Building with nature for coastal resilience

Restoring tropical mud coasts

Innovative solutions are needed to address the on-going loss of ecosystem services due to unsustainable land use. In tropical coastal areas, large tracts of mangrove forest have been cleared to make room for aquaculture ponds, urban settlements and other land uses. The resulting coastal erosion, saltwater intrusion and increased vulnerability to flooding from storm surges increase the exposure of people and their livelihoods to natural and man-made hazards.

In order to address this problem, coastal managers tend to turn to 'hard' engineered structures - such as dykes and breakwaters. However, such structures are often expensive and inflexible, and may fail to provide adequate protection to people and property. Sometimes these structures become counterproductive, exacerbating the problem they were supposed to solve.

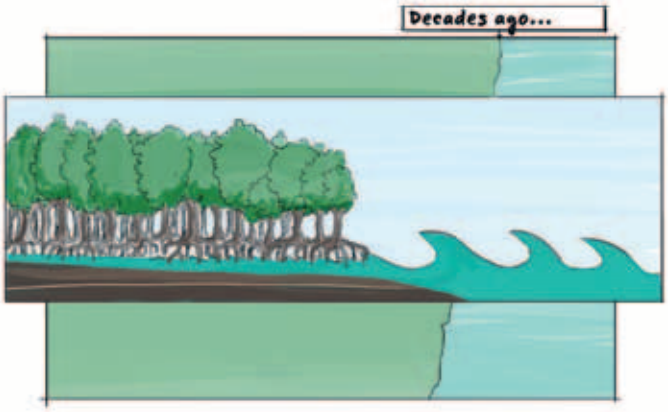
Hybrid engineering

Hybrid engineering is an innovative concept that seeks to work with nature rather than against it. It combines engineering techniques with natural processes and resources, resulting in dynamic solutions that are better able to adapt to changing circumstances. Some hybrid structures may literally grow on their own and/or maintain themselves, for example where they facilitate the establishment of living plants or bivalves. Such structures may get stronger over time, as mangrove trees grow and oysters settle on top of one another; by contrast, man-made structures generally become less effective over time and have a limited lifespan. Moreover, hybrid structures can provide a variety of ecosystem services in addition to coastal protection, like provision of food and climate regulation.

This leaflet explains the concept of hybrid engineering as it relates to mangrove coasts. It provides a rationale for moving away from over-reliance on hard engineered structures, and moving towards working alongside and with nature for coastal resilience. The information contained in this leaflet can be used by policy makers and practitioners when considering options for coastal defence in tropical coastal regions.

Hybrid engineering approaches can be applied in a variety of situations and ecosystems. Several examples exist - some are hundreds of years old and reflect local and/or traditional knowledge regarding ecosystem management. Since 2008, the Building with Nature[1] programme has been implementing hybrid engineering approaches in different contexts. This leaflet focuses on a potential approach to tackle coastal erosion in tropical mud coasts by using the natural mangrove forest to stabilise the coastline.

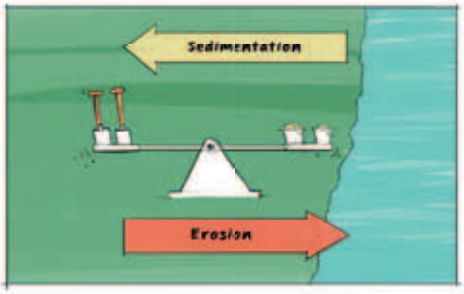
Formerly healthy coastlines now threatened by erosion

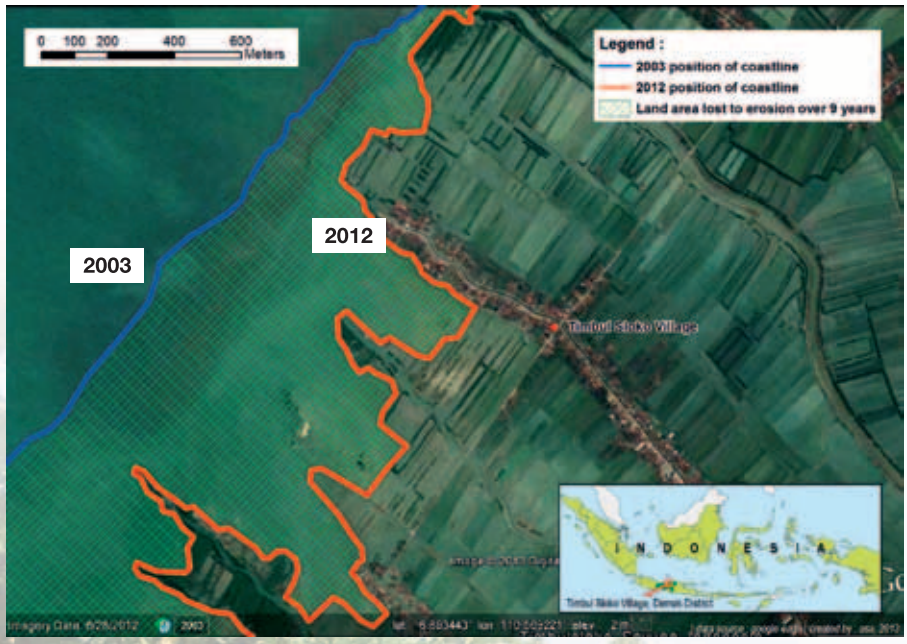


Intact mangrove forests protect mud coasts by attenuating the height and strength of sea waves[2] and by reducing the impacts of storm surges[3]. In the long term, they provide protection by vertically building up the soils through storage of organic matter and sediment.

In addition, healthy mangrove forests provide a variety of ecosystem goods and services, such as fish, shellfish, fuel wood, fibres, water filtration and carbon storage. They are also an important nursery for commercially exploited offshore fish species.

Healthy mangrove mud coasts are in a dynamic equilibrium, with sediment naturally eroding and accreting as a result of wave and tidal action. However, in most areas, the net effect of erosion and accretion is more or less stable.



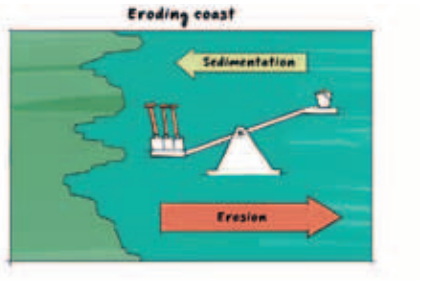


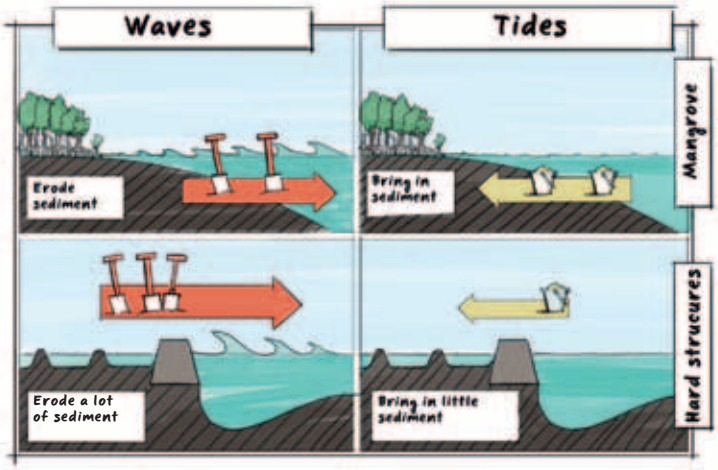
◀ Estimated land loss of 200-900 meters between 2003 (blue line, Google Earth image) and 2012 (orange line, Google Earth image) due to erosion in Demak District, Central Java, Indonesia. By Apri Susanto

Nowadays, many tropical mud coasts face dramatic erosion. The conversion of mangroves into fish or shrimp ponds has led to a loss of their coastal protection function[4]. In some areas, the coastline has receded between 100 and 2000 metres, jeopardizing people's homes and livelihoods[5]. Aquaculture ponds are lost to the sea, and crucial infrastructure is damaged. Other ecosystem goods and services provided by mangroves are also destroyed. These problems are exacerbated by sea level rise and soil subsidence, caused by drainage, peat oxidation or water extraction from deep wells.

Hard structures exacerbate the problem

When mud-coasts start to erode as a result of unsustainable land use, the delicate balance between erosion and sedimentation is disturbed. Sediment is lost to the sea. The coastline progressively recedes. Coastal managers often try to fight coastal erosion with hard structures.

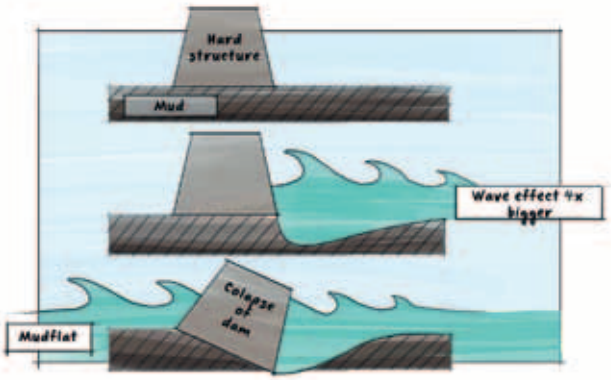




In a healthy mangrove ecosystem, waves take sediment away and the tides bring sediment in. The mangroves' root system helps to capture and stabilize the sediment. The tidal flat is convex up, with a gentle slope and shallow water at the seaward edge of the mangrove forest.

Hard structures, such as aquaculture pond bunds and breakwaters, disturb the balance of incoming and outgoing sediment. Waves reflect on the structure, becoming bigger and taking even more sediment away. The tide cannot bring enough sediment in, as it is blocked by the hard structure. The tidal flat becomes concave up, with steep slopes, and deep water at the seaward edge of the mangrove forest.

Hard structures only exacerbate the problem. Waves get bigger when they reflect on a hard structure. These bigger waves can erode 2 to 4 times more soil in front of the hard structure, eventually leading to the collapse of the structure. Such collapsed sea walls are useless in preventing erosion, but still increase the height of the waves[6].

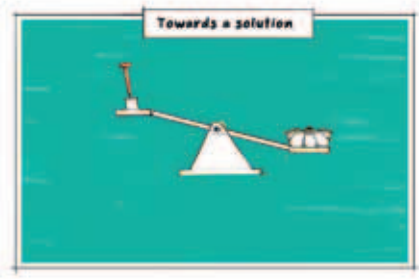


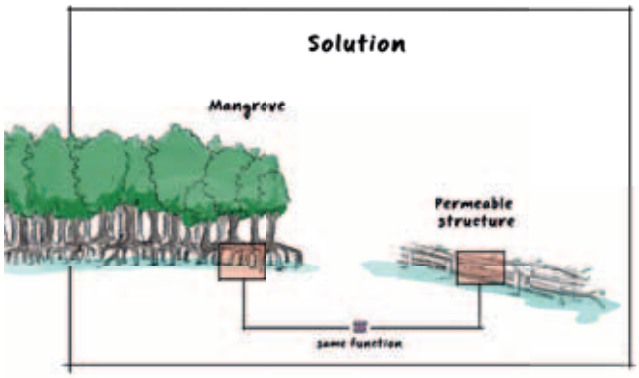
Collapsed coastal structures in British Guyana. By Han Winterwerp

Towards a solution

In order to stop the erosion process and regain a stable coastline, the first necessary step is to reverse the loss of sediment. More sediment needs to be deposited on the coast than the amount that washes away.

The best way to do this is by working with nature, using smart engineering techniques - giving nature a little help, but letting it do the hard work for us.

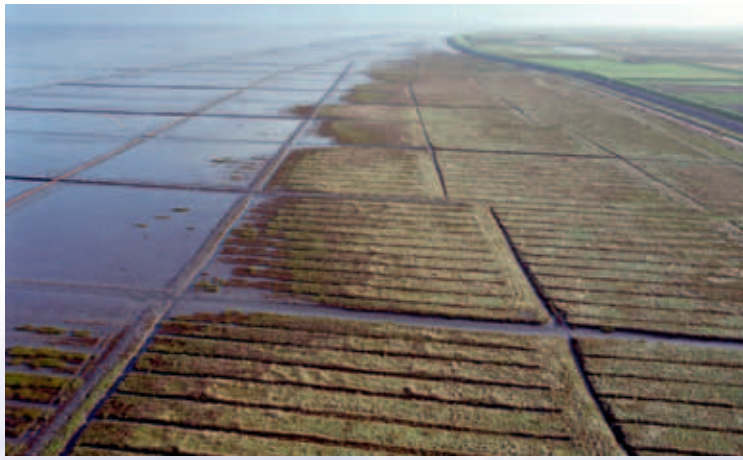




Permeable structures made of local materials such as bamboo, twigs or other brushwood can be placed in front of the coastline. These structures let the sea water pass through, breaking the waves rather than reflecting them. As a result, waves lose height and energy before they reach the coastline. The permeable structures also let mud pass through, and increase the amount of sediment trapped at or near the coast. These devices imitate nature - mimicking the structure of a natural mangrove root system.

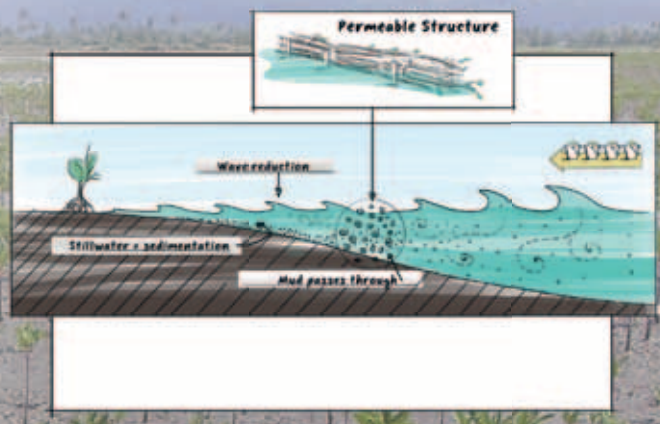
Saltmarsh works have protected the Dutch coast for centuries. Kite aerial photograph of saltmarsh works near Groningen, the Netherlands. By Jaap de Vlas

Mangrove restoration is only possible after the sediment is stabilised. Photograph of coastal restoration work in Indonesia. By Jane Madgwick

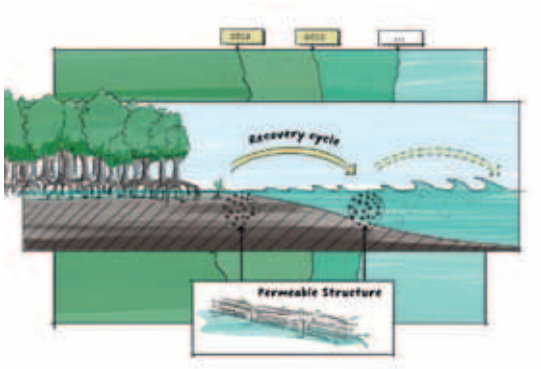


Hybrid engineering combines these permeable structures (to break the waves and capture more sediment) with engineering techniques such as agitation dredging, which increase the amount of sediment suspended in the water.

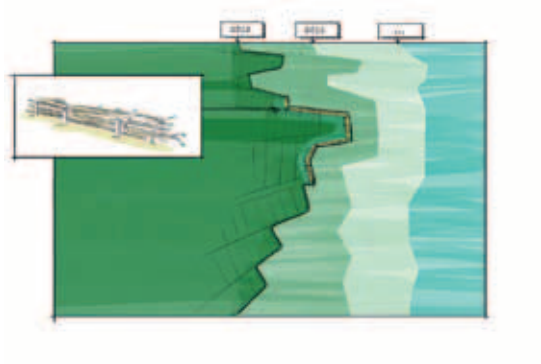
Once the erosion process has stopped and the shoreline starts accreting, mangrove restoration can take place. The mangrove saplings are no longer washed away by the currents and a new mangrove belt can further break the waves and capture sediment in the long term.



Hybrid engineering to protect the coast



The hybrid engineering technique described above is applied in grids, to slowly but steadily reclaim land from the sea. This technique has been applied successfully in salt marshes in the Netherlands for centuries. Hybrid engineering is being increasingly applied in vulnerable coastal areas across the world, replacing hard structures in a cost-effective manner.



However, the technique only works if properly applied. Regular maintenance of the permeable structures at the seaward edge is needed. New structures need to be placed at the seaward end once sufficient sediment has been trapped on the coast and until the desired amount of land is reclaimed.

Mangrove management needs to maximize wave attenuation, for instance by opting for species with aerial roots and by aiming for a mix of trees of different age and size in order to continuously sustain and enhance coastal protection. Conversion of the restored mangroves must be avoided, so that the erosion process does not begin anew.

Once mangroves are restored, they can offer multiple benefits besides coastal protection. Such benefits include carbon sequestration and storage, enhancing offshore fisheries, and enhancing aquaculture (on the landward edge).

References

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Mission:

To sustain and restore wetlands, their resources and biodiversity

Join our efforts

Wetlands International, Deltares, The Nature Conservancy, Wageningen University and Indonesian partners are working together to improve the way in which government agencies, the private sector (including smallholders) and civil society manage their mangroves. We envision a future in which mangroves underpin economic prosperity and coastal resilience.

We are pursuing this goal through collaboration and knowledge exchange between governments, civil society and the private sector, and by encouraging innovative solutions such as hybrid engineering. Join us and support our initiatives by advocating sustainable coastal management, assisting us with implementation and applied research, contributing to community-based conservation and restoration, and funding our activities on coastal resilience.

For more information on our work and opportunities for collaboration, please contact:

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