Exploring coastal morphodynamics of Ameland (the Netherlands) with remote sensing monitoring techniques and dynamic modelling in GIS

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PART 4

SYNTHESIS

Chapters are constantly changing. An understanding of these changes is required for proper present-day management and for prediction of future changes. Morphodynamics, the mutual influencing of processes and factors, have been expressed as change in the spatial and temporal distribution of sediment volumes. These changes can be detected, monitored and modelled.

The aim of this research has been to describe and predict the morphologic development of a sandy coast under the influence of natural processes (e.g. storms) and human impacts (e.g. nourishment) on a time-scale of months to years. An additional aim was to find a method for qualitative and quantitative prediction of the morphologic development, based on input of suitable elevation and remote sensing data and on the application of dynamic modelling and GIS techniques.

The purpose of this chapter is to integrate the methodological and geomorphological results of the research while taking account of the concept of morphodynamics. Advantages and limitations of the study are identified with respect to the method development and the geomorphological investigation.

DEVELOPMENT OF METHODS

Remote sensing and elevation data were used for the detection and monitoring, and spatio-temporal GIS tools for the description and prediction, of meso-scale morphodynamics.

These studies have contributed to method development for coastal research. It has been demonstrated that these new tools and techniques are operational. Remote sensing data and elevation data allowed monitoring of the present and previous morphodynamics, so that they are useful for the study and management of coastal areas. Models in GIS allowed coastal behaviour to be predicted, so that management decisions can be made in time. Remote sensing and other geospatial data studied with image processing and GIS techniques are very suitable for studying changes in the coastal zone. Maps communicate the spatial information effectively as they are a well-understood and accepted form of spatial data display, generating a widely-accepted and familiar format for shared information (Ferrier, 1997). The geomorphological changes on the meso-scale can also easily be related to practical experiences of coastal managers. This is in contrast to graphs that show the changes of a certain process variable, from which the implications cannot be overseen.

The innovative data and tools allow patterns familiar from coastal process studies to be recognised. In this way the research could also contribute to these studies.

The approach also has some limitations. The study has shown that many remote sensing images present only part of the required information on geomorphological features on a certain scale. Therefore, this research assesses the suitability of various data for the study of
CHAPTER 10

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various morphological features. It appeared that careful data selection was necessary to express coastal morphodynamics, and that information about elevation was required, because height is an important parameter for the description of forms of the earth. A study of height extraction from video images showed limitations in the use of video data and photogrammetric software. It is not economic to derive heights from remote sensing data for this research area; relative height can be extracted from the video data for the foredune area; for the beach the result is unreliable. Therefore, measured heights from an existing database 'JARKUS' (comprising photogrammetrical and echosounding data) and laser altimetry have been used for quantitative prediction.

The research revealed which parameters are needed for qualitative and quantitative prediction. For qualitative prediction, the morphological units of the process-geomorphological interpretations are the variables to be considered. For quantitative prediction, the variable height is sufficient to describe coastal morphological changes.

The understanding of the meso-scale coastal systems is still very limited. Little quantitative information is available. Therefore it was attempted to link studies on this scale to process studies on a micro-scale. Some of the parameters for the meso-scale study were derived from the causal links known from the process method. Modelling in a spatio-temporal GIS can meet some limitations, because it requires spatial data. In this case spatial elevation data was available.

GEOMORPHOLOGICAL INVESTIGATION

Three sand-sharing systems on Ameland were studied. They are open systems that are governed by many feedback mechanisms and show dynamics on many temporal and spatial scales. These systems were analyzed geomorphologically. Trends in the evolution of sand mass (or volumes) were used for the formulation of conceptual models and for predictions of the future morphology of the three systems.

The results obtained by these studies contribute to the existing insights into coastal geomorphology. The concept of morphodynamics (Wright & Thom, 1977) has been redefined for a meso-scale. The factors which determine meso-scale morphodynamics of three different sand-volume sharing systems were identified. The knowledge of the interaction of the morphology and the geomorphological processes in relation to other parameters has been indicated in conceptual models and has been formalised and elaborated by interactive modelling in GIS.

Some of the knowledge gaps on the meso-scale could not be bridged by this study. Because of limited knowledge available on this scale level, certain systems were just described, and their prediction was subsequently based on this description. As far as possible, the variables that came from process research were used in the description.

There are still gaps in knowledge of the Western system. Although this study illustrates the importance of channel and shoal behaviour for Ameland's northwestern beachplain, no long-term trend could be derived from the description of the behaviour of the northwestern beachplain.
There remains also a hiatus in the knowledge on the functioning of the Central system. The research has shown that stormfloods and nourishments are related to the sediment exchange between landscape units. The sediment balance on the level of forms is, however, not fully understood, particularly for the behaviour of bars and the influence of rip currents on sediment volume changes.

There are still problems in quantifying the interactions in the Eastern system. Although the approach seems promising, the quantification of the influence of morphometric and vegetation parameters on the geomorphological processes could not be proven.

It was found that coastal geomorphology can be studied on a meso-scale level, but only limited causal relations are found on this level. The multi-scale approach described in this thesis implicitly acknowledged the relationships on each scale level, without focusing on knowledge transfer from meso-scale to process-scale. The possibilities for such a transfer after further analysis should not just be discarded though.

FURTHER PERSPECTIVES

The morphological development of a sandy coast under the influence of natural processes (e.g. storms) and human impacts (i.e. nourishments) on a time scale of months to years has been examined. The results and insights may be used for management of the coast.

Various questions arise when working on this landscape scale. Often, they can be answered by process geomorphologists or coastal engineers. The changes that can be perceived can be linked back to process measurements. Sometimes, a lack in knowledge appears. By offering this meso-scale perspective on coastal morphodynamics, perhaps these studies can promote a better understanding of coastal changes. It is clear, however, that this is still an open field and that more research is necessary.

Certain aspects of the approach can be applied to other fields or disciplines. Most of the individual methods used were developed in other fields, or are already being used in different fields. The use of remote sensing data instead of field measurements is common in environmental sciences, earth sciences, agricultural sciences and even social sciences (e.g. urban planning). The approach adopted for modelling is to a large extent related to system theory, which originates in different disciplines, and has been used in e.g. biological and soil sciences (Von Bertalanffy, 1968; Phillips & Renwick, 1992). The volumetric change approach, in which certain units share a certain amount of sediment, has probably been used in other (water) erosion studies as well. The integration of behaviour and process modelling is strongly influenced by river and coastal engineering research (De Vriend et al., 1993). Modelling with GIS was originally developed for catchment areas (Van Deursen & Kwadijk, 1993). The combination of these individual methods or techniques to one method or approach is new, however, and could be useful for all the disciplines mentioned.

This study benefited from the practical answers given by process geomorphological scientists and coastal engineers on practical questions, and the approach taken in the study encouraged the participation of people from different disciplines. The approach adopted in this study could be extended for decision making, because it incorporates many of the steps needed for
a decision support system (DSS) and uses methods that could be components of a DSS (Schiereck & Van der Weide, 1995).

The method will be directly or indirectly applicable to other coastal regions. Some parts of the method apply specifically to the Dutch situation, where nourishments are being used for coastline management, making trend analysis of sediment budgets possible. The prediction of yearly morphological changes of coastal stretches requires meso-scale research (in time and space) that focuses on these morphological changes themselves. Therefore, there is a need for studies on a landscape scale, which could be performed with the data and method mentioned in this thesis. The data and method facilitate a quick and efficient monitoring of more inaccessible areas, and allow for the prediction of their near-future changes. The coastal community can benefit from research on different coastal systems on a similar scale.

It is clear that the micro-scale process method and the meso-scale morphological method can complement each other. Further integration is therefore logical. There are several approaches to linking the methods. Formal, mathematical integration methods have been proposed by De Vriend et al. (1993). This thesis is the product of a less formal approach, but the feedback from meso-scale information to process-scale knowledge has not yet been fully explored. Because of the large amount of process research that has been performed on the Dutch coast, there are ample opportunities to link this work to process research, i.e. to the aeolian research of Van der Wal (1999) on Ameland, of Arens (1994) on Schiermonnikoog and to the marine studies of Hoekstra et al. (1996) on Terschelling.

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