of the dynamic characteristics of a natural dune landscape. Introduction of dune dynamics (by removing vegetation) leads to a rejuvenation of the landscape through the burying of vegetation by freshly deposited sand or by abrasion of vegetation and development of (wet) deflation surfaces after wind erosion. Ideally the reactivation results in enduring aeolian activity, ensuring permanent rejuvenation and possibilities for pioneer vegetation. If this succeeds, no further interference is necessary.

Managers applied the method of reactivation of blowing sand at several scales. Most experience was gained from small scale experiments with blowouts (*e.g.* Van Boxel *et al.*, 1997; Ketner-Oostra and Sykora, 2000). Between 1995 and 2004, several larger scale projects have been started in the coastal dunes and the inland drift sands. In this

paper results from large scale projects in several dune areas along the mainland coast are discussed. Main research questions are: 1) what is the best method for large scale dune remobilisation; 2) is the result durable on a long time scale (>10 years). In this paper we give some examples from large scale measures to ensure durable landscape rejuvenation.

Methods

In this paper we present results from three different areas, with different management, different perspectives, but comparable aims. Fig. 1 shows a map of The Netherlands with the location of the sites. The Kerf is situated in the north, in the region where dune sand is poor in carbonates. The other areas are located in the calcareous dunes.

Kerf

The Schoorl dunes are managed by Staatsbosbeheer (State Forestry Service). In the area dunes are often dome or barchanoid shaped, and bordered by huge deflation plains. Many of the dunes are pocked by blowout development, with different sizes. Most of the area was stabilised in the past by human intervention. In the southwestern part, in 1997 a notch was created in the foredune, and vegetation and topsoil were removed from the dune slack behind (Staatsbosbeheer, 1997). As a result, the sea has access to the dune slack during storm surges. Beach sand is blown inland through the notch, and covers the stabilised slopes of adjacent dunes. The area was monitored intensively between 1997 and 2002 by means of yearly air photographs. Apart from the geomorphological development, ecological changes (vegetation, insects, fungi) were also monitored (Vertegaal *et al.*, 2003).



Fig. 2. Kerf with inundation (left) and dune development (right).

van Limburg Stirum area

The van Limburg Stirum area (VLS) is situated in the Amsterdam Water Supply dunes. The area consists of a complex pattern of dune slacks and dunes. Most of the landscape was stabilised, but locally some blowouts remained active. Near Zandvoort an extraction canal used for the extraction of drinking water was filled in again in 1995, thus restoring the former dune topography (Geelen *et al.*, 1995). The sand from the canal was still

present in the area. After restoration of the topography, the surface was left bare and dunes could develop freely. The development of the area was monitored by analysing aerial photographs, taken at a two-year interval. For details of the project, see Arens and Geelen, 2001 and 2005.



Fig. 3. Van Limburg Stirum area with slack development, facing southwest (left) and north (right).

Verlaten Veld

The Verlaten Veld (VV) is located near Haarlem, in the area of the North Holland Drinking Water Company in Kennemerland. The area is characterised by large parabolic dunes, alternated by wide deflation plains. The size of the parabolic dunes generally increases with distance from the sea. The whole area is stabilised, apart from some scattered, active blowouts. A parabolic dune was reactivated in 1998 by removal of vegetation (pine forest) and top soil (Terlouw and Van der Bijl, 1999; Arens *et al.*, 2003). Monitoring is performed by means of aerial photographs at two-year intervals, measurement of height changes every year, and frequent (4-6 weekly) recording of erosion pins. For details of the project, see Arens *et al.*, 2003.



Fig. 4. Verlaten Veld: lee face of the parabolic dune.

Interpretation of aerial photographs

For all areas, air photo interpretation was used to derive maps. For the purpose of this study, all maps were generalised by using the same legend. Because all projects share the aim of recording dune mobility, available maps were generalised to three classes: 1) strong aeolian activity; 2) weak aeolian activity; 3) no aeolian activity because of stabilisation.

1) Strong aeolian activity: this unit comprises all units with strong aeolian activity, either erosion or accumulation. Erosion is from bare surfaces, where pioneer establishment is prevented because of erosion of several cm per year. Accumulation is often strong, and plants often are buried completely. Also, locally slipfaces are developed. Because of sand burial, new plants may benefit.

2) Weak aeolian activity: this unit comprises all parts with moderate or slight accumulation, without complete burial of the vegetation.

3) No aeolian activity: bare surfaces get stabilised, either due to colonisation by plants, re-growth from root remnants or because of increasing moisture levels, either by a change in groundwater level or by erosion down to the groundwater. This unit is mainly used for the bare surface where vegetation was removed. This unit does not comprise surfaces which are restabilised because of plants growing through accumulation. Those parts are not mapped. Stable surfaces which were no part of the reactivation or were not influenced by sand deposition were not mapped either.

Results

The restoration activities resulted in a massive increase in aeolian activity within the areas. In the first years large areas were invaded by sand, giving rise to changes in vegetation development. Due to deflation, locally surface height was reduced considerably. After five years, stabilisation of the areas became more important.

Kerf

Parts of the dune slack are stabilised by vegetation after five years. The notch is still open, probably thanks to heavy recreational use. The width of the entrance has declined from 60m in 1999 to 36m in 2002. The dune slack is occasionally flooded by the sea, mostly in winter (Fig. 2). As a result, part of the slack is covered by water, and protected from aeolian processes. Sand is blown inland, resulting in deposition and the development of small dunes (Fig. 5). For the Kerf area, the supply of fresh beach sand and occasional flooding, in combination with high recreation pressure ensures continuous pressure acting against stabilisation. The input of fresh sand from the beach, containing carbonates, has important consequences for ecological development.

van Limburg Stirum area

In the van Limburg Stirum area, large parts are stabilised after eight years, and the landscape has changed to a mosaic of bare patches, pioneer vegetation, sand burial and stabilised surfaces (see photograph and Fig. 6). Only locally new dunes are formed, but these are mostly small. The landscape changed from a large sand drift area into a

landscape with smaller scale dune activity and blowout development. Stabilisation is mainly prevented by aeolian processes, and, occasionally, some small scale water erosion. Stabilisation is enhanced by vegetation development, either from re-growth from root remnants (mainly Sea buckthorn - *Hippophae rhamnoides* and Reed – *Phragmites australis*), or from pioneer establishment (mainly Marram grass – *Ammophila arenaria* and Saltwort - *Salsola kali*). Lower parts in the terrain are stabilised by changes in groundwater level.

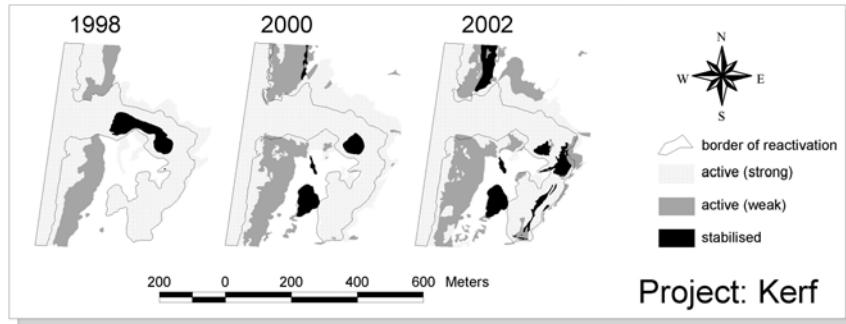


Fig. 5. Changes in extent of dynamic processes in the Kerf area between 1998 and 2002

Verlaten Veld

On the parabolic dune, the reactivation resulted in huge erosion on the windward side and crest. Locally the height of the crest was lowered more than 4m. At the lee massive sand burial occurred (Fig. 4). In part of the area, the parabolic shape of the dune was transformed to a dome shape. The trailing edges tend to stabilise (Fig. 7). Formation of pioneer slack after migration of the dune has been observed for the first time in 2004. The dune now seems to be partly remobilised, moving over a distance of approximately $1\text{-}5\text{m.year}^{-1}$. In the western part of the area the surface is deflated down to the groundwater, on average lowered by 0.6m. A large part was already close to the groundwater, and is stabilising relatively fast. On the parabolic dunes, stabilisation is prevented by the severity of aeolian processes. Deposition and erosion is so strong that establishment of vegetation is impossible thus far.

Comparison of the projects

To compare the results of the three case studies, surface areas are calculated, expressed as percentage of the area that was de-vegetated. The sizes of the initial areas were:

- Kerf: 6.2ha (de-vegetated surface); 1998 = year 1
- van Limburg Stirum: 30.3ha (de-vegetated surface); 1995 = year 1
- Verlaten Veld: 12.7ha (de-vegetated surface); 1999 = year 1

In all areas, aeolian activity increased after the intervention, up to a maximum in the third year (Fig. 8a). From then on, the total area with activity started to decline, because of vegetation development on bare spots (Fig. 8bc). The area where vegetation is buried by drift sand, continues to expand in the first five years after reactivation (Fig. 8d). The size of this area seems to be correlated to wind activity: during years with less wind than average, the size may decrease temporarily. In the VLS area, and to a lesser extent in the Kerf, this is reflected in yearly variation of sand burial. The size of the bare, mainly erosive area is hardly or not related to meteorological conditions. Stabilisation starts from the beginning and proceeds gradually. It is striking that all lines in Fig. 8 follow more or less the same trend, which implies that meteorology is not the dominating factor in the response of the landscape after a large scale disturbance.

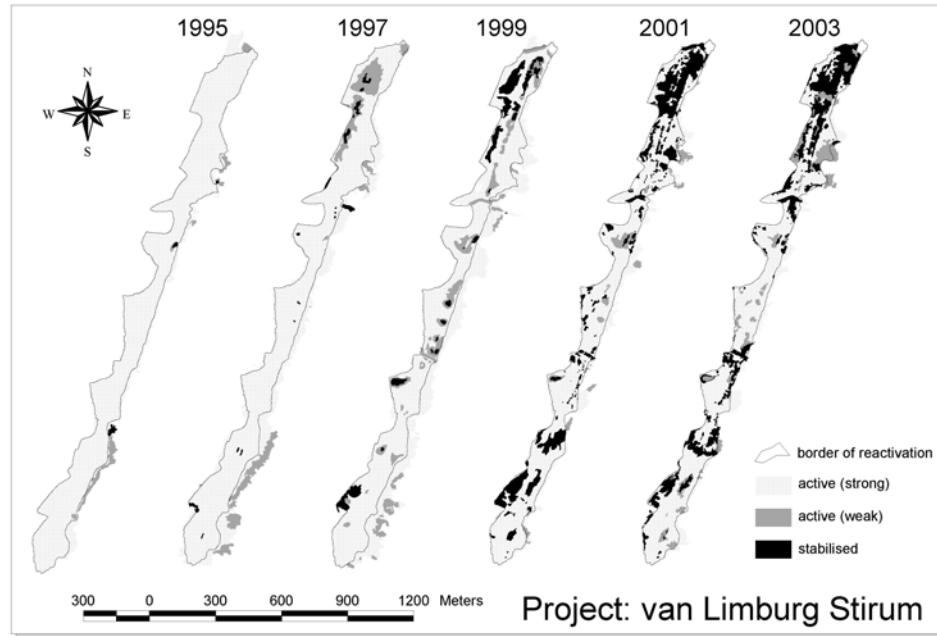


Fig. 6. Changes in extent of dynamic processes in the Van Limburg Stirum area.

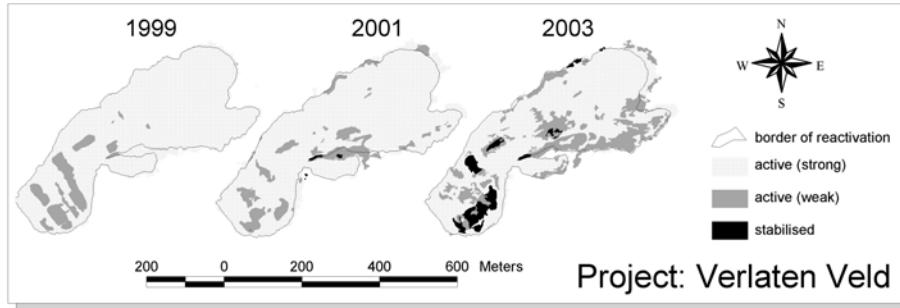
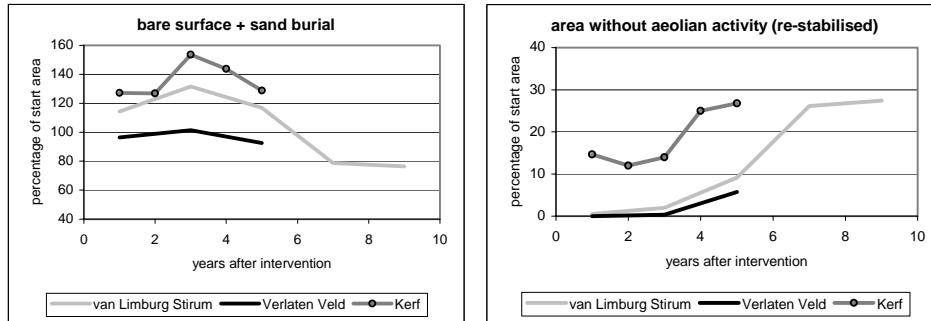


Fig. 7. Changes in extent of dynamic processes in the Verlaten Veld between 1999 and 2003.

Relatively spoken, the expansion of area with dynamic processes is the smallest in VV (Fig. 8a). The purpose here is to mobilise a large dune form. If this succeeds, the dune moves only over a small distance, which means that expansion of the area covered by sand is slow as well. Meanwhile, in the deflation plain, stabilisation proceeds. A large reduction in activity was expected in the first years of the project, since large parts of the bare area in the west are close to the ground water.

The largest expansion occurred in the Kerf area (Fig. 8a). A large surface of formerly stabilised dunes is affected by sand burial. In this case, a continuous source of sand ensures ongoing burial by sand. The size of the influenced, but not devegetated area is about half the size of the devegetated area.



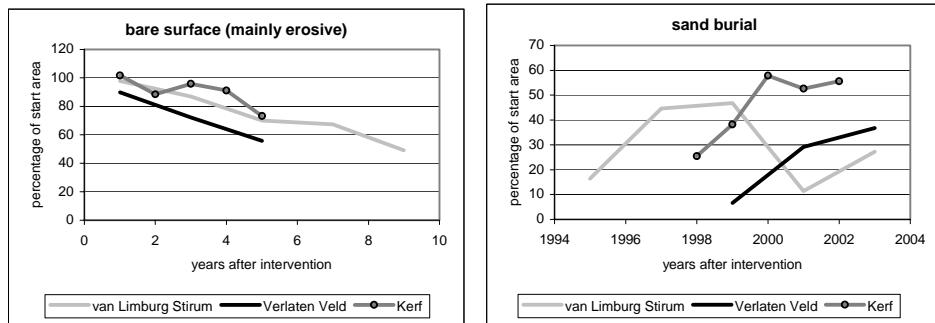


Fig. 8. Changes in dynamic and stabilised surfaces for the three areas.

In the VLS area the scale of the landscape is different. High and dry dunes are alternated with low and wet spots at relatively small distances. In the north, strong stabilisation is enhanced by re-growth of roots of *Hippophae rhamnoides* that were not removed. Dune slacks are deflated, but some were also filled with sand, because higher and drier dunes were located at their windward (western) site. Locally strong sand burial occurs, with development of slip faces at some places. As a result of these developments, the landscape tends to become a mosaic of bare spots, wet slacks, freshly formed dunes and drift sand areas. Some spots stabilise, other remain mobile and some former stable spots become mobile. The reason for the specific distribution of the different spots is not fully understood yet.

In the VV area, strong deposition in the lee faces of the parabolic dune prevents vegetation growth (see Fig. 4). In the other areas, deposition is not so strong that it results in remobilisation of buried dunes; the areas with deposition re-vegetate when the supply of fresh sand ceases. Continuous input is required in order to keep these parts dynamic. However, the input results in important ecological changes, which continues for a number of years. On the bare parts, slight erosion of about $5\text{-}10\text{cm.year}^{-1}$ prevents establishment of seedlings.

Conclusion and discussion

Based on the results of the three projects, we can conclude that large scale destabilisation of dunes by removal of vegetation results in a massive increase of dynamic, aeolian processes in an area. After such an intervention, the area influenced by aeolian processes expands to a maximum after three years, followed by a gradual decline due to stabilisation of the lower parts near the groundwater. The area influenced by sand burial expands for two more years, but the expansion is smaller than the decline due to stabilisation.

In order to achieve durable dune mobility, the sand must stay in movement, either by permanent disturbances (Kerf) or by a permanent availability of high, erodible dunes. Continuous erosion prevents vegetation to stabilise the surface, whereas continuous deposition does not necessarily. Over a period of 10 years, it seems that the scale of the

intervention in the VLS area is appropriate, at least for this period of time: a number of dry surfaces of at least 100m, exposed to westerly or southerly winds seems to be sufficient.

Despite the positive results of these studies, it still is too early to decide that large scale interventions will lead to durable dune mobility, on a time scale of decades.

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