

Precepts, approaches and strategies

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Precepts

Apart from climate change and the associated sea level change, there is a multitude of other environmental threats: acid rain, the hole in the Antarctic ozone layer, population pressure, desertification, widespread erosion, the pollution of the atmosphere and the sea, etc. Several of these other factors are also affecting the dune landscape. And rapidly we find out that the threats of climate change are also but all too real. At the International Conference on Landscape-ecological Impacts of Climate Change (LICC) held in December 1989 in the Netherlands, during which the idea of this collection of papers originated, the discussion was still in terms of the 'What...if' approach: what will happen if some scenario on climate change will materialize.

However, soon afterwards projections on future climate became increasingly accurate. This is particularly due to the Intergovernmental Panel on Climate Change. According to their report (IPCC, 1990a), if emissions follow a 'Business-as-usual' pattern, global mean temperature will be increased by about 1°C above the present value by 2025 (about 2°C above that in the pre-industrial period) and 3°C above today's before the end of the next century. Due to uncertainties the latter estimate ranges between 2°C and 5°C, but there are significant regional and seasonal variations.

For Southern Europe (35-50 N, 10 W-45 E), the warming is about 2°C in winter and varies from 2 to 3°C in summer. There is some indication of increased precipitation in winter, but summer precipi-

tation decreases by 5 to 15%, and summer soil moisture by 15 to 25%. The warming in the maritime part of Western European regions is of the same order. Increases in precipitation of 0-2mm per day during winter are being predicted, whereas during summer precipitation will remain more or less the same. Simulation of regional climate is still rather inaccurate. Recently new methodologies have emerged (Giorgi and Mearns 1991).

With respect to extremes and storm intensities, the IPCC report is less conclusive. This is disappointing, because changes in the variability of weather and the frequency of extremes will generally have more impact than changes in the mean climate at a particular location. With the possible exception of an increase in the number of intense showers, there is no clear evidence that weather variability will change in the future. As the equator-to-pole temperature contrast will probably be weakened in a warmer world (at least in the Northern hemisphere), it might be argued that mid-latitude storms will also weaken or change their tracks. The latter may result in an increase of storminess at a particular location.

Very recently, a paper by W. Kellogg, *Response to skeptics of global warming*, appeared in the Bulletin American Meteorological Society (Kellogg 1991). In it he critically analyses the arguments of the skeptics of climate change. These arguments range from that we do not understand the earth's climate system well enough to predict the future, to more complex arguments involving negative feedbacks and changes of solar activity. Also, some

claim that future global warming will be beneficial to most of mankind and that it should be encouraged. In conclusion he states:

“We have pointed out that the greenhouse theory is one of the best established in the field of meteorology. Thus, the observed increase in carbon dioxide, methane and other infra-red absorbing greenhouse gases must theoretically be causing a global warming. Moreover, observations of global near-surface temperature show that indeed a warming trend has taken place in this century. The decade of the 1980s has had six record-breaking warm years. Never have we experienced such a warm earth since the invention of the thermometer, nor a period when the rate of warming was so prolonged and rapid.

Furthermore, we can point out, for the benefit of those who are not entirely satisfied with the evidence offered by the surface temperature record, that there are other changes taking place that also signal a global warming that can be ascribed to the greenhouse effect. Good examples are the observed increase in tropical tropospheric moisture, and a cooling of the stratosphere.”

According to the IPCC report sea level has been rising over the last 100 years by 1.0-2.0 mm/yr. There is no firm evidence of an acceleration in sea level rise during this century, although there is some evidence that sea level rose faster compared to the previous two centuries. For the ‘Business-as-usual’ scenario the sea level rise will be 4-5 mm/yr for the next forty years. For the forty year period thereafter, to 2070, sea level rise will be 8-9 mm/yr.

This issue of *Landscape Ecology* is on the impacts of climate change on coastal dune landscapes of Europe. This editorial introduction draws heavily from available studies from the Netherlands (Delft Hydraulics 1990). In this low-lying country the response of coastal dunes to a rising sea level is of particular importance.

According to Vessem (1990) the net sediment budget of the Dutch coast is negative. There is a shortage of 510.000 m³, which corresponds to an erosion rate of 2 m³/m.yr. For comparison: the total volume of the young coastal dunes is approximately 2.700.000.000 m³ (Pool and Valk 1989; Pool 1989). Also, the yearly shortage is

relatively small compared with the contribution of the Wadden Sea (separating the Dutch Wadden islands from the mainland), which withdraws about 5.000.000 to 8.000.000 m³/yr. Its ‘sand hunger’ has increased considerably because of the closure of the Lakes IJsselmeer and Lauwerszee.

Coastal dynamics are the result of many processes, acting on several time-scales. Table 1 gives a summary of these processes. From this table it is clear that sea level rise is only a partial clue to coastal dynamics, and thus to the fate of the outer dune landscape. Also, it is generally recognized that sea level rise is not the key driving force. Evidence from the past in the Netherlands shows that sea level rise may even be accompanied by coastal accretion (Straaten 1965, Jelgersma *et al.* 1970, Klijn 1981). The availability of sediment or a change in climate may be much more important factors. Important climatic variables are changes in the predominant wind direction and changes in cyclonic activity.

With respect to the fate of the inner dunes, it is much harder to identify driving forces and to describe the relationships between them.

Approaches

Transport processes of material by water and wind are threshold processes, interacting in a complex manner, and exhibiting fluctuations on a wide range of time scales. Modern geomorphology recognises that the old theories of simple cause-effect change in landforms that develop in a linear fashion are untenable. Catastrophe theory seems to be a closer approximation to reality but it has been superseded by event theory based on nested but interdependent time scales.

These methodological concerns may appear excessively theoretical but they are of critical concern for designing both detection and monitoring research programmes. For example, in a beach/dune system, ripples on a beach may change in hours; the beach will have a morphodynamic cycle usually measured in weeks; the beach configuration as a whole corresponds to wave climate and

Table 1. Processes affecting coastal dynamics (after Stolk 1989).

Process	Time-scale (years)	Causes (Natural/ Anthropogenic)
Relative sea level change	>100	N
Differential bottom movement	> 100	N
Climate change	>100	N/A
Sediment availability	> 100	N/A
Paleomorphology	> 100	N
Medium-term climate fluctuations	10-100	N
Sand waves	10-100	N
Migration of tidal inlets	10-100	N
Small changes in hydraulic or meteorological parameters	< 10	N
Migration of breaker ridges	< 10	N
Dynamic equilibria	< 10	N
Coastal management	> 10	A
Coastal defence	> 10	A
Bottom movement	> 10	A
Accelerated sea level rise	> 10	A
Suppletion of sand	< 10	A

bathymetry which is changing within event cycles of decades or centuries; the coastline is changing as a result of relative changes in the land-sea boundary and, probably, total sediment budget on various time-scales (see Table 1). This complexity may be almost insurmountable and therefore it is essential that the design of any monitoring programme is not set within a constrained spatial or temporal framework in such a manner as to cast doubts on the validity of the results that will be obtained in the future. For example, it is invalid to study the development of a blowout in a frontal dune without studying total beach sediment budget change and alterations in the frequency of wave uprush attaining specific threshold levels above still water level. In other words, if total beach sediment budget and/or storm frequency cannot assumed to be constant, the experimental control volume should be extended from the blowout to a larger part of the land-sea interface.

Apart from choosing the size of the experimental control volume (and, implicitly, the length of the time-span to monitor processes), the choice of the target variable needs care. The difficulties of using vegetation as a target variable in studying the effects of climate change, are well-known since climate operates partly direct on vegetation, partly

through the medium of the soil and ground water chemistry. Also, other factors such as land use and management changes, and the deposition of nutrients via aerosols are significant factors that induce changes in dune vegetation. These may even operate with faster response rates than climate. Thus vegetation, often regarded as the best indicator of change is a poor focus of attention, paradoxically because it is the sum total of most causal factors in dune environments.

Thus, to distinguish between changes that can reasonably be ascribed to global warming and to natural changes that are cyclic or normal system perturbations, it is necessary to study morphological features or biotic indicator species that are sufficiently sensitive but are also less complex in their systems linkages. Changes must be linked unambiguously to climatic variables and must not be explicable by other factors of which sand supply and dune management are conspicuous complications. Specifically, when choosing the beach-dune and/or frontal dune area as an experimental area, a larger control area should be adopted in order to account for the large number of compounding process factors which occur at the land-sea interface. Logically, the best results will be obtained from natural or artificial closed systems. It is surprising that in

studying the effects of climate change little use is made of pot-trial experiments. Further, the promising results from the methodology that is based on inclusion-exclusion plots in different types of dunes should be pursued.

Existing literature on coastal sand dunes in Europe is mainly of the ecological-evolutionary type (Robertson-Rintoul and Ritchie 1990) and is essentially descriptive. The papers by Corre and Sanjaume (this issue) are of this type. In contrast, Meekees (ornithology), Sevink (soils), Jungerius *et al.* (blowouts) and Noest (water table-vegetation interaction) - all this issue - attempt to predict changes in specific dune phenomena on the basis of existing trends and models which have varying levels of scientific reliability. Elsewhere, Wright and Harris (1988) and Ritchie (1990) have attempted to use sequential aerial photographs and repeated geomorphological mapping (both studies using a 10 to 20 year interval) to measure biotic and abiotic changes. These changes can be described with a high level of accuracy but it is difficult to go beyond description to explanation.

In order to assess the impact of climate change on the coastal dunes of Europe several conditions need to be satisfied to ensure that there is scientific validity in the research outcomes. The research must satisfy the following conditions:

1. The target variable is a sensitive indicator of some climatic variable;
2. Sufficiently robust techniques of measurement should be available;
3. The length of the time series is sufficient in order to distinguish between induced changes and normal cyclic and random variation;
4. A sufficient body of research on various environmental attributes of the study area is already available, including adequate meteorological instrumentation and tidal wave observations;
5. No unquantifiable sediment budget additions or subtractions occur;
6. Management regime will not change.

In reality, a survey of the dunes of Europe suggests that few areas can satisfy these criteria. Arguably, therefore, more controlled experimental situations should be developed for a variety of biotic and

abiotic phenomena. Logically, the complex, multiple loops of coastal dune systems should drive both research methodology and the selection of targets for monitoring into a 'quasi-laboratory' mode of study, preferably at a series of dune sites in a range of sub-regional climatic settings. This is a European problem and should be tackled on the basis of a multi-national network.

Strategies

Strategies for management of dunecoasts are being developed presently by various organizations on a national and international level (management is used here in the context of nature and landscape conservation). This is extremely urgent: dunecoasts belong to Europe's major nature conservation areas with high ecological diversity and scenic beauty, at the same time these narrow landscapes are under extreme threat from human activities like mass-tourism, industry, coastal defence, housing and drinking-water production. A greater scientific and public awareness is needed to establish appropriate management strategies. Within the European Community, the EUCC (European Union for Coastal Conservation) is playing an active role to achieve this. Presently the concept of 'sustainable use' is important. It combines aspects of commercial and recreational use of coastal resources with real activities to protect, maintain or even develop the natural resources and ecosystems at the same time. In some areas, nature conservation will have to be the only effort, in others a combination of use and conservation may be considered. Wise use of the coastal zone will be an important effort whether the climate is going to change or not.

Which are the extra threats posed to the coastal dune environment by climate change and sea level rise? Which management strategies can be applied so that the coastal landscape can adapt to possible sea level rise and climate change? In essence, we deal with two different systems, the outer dunes (or foredunes) and the inner dunes. The foredunes will respond immediately to sea level rise because one of the first driving forces involved will be the sand budget in the foreshore-beach-foredune sector.

The inner dunes will respond more to climate change as such. It is important to realize that both systems harbour different functions or combinations of them.

Foredunes. In lowland areas the prime function of the foredunes is coastal defence. In the policy analysis for coastal defence 1990-2090, carried out by the Dutch Government (Ministry of Transport and Public Works 1990) four management alternatives were considered, increasing in costs:

- * **Withdrawal:** to allow further retreat of the shoreline, except for the places where minimum safety cannot be guaranteed;
- * **Selective Erosion Control:** to counteract further shoreline retreat at places where economical functions like drinking water supply and recreation are present in the innerdunes or where valuable nature areas are threatened;
- * **Full Erosion Control:** to counteract further shoreline retreat at all places where this occurs;
- * **Expansion:** seaward expansion of the shoreline at places where the coastal defence is relatively weak. The aim is to improve the defence system. This alternative is more offensive than the others. Structures of hard material, like groins and dams are chosen.

Two types of measures for coastal defence must be distinguished for the first three alternatives. Both make use of additional sand supplies. In this way the natural character of a soft coast is not irreversibly affected and there is much experience with this type of defence measures. The first type concerns the shifting of sand from the seaward side of the foredunes to the landward side. In this way a certain retreat is allowed while the dimensions of the foredunes are maintained at the required level. The second type concerns beach (and foreshore) nourishment. It is applied when shoreline retreat is not allowed. In both cases the regular coastal defence (dykes, groins, etc.) is maintained.

The Dutch Government has chosen the full erosion control alternative, which was called 'dynamic preservation'. The choice was for enduring safety and at the same time for a sustainable preservation. The coastline is going to be preserved within certain limits of movement. At certain places the coastline

is allowed to move; freedom of movement will be dependent on the functions of the innerdunes (tourism, drinking water production, industry, nature conservation for example). At some places one may allow tidal inlets to develop. It is thought that a more natural, dynamic coastline will be cheaper and more durable to manage at the long run. The concept of dynamic preservation offers possibilities for a combination of coastal defence and nature conservation in the coastal dunes. This aspect is discussed by Lousse and Meulen (1991) from the viewpoint of landscape ecology.

The alternatives mentioned here greatly conform to the findings of the IPCC Coastal Zone Management subgroup (IPCC 1990b). This report presents adaptive options on a global scale in response to an expected acceleration in sea level rise. The report mentions three strategies:

Retreat, abandonment of land and structures in vulnerable areas and resettlement of inhabitants;

Accommodation, continued occupancy and use of vulnerable areas;

Protection, defense of vulnerable areas, especially population centres, economic activities and natural resources.

Defence options for protection may include hard ones like dikes, groins, levees, floodwalls, seawalls, salt water intrusion barriers and floodgates or tidal barriers and soft ones like beach nourishment, dune building and wetland/mangrove creation (especially for tropical areas).

Hard structures like groins trap sediment which is moving alongshore. However, protection of one area is generally found at the expense of an increased erosion downdrift. Such structures do not increase the total sediment available to beaches, they merely move erosion to other places. Dams and saltwater intrusion barriers may protect water supplies and fresh water habitats. On the other hand they can prevent sediments to reach the coastal zone and thus increase erosion of coastal headlands.

Soft structures have a less severe impact than hard ones. They usually make use of simulated natural features like beaches and wetlands (tidal inlets as well as fresh water habitats). Soft options are thought to be more durable to maintain and

favourable for nature conservation because coastal ecosystems will get a change to adjust to increased levels of the sea.

Inner dunes. Inner dunes are not directly used for defensive purposes, although they offer an extra sand supply in this respect. Inner dunes are affected by sea level rise in the case of the retreat (or withdrawal) option or in the case of the dynamic preservation option. From the point of view of landscape ecology one will always have to weigh the losses of existing ecosystems against the gains of possible new ecosystem development. Nature conservation is not the only function to take into account because inner dunes often are multifunctional landscapes, especially in areas having large populations.

If we exclude the shoreline processes, climate change for the inner dunes will affect the interaction between abiotic and biotic processes in the dune environment (Meulen 1990). The equilibrium between relief, soils and vegetation will change. Landscapes will develop either with more vegetation, mature soils and stable dunes, or with sparse vegetation, young soils and mobile dunes. Which way the shift will go depends on climate factors like rainfall, air temperature, wind and radiation. These factors interact with existing factors of land use and grazing.

At present there is a lack of causal and quantitative information on the interaction between vegetation (and animal life) and the abiotic environment in dunes. It is our hope that in the near future this knowledge will be accumulated through the development of ecological interaction or response models for special and vulnerable sites (ecosystems). The extrapolation of site information to entire landscapes may be enhanced by using Geographical Information Systems which can also play a role in inventarisation and monitoring programmes. Worthwhile mentioning in this respect are the activities of the recently established European Union for Coastal Conservation (EUCC) to arrive at a landscape ecological mapping of European dunecoasts and a joint monitoring program for coastal zone management purposes (EUCC 1989c, Meulen and Janssen 1991).

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