Reducing the impact of wave attack: dunes as natural buffers

Work package leader : Prof. dr. ir. L. Stroosnijder

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1 Description work package

1.1 Problem definition, aim and central research questions

Coastal dune systems, with their self-regenerating capacity after storm erosion, represent natural defense zones against flooding of the hinterland. Condition: the total dune volume exceeds a certain minimum value related to the safety standard. As such, coastal dune systems represent natural buffers to climate change.

The quality of this climate buffer is related to the sediment balance in the system. During the last centuries, the Dutch coastline has retreated landward resulting in a loss of total dune area; the consequence of a negative sediment balance. The quality of the Dutch coastal system as a climate buffer has deteriorated.

In 1990 the Dutch government decided to stop this negative trend, adopting a policy of Dynamic Preservation. Sand nourishments are applied to maintain the coastline at it's 1990 position and, since 2001, to preserve the sand volume of the coastal foundation (and implicitly to preserve the quality of the coastal zone as a climate buffer). Since 2001 the annual nourishment volume has been 12 million m^3. In the light of Climate Change predictions, the Delta Committee (2008) has recommended to raise the total yearly nourishment volume to 85 million m^3 per year, to extend the climate buffer, preparing for an increase in rate of sea level rise from 2 to 12 mm/year until 2050.

An underlying assumption of the nourishment policy is that natural processes will redistribute the nourishment sand – on the shore face and occasionally the beach – in such a way, that the coastal system will "grow with sea level". To maintain the functions of the dune system at a certain level under conditions of sea level rise, the dunes require an input of sand proportional to the rate of sea level rise.

Problem statement: Can dunes grow fast enough under changing climate conditions to "grow with the sea level"? We focus on the problem of how sediment supply and dune management may be optimized under conditions of climate change in order to sustainably preserve the safety function of the dunes in harmony with other functions of the system.

The **aim** of this project is to derive a model of dune development (project 2.1) and apply it together with other models and expert judgment, to develop and evaluate a set of potential dune management strategies, aimed at improvement of the climate buffer function of dunes (project 2.2).

Main *research questions*:

- Which processes, process interactions and other factors are dominant for the sediment supply to dunes?
- Which dune management strategies are feasible in terms of technique and of support by the various stakeholders?

1.2 Interdisciplinarity and coherence between the projects

The first and main project (2.1) will focus on geomorphological processes, vegetation development and dune formation. Emphasis will be on modeling the positive terms in the sediment balance. The effect of the negative terms (sea level rise- and dune erosion effects), included in the model in a parametric way, will be estimated in close co-operation with KvK theme 6 “Climate scenario projections for wind and sea level rise”.

The second project (2.2) will focus on the development of feasible dune management strategies. Stakeholders will be involved from an early stage. In expert sessions we will start with an inventory of existing functions, the objectives of the related stakeholders, their views on the effects of climate change and their sense-ofurgency for adaptation measures. In successive stakeholder sessions, the potential strategies will be elaborated cooperatively, providing a continuous feedback on the results of project 2.1 and related research projects.

1.3 Stakeholders

Stakeholders play a central role in the development and assessment of feasible dune management strategies. The main stakeholders will be invited to participate actively in the project as members of the Stakeholder Committee, meeting every 6 – 9 months.
Possible stakeholders are: Rijkswaterstaat Waterdienst, Province of Friesland, Province of Zeeland, Water Boards, State Forestry (SB), LNV and Municipalities.

Besides the Stakeholder Committee, we intend to install a Scientific Committee consisting of a team of specialists, that will meet every three months.
Members nominated for the scientific committee are H. van Dobben and P. Slim (Alterra), A. Oost (Deltares) B. Arens (Buro voor strand en duin onderzoek), dr. ir. Bert Lotz, (Plant Research International) prof. dr. Wim van der Putten (Plant Science Group Wageningen UR).

2 Project 2.1 Aeolian transport and coastal dune formation under climate change; a model study

Project leader: dr. ir. M. Riksen

2.1 Problem definition, aim and central research questions

Before 1990, ca. 20 ha of dunes disappeared annually through coastal retreat. In 1990 the Dutch government decided to stop further long-term coastal recession and initiated ‘dynamic preservation', which primarily aims at ensuring safety against flooding and sustainable preservation of the values and interests attached to the dunes and beaches (de Ruig, 1998).

Dynamic preservation has some major advantages over more traditional (hard) coastal defense measures such as groins, dams and dykes. Most important is that hard coastal defense measures are unable to counteract the structural loss of sand occurring along the Dutch coast. Evaluations have shown that the 1990-choice for dynamic preservation was right: the coast line has been maintained, the loss of dune area has reversed into an extension (de Ruig, 1998; Van Koningsveld and Mulder, 2004). Sand nourishment is proven to be an effective method of coastline maintenance, at the same time serving the functions of the beach and dune area for human society. Compared to traditional management of fixing the dunes at a certain position with very few young phases of vegetation succession (Arens and Mulder, 2008) dynamic preservation can lead to an increase of the ecological value of the dune landscape.

This new management based on sand nourishments has generally resulted in a positive sediment balance and the formation of new dunes (Van Koningsveld and Mulder, 2004). These new dunes contribute to extension of the climate buffer as a protection against the sea level rise and increasing storm frequency and intensity. Despite the work of e.g. Arens (1994), Van der Wal (1999), and some local monitoring projects on dune development, knowledge of aeolian sediment transport and dune formation processes in the Netherlands, still is limited.

Dune formation plays an important role in the creation of a natural defense zones against flooding of the hinterland and in recovery after coastal erosion from storm events. The rate at which a system can transport and fixate sediment volumes that match the sediment demand created by sea level rise, and match or exceed erosion during storms, is crucial to keeping the dune system within the safety standards for the long term. Houser and Hamilton (2008) found that for barrier islands the alongshore variation in recovery is not only related to the island width, but also the offshore bathymetry, the height of the pre-storm dunes and the overwash penetration. The level of impact during subsequent storms and the ability of the island to recover will depend on the frequency of storm events because this determines the time allowed for the return of vegetation and the recovery of the dunes.

Coastal evolution under conditions of a changing climate during the Holocene, is determined by the balance between sediment demand and -supply. The demand is created by the accomodation space for sediments resulting from a rise in sea level; the supply depends on the availability of sediment resources and the transport capacity of the system. The sediment balance is determined by feedbacks between hydrodynamic- (rate of sea level rise, transport capacity), morphodynamic- (geomorphological characteristics) and ecodynamic boundary conditions (vegetation characteristics), which in turn, determine the boundary conditions for dune development.

The main problem we want to address is: the threat of climate change for dune functions through its impact on coastal erosion and dune formation. The aim of this project is therefore to develop a model which describes and can forecast dune formation under conditions of climate change.

To be able to model dune formation under different climate scenarios the following research questions need to be answered:

- What is the aeolian sediment transport, vegetation development and dune formation under present conditions for the different dune systems in the Netherlands?
- What is the rate of dune formation under present conditions?
- What are the main process controlling factors?
- What is the effect of climate change on these factors and thus dune growth rate?

2.2 Approach and methodology

Before we can answer these questions we need to make a distinction between the different dune systems present. To classify the dune systems we need to define the classification criteria. Carter (1990) distinguished three basic coastal types associated with low, balanced and high sediment influxes. The first type results in an erosional dune face with a narrow beach. The second type results in a mixed dune face with a medium beach and no change in the coastal line. The third type is associated with an accretional dune face, a wide beach and a progradational coastal change. Although this seems a useful concept to classify dune systems, in practice the dune systems along the coast of the barrier islands show more complex patterns. There are many different dune development stages as figure 2.1 shows. Based on literature we will define classes which can be easily identified making use of aerial photographs and the Dutch digital elevation model (AHN). A remote sensing tool will be developed to automate this process. Also a tool to map dune vegetation will be developed using remote sensing techniques and Definiens Developer software.

To estimate the potential dune growth rate, sediment transport and vegetation development and sedimentation patterns and rate, the PhD student will perform a literature search on coastal recovery and dune formation to conceptualize the process of coastal development. He or she will use this concept to develop a model to predict dune development: rate, shape and volume. For this he or she will work together closely with a PhD student working on modeling wind erosion on a beach, and a postdoc working on a dune model based on a deterministic sediment transport model WEPS a stochastic dune model DECALby Baas (2002), and the deterministic vegetation model NUCOM (Van Oene et al., 1999). The models will be combined and adapted to a spatial and temporal resolution suitable for this study and applied for the main dune systems of the Dutch coast. Field measurements will be carried out for the parameterization and validation of the dune model. The range of responses of the model under different scenarios will be assessed by carrying out a sensitivity analysis for each model parameter related to climate and adaptation measures. In this respect special attention is paid to the effect of extreme events on dune development supported by detailed event based field measurements.

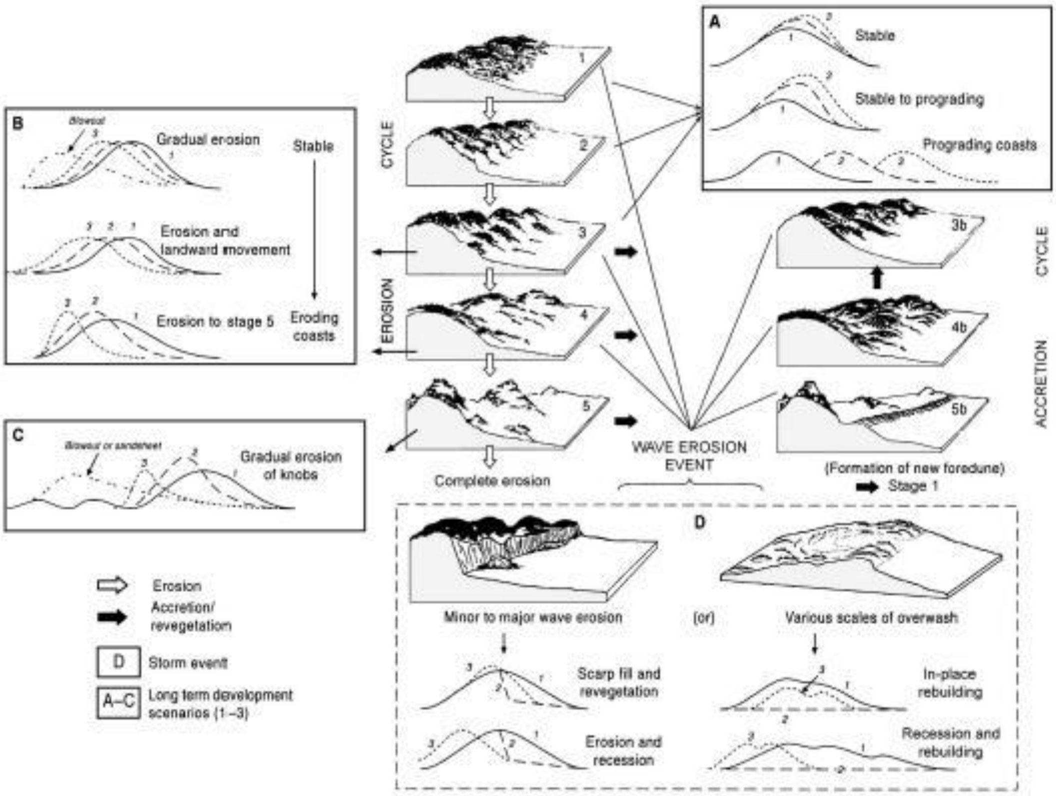

Figure 2.1. Foredune morphology and evolutionary trends on stable, accreting, and eroding coasts. A foredune may develop towards and remain in a particular morpho-ecological stage (Types 1 to 5), or evolve to another stage (e.g., from types 1 to 2 in the erosional cycle, or types 3 to 3b in an accretional/revegetational cycle). Foredunes may recover, rebuild landwards or be completely removed. In the long-term,foredunes may be relatively stable [Box A] (stable coasts), slowly build up seawards (stable to prograding coasts), or be replaced by new foredune development (prograding coasts). Other long-term evolutions are indicated in Boxes B and C (Hesp, 2002).

Main research activities:

- Classify the dune systems according to their present sediment balance making use of existing monitoring data on beach profiles along the Dutch coast (JARKUS-profiles), and aerial photographs and field observations to verify the classification.
- At different locations which are representative for the different dune classes: Measure the wind erosion activity with saltiphones (Spaan and Van den Abeele, 1991) in front of the dune field in combination with weather conditions and event based measurements of sediment transport at the foot of the embryonic dune field and at the foot of the primary dune with Modified Wilson and Cooke Catchers (MWAC) (Sterk et al., 1996).

- Determine what the main process controlling parameters are by measuring the local field characteristics of the deflation and transport zone.
- Monitor the dune formation with erosion pins and D-GPS including vegetation development.
- Develop the dune model.
- Parameterization of the dune model for the main dune systems along the Dutch coast.
- Perform a sensitivity analysis for the different parameters.
- Validation of the model based on field measurements.
- Perform dune simulations for climate scenarios in cooperation with KvK theme 6 on high resolution scenario development on climate change and sea level rise.

2.3 Scientific deliverables and results

A dune model for the main dune systems along the Dutch coast.

At least 3 peer-reviewed publications on:

- remote sensing tools for rapid assessment of dune systems: morphology and vegetation.
- aeolian sediment transport in dune systems with low medium and high sediment supply.
- modeling coastal dunes.

PhD thesis Dune formation under climate change

2.4 Integration of general research questions with hotspot-specific questions

The hotspot Wadden Sea is interested in the status of the different dune systems present on the islands: How will the coastline develop in the future under climate change and sea level rise?

Hotspot SW delta is interested in the effect of measures on dune formation. The dune model will give insight in both.

2.5 Societal deliverables and results

The results will be communicated on a regular basis with the stakeholders (see also 2.2.). The model will be used to show the effect of climate change and sea level rise on dune formation and can help in future planning of human activities along the coast.

2.6 Most important references

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3 Project 2.2 Management strategies for preservation and improvement of the climate buffer potential of dunes

Project leader: Dr. J Mulder

3.1 Problem definition, aim and central research questions

Climate change has a huge impact on the development of the coastal zone. A change in storm climate (frequency, intensity, and direction) may have a drastic effect on the amount and spatial distribution of coastal erosion and on the capacity of the system to recover between storms. More important, however, is the long term effect of a change in rate of sea level rise. The extra sediment demand created by an increased sea level rise, when not compensated by a proportional increase in sediment supply, will result in a structural recession of the coast. This insight for the Netherlands represents the basis of the nourishment policy of Dynamic Preservation and of the recommendations of the Delta Committee (2008) on a climate change adaptation policy for the coast.

The general management approach to the problem is nourishing of sand, predominantly on the shore face and occasionally on the beach. However, several questions remain with regard to more detailed aspects of the management approach. Basic assumption is that the nourishment sand represents the sediment supply to allow the dunes to grow with the sea level. Then the question is which management of the dunes is optimal to achieve this goal.

Sand nourishments primarily serve to guarantee the function of the dunes as a natural defense zone against flooding of the hinterland. *The problem* however, is that at the same time, other important dune functions (natural and ecological values, recreation and tourism, drinking water supply) are just as well affected by nourishments.

The aim of project 2.2 is to find a combination of nourishment and additional management measures, that preserves the climate buffer potential of the dunes and is optimal with regard to all dune functions.

Main research questions are:
- which dune management strategies are feasible in terms of technique and what is their effect on respective dune functions ?
- which dune management strategies are feasible in terms of support by the various stakeholders?

3.2 Approach and methodology

Stakeholders at national, regional and local level (Rijkswaterstaat, Water Boards, nature managers, local municipalities, the tourist branch, etc) all have their specific interests. To develop a supported management strategy it is therefore important to involve all these stakeholders in an early stage.

To this end, we shall apply a participatory planning approach involving both stakeholders and experts (e.g. Hommes, 2009). In a combined session of stakeholders and experts we will start with an inventory of existing functions, the objectives of the related stakeholders, their existing management strategies, their visions on the effects of climate change and their sense-of-urgency for adaptation measures (e.g Van Koningsveld, 2003). Experts will provide information on existing knowledge on dune formation in relation to climate change.

Then we shall jointly scan and select potential strategies, select (pilot) areas where these are applied (or applicable) and the effects are (or can be) monitored, and identify ‘white spots’ in knowledge.

Based on this, a first cycle of research will be started aimed at a quantification of the potential effects of selected strategies under certain climate scenarios. If necessary, additional measurements will be performed in order to establish the effect of alternative strategies on the parameters which control dune formation (project 2.1 and 2.2 together) and to provide data for the validation of the model for these pilot areas.

The results of this cycle are then fed back into a second stakeholder-expert meeting, which will lead to an update of potential strategies, and will provide input for a second cycle of research. And so on.

The length of each cycle is ca. 9 months. So, we expect a total of 4 iterations. In successive stakeholder sessions, the potential strategies will be elaborated co-operatively, providing a continuous feedback with the results of project 2.1 and of related research programmes.

Main research activities:

- literature research,
- stakeholder interviews,
- model simulations: long term morphological development (e.g Mulder et al., 2007); dune erosion (Van Thiel de Vries, 2009),
- monitoring of dune development (e.g. related to erosion berm experiment along Westerschelde in SW Delta)

3.3 Scientific deliverables and results

2 papers in peer reviewed journals, on:

- Design criteria for dune monitoring;
- Options for climate proof dune management

1-2 papers in a management journal

3.4 Integration of general research questions with hotspot-specific questions

The Province of Zeeland is especially interested in the effect of management measures implemented along the Westerschelde and Delta Coast on coastal development. Monitoring of the effects of erosion berm experiment in cooperation with province Zeeland, will be part of subproject 2.2.

In the hotspot Wadden the effect of sand nourishments is one of their main questions which gets our full attention in project 2.1 (monitoring and modelling) as well as in project 2.2 (stakeholder workshops).

Representatives of both hotspots will be invited to participate in the stakeholder-expert meetings.

3.5 Societal deliverables and results

This project will contribute to a supported, climate-proof management approach for dunes, based on a shared awareness of the service delivered by dunes as a climate buffer and as a carrier of other functions.

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