Environmental sustainability of coastal areas and building-with-nature, 10 years of experience in a Dutch nature compensation project

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1. ABSTRACT: The paper discusses 10 years of experience with a unique dune compensation project at the Dutch coast (total project duration 20 years). The compensation was needed because a large extension of Rotterdam harbor would damage two high-quality dune ecosystems nearby. EU legislation obliged to compensate these two ecosystems. The compensation area was constructed and developed according to the principles of Building-with-Nature.

The use of local natural materials and processes and a minimum of human interference is a leading principle. Careful monitoring is done for evaluation. However, over time some important human interferences were necessary to stay 'en route' and to reach the two compensation targets. The management measures and their results are discussed. The insights gained and their importance for environmental sustainability of coastal areas in general, are given.

Keywords: *harbor extension, compensation of nature damage, dune ecosystems, building with nature, dune landscape development*

2. INTRODUCTION

First, the principles of building-with-nature are given. Next, the paper discusses how the recent extension of Rotterdam harbor will damage two existing high-quality dune ecosystems nearby. According to EU-legislation, they need to be compensated. For the compensation, an entirely new dune area was constructed. The construction and the following development of this area, were done according to the principles of building-with-nature. But compensation of nature and nature development takes time, sometimes several decades. While a minimum of human interference was the intention at the start, over the past ten years some drastic management actions were necessary. Particularly at the level of geomorphology, groundwater and vegetation development. The management actions and their results are discussed. The paper concludes with lessons learned from the project so far and conclusions about environmental sustainability of coastal areas and transfer to other countries.

Building-with-nature

Building-with-nature is a new way of engineering, which makes use of the local properties of nature (green technology) (Waterman

2008, van Eekelen and Bouw 2020, World Bank 2017, 2018). At the coast, this means respecting and using the coastal ecosystems and processes, as much as possible and with minimal human interference. As such, building with nature contributes more to environmental sustainability than does the traditional building in nature. The latter often ignores and destroys nature. In that case, we may even speak of building against nature. An example: at sandy coasts, building coastal defense structures is traditionally done with hard solutions, like groins, breakwaters and concrete slabs. But soft, more nature-based solutions can also be considered, like sand nourishment. This is more in line with building-with-nature principles (fig 1).

Figure 1: Developments in coastal engineering: change from hard designs (left)to softer more nature-based designs (right; beach nourishment, Netherlands). Hard structures with alien materials, like basalt rock, decrease natural properties of the coast (building in nature). Soft ones with local material, are more in line with coastal characteristics (building with nature).

Extension of Rotterdam harbor and compensation of nature damage

In 2010, a new dune area (called Spanjaards Duin; size 35ha) was constructed at the dutch coast, in the southwestern part of The Netherlands, by beach nourishment (6 million m^3) (figs. 2, 3). The nourishment was laid out in front of the exiting coastline. This new area is meant to compensate for the damage to existing Natura 2000 dunes, caused by the extension of Rotterdam harbor (Maasvlakte 2; www.maasvlakte2.com) (fig 2). Natura 2000 is a network of European high-quality nature reserves. EU regulations required compensation of the damage (van der Meulen et al 2015, van der Meulen 2016).

The damage to nature that was expected, is high airborne deposition of NOx (N is an important nutrient for plants), caused by the increase of harbor traffic. This high NOx deposition is detrimental for two high-quality and nutrient-poor dune ecosystem types: Grey dune and Dune marsh. (fig. 4). So, these two types are the targets for compensation in Spanjaards Duin. The time period for the compensation project ends at about 2030, the same year in which the new harbor extension would be in full operation (and full emission of NOx). Under normal conditions, these ecosystems will take about 20 and 5-10 years to develop, respectively.

Figure 2: Part of the southwestern Netherlands coast. Extension of Rotterdam harbor with Maasvlakte 2 (white). Nature damage (red) and nature compensation (green).

Figure 3: The new dune area, two years after construction (2011). Prospective dune marsh to develop in the lowest parts of the valley (middle). Prospective Grey dune to develop on the surrounding, more elevated sites. In the distance the new harbor extension of Rotterdam (Maasvlakte 2). Yellow line marks the border between existing dunes (left) and nourished dunes (right).

Figure 4: Compensation targets, two high-quality and nutrient poor ecosystems: dry Grey dune (left) and Dune marsh (right).

From the start, the compensation project was carried out along the principles of building-with- nature. In 2010, the new dune landscape was constructed by beach nourishment with local sand taken from the nearby North Sea bottom. Once the sand was deposited, local, natural processes were given free hand, without human interference as much as possible. This implies: shaping of dunes and dune valley by wind, fresh ground water development by rainfall (the initial nourished sand had a salinity of 300mg/l, the salinity of North Sea water. The nourishment had to desalinize first before a fresh groundwater dome could develop in the new dune body. This takes some 5-10 years), and natural vegetation development by pioneer colonization and succession. So, the landscape development started in 2010.

A unique experience of worldwide interest

The compensation project is unique worldwide. Never before was, in the context of a large civil engineering harbor project, at the same time, a dune building project undertaken to develop specific dune ecosystems of high nature value in about 20 years. The development of the area was yearly monitored for evaluation. After more than 10 years of monitoring and experience we can make up a first balance, halfway the project duration time (2010-2030).

3. DEVELOPMENT OF THE NATURE COMPENSATION PROJECT AND HUMAN INTERVENTION

The initial Building-with-nature philosophy, of development with minimal human interference, appeared too optimistic. Nature is not always makable and predictable. In the field, there were unexpected developments. At the political level, there was increasing pressure to speed up the ecosystem developments into the desired direction. This is important to note, because it means that political arguments can become dominant over nature/ecological arguments.

Most often, the available time is the crucial factor for success. Politicians think in terms of elections, which is in periods of 4 years of election time. Nature, on the other hand, needs more time, often decades. This can cause friction. In order to steer the development towards the two compensation targets, it was decided to make some drastic management interventions. In the past ten years, following actions were carried out.

Management interventions

Process 1-Dune dynamics and morphology: too much sand dynamics The nourished sea- bottom sand was rich in sea-shell fragments (ca 30%). After this sand was deposited, ongoing wind erosion blew out the sand particles from in between these shell fragments. After some years, the substratum surface was largely covered with shell fragments, appearing like a kind of desert pavement (fig. 5).

Figure 5: Left: numerous shell fragments at the surface, forming a 'desert pavement', difficult for plants to colonize. Right: large gap in the fore dune ridge to be closed to reduce sand dynamics. (Photo: Bert van der Valk).

Such a 'sealed' soil surface and strong sand blasting is an obstacle for the colonization and establishment of Grey Dune vegetation. At the same time, the sealed surface blocked further erosion of the valley floor down to the ground water level. This was an obstacle for the colonization and establishment of Dune marsh. Several years of monitoring showed that these obstacles where indeed persistent and the compensation project appeared to be in danger. Finally, intervention was necessary to stay 'en route' towards the two compensation targets.

Over the years 2017-2019 it was decided to minimize the overall sand dynamics in order to create better ecological conditions for Grey Dune vegetation development (no more sand blasting and less shell fragments at the surface). Some large openings in the fore dune ridge gave way to large amounts of sand from the beach to enter the valley (fig. 5). These gaps were closed with sand that was stabilized with marram grass.

Process 2. Groundwater dynamics. Excavate and lower the valley floor

To create better ecological conditions for the Dune marsh, the valley bottom floor was excavated further down to the groundwater level (fig. 6). Five oval depressions were dug out, aligned with the prevailing southwest-northeast wind direction and looking like natural blow-outs. By this work the groundwater-level now was near or at the surface, the right ecological condition for Dune marsh vegetation development.

Figure 6: Excavating the valley floor (left; photo: Bert van der Valk) and creating oval depressions with ground water near the surface (dark grey colors in right picture).

Process 3. Vegetation development. Introduce plant material to boost the seed bank

The monitoring of vegetation showed that the development towards the targets, Grey Dune and Dune Marsh, went very slow. Soil profile studies revealed that, even after about 8 years, there was hardly any seed bank in the sediment. Not a surprise, because the original sediment was taken from the sea bottom and all plant seeds have to be brought in (f.e. by wind, birds) from nearby dunes.

In 2019 it was decided to bring in plant material (clippings, that were cut yearly) from Grey dune and Dune marsh elsewhere. The clippings were brought in and spread out over the soil surface (fig. 7). The clippings contained a lot of seeds from plant species that are characteristic for Grey Dune and Dune Marsh. This measure will give the seed bank a boost and speed up vegetation development. Similar experiments from other comparable dune areas in northwestern Europe, all had positive results.

Figure 7: Bringing in plant material from high quality ecosystems nearby, to give the seed bank a boost.

4. RESULTS OF THE INTERVENTIONS

The interventions were done to provide for better ecological conditions and to speed up the development of the target vegetations. Three characteristic dune processes were managed: (i) dune morphology and sand dynamics, (ii) ground water development and (iii) vegetation development. Although the time is still short for a solid evaluation, the first positive results can already be seen: the overall sand dynamics in the area are greatly reduced thus providing stable conditions for plants to germinate and for vegetation to grow. At places where grass material was spread out, several characteristic species of high-quality Dune marsh already appeared after one year. Examples are some orchids (Orchis spec.), Grass of Parnassus (Parnassia palustris) and Yellow-wort (Blackstonia perfoliata).

The project and the monitoring will go on till 2033. This is the same year that the new harbor is expected to be in full operation. There is good evidence that the near future will show more positive results of the interventions, in favor of the compensation aims.

5. LESSONS LEARNED ABOUT BUILDING WITH NATURE

The following lessons can be learned now the project is about halfway.

(1) Nature is not always makable and predictable
(2) Building-with-nature (and few interventions) is a good concept to apply in practice, but one should always be aware that small or larger adaptations may be needed. In this project this meant, for example, that, even if local material is used (sand from the nearby sea bottom), adaptations were necessary because the material differs from aeolian dune sand. This caused deviating dune developments, which made extra management necessary.
(3) Always monitor and evaluate to make the right adaptations at the right time and place.
(4) Monitoring also helps to learn more about the ecosystem (behavior); learning by doing enhances your expertise.
(5) Have patience; nature development takes time; often more than politicians have or want. This is often a crucial point in the debate between nature and economic development. The 'dynamics' of nature differ largely from those of governmental politics, but the latter is often deciding.
(6) Protect the building-with-nature area right from the start, to allow an undisturbed development. In the beginning the actual ecological quality may not score high. The reason for protection is not the present quality but the prospective and intended, future quality.

6. CONCLUSION: ENVIRONMENTAL SUSTAINABILITY OF COASTAL AREAS AND TRANSFER TO OTHER COUNTRIES

This example is taken from Dutch coastal dunes. But knowledge gained here can be transferred to other coastal countries that want to develop a policy for environmental sustainability of their coasts, for example in the future of adaptation to climate change.
Some main points to consider are:

(1) Always compensate nature damage
(2) Civil technical solutions should be weighed against nature technical solutions to assess which one is a more sustainable solution or a better combi of both.
(3) Install monitoring to learn more about the coastal ecosystems in question and to apply more green technology in future coastal development.
(4) Consider building-with-nature as an added and valuable technique in all future coastal engineering projects.
(5) Cooperation between various disciplines, ecological, civil engineering, nature management and policy making, is essential.

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