Smart plant use in water management and shown in a new display water garden in Delft Botanic Garden

Bob (W.N.J.) Ursem

Botanic Garden, Delft University of Technology, Delft, The Netherlands

Abstract

Modern water management has preferably been carried out in the system of 'Building with Nature'. In 1980, Ronald E. Waterman started to initiate this new approach and principle in civil engineering to create coastal extensions and/or artificial islands by using materials and forces present in nature. These natural forces, as well as marine organisms and sand/silt/clay particles in beaches, dune areas and near shore, include the action of tides, waves, swells, estuarine, bay and sea currents, river outflows, gravity, wind and precipitation, solar radiation and interaction with vegetation. Two case studies, one with plants such as mangrove, of coastal defences in Vietnam and the use of *Vetiver zizanoides* (vetiver grass), are discussed. Next, the case studies and current construction of new coastal defences in the Netherlands and the concept of 'Building with Nature' in a new display water garden adjacent to the Delft Botanic Garden.

Key words

Water management, building with nature, mangroves, vetiver grass, coastal defence, Vietnam, the Netherlands, display water garden

Introduction

Traditional water management, especially in coastal defence, has nearly always been carried out with man-made constructions such as sea walls, concrete blocks deposits, or artificial dams. These methods need to be reviewed. Modern water management uses the forces and materials of nature, and creates long-lasting, very cost-effective coastal defence systems. These methods could also be applied in solving water management problems and in land stabilization of coastal hinterland. For example, mangroves in Vietnam have replaced concrete sea walls as coastal defences; they provide a natural belt of tidal mangrove forest in front of the current coastline in order to break the waves and to diminish the tidal wave impact and tidal forces. They form a very simple clay or soft soil dike that can protect against the highest water levels, such as experienced in typhoon conditions.

The other example is the use of tropical and subtropical *Vetiver zizanoides* to reduce the impact of waves in front of a dike or, when planted on a dike, to diminish the run-up or wave overtopping. Furthermore, not only do the sod or pieces of grass clumps reduce the force of the water, but also their root systems contribute to dike stabilization, because of their long taproot system and horizontal adventitious roots which sprout at several layers from the taproots; this creates a matrix of fixating root-structure in a dike.

A similar root system to *Vetiver zizanoides* is formed by *Ammophila arenaria* (European marram grass) in Dutch dunes and beaches, capturing sand forced by wind and forming primary dunes on the highest beach parts. These primary dunes evolve in the same way, further capturing and building sand deposits, until the dunes grow to mature sizes up to 70 metres in height and thus creating a perfect long-lasting coastal defence.

The Vietnam and mangrove case

Vietnam has lost nearly all its natural mangrove forests along the coast. Only remnant pockets of inland mangrove species can still be seen today on the shoreline, which will be destroyed by its unsuitable natural conditions in a very few years. During the Vietnam War (1962-1971) nearly 40% of the mangrove forests in southern Vietnam were destroyed (Hong & San, 1993). In Camau province, for instance, it was estimated that there were 200 000 ha of highly diverse mangrove forest, but after the war approximately 100 000 ha had been destroyed.

In the 1980s and early 1990s the mangrove forest was again heavily destroyed, due to the overexploitation of timber for construction and charcoal and the conversion of forest land into Silvo-Aquaculture-Fisheries Farming Systems (SAFS) (Christensen, Tarp, & Hjortsø, 2008). By the end of the 1980s the highly diverse mangrove forests of Ca Mau had been turned into 51 000 ha of monoculture forest, consisting mainly of planted *Rhizophora apiculata*.

By the mid-1990s forest-felling bans were imposed and the forest enterprises were now to replant and protect forest rather than utilise it; by 1999 the felling ban ceased. The mangrove forests remain in the middle of everywhere, like elsewhere in the world, described in publications such as 'The Botany of Mangroves' (Tomlinson, 1986), 'The Biology of Mangroves' (Peter J.Hogarth, 1999) and the specific book about mangroves in Vietnam by Phan Nguyen Hong (Hong & San, 1993) published by IUCN in 1993.

Figure 1. Coastal area in Vietnam with revetment on clay soil and remnant pocket of mangrove

But, due to the collaboration between in Delft Universiity Bptanic Garden and its Vietnamese partners, interest in mangroves had grown since 2004. Mangroves could be the solution to uncontrolled problems of coastal defence for nearly the whore shoreline of Vietnam and a replacement for ugly and non-effective sea walls, sea ramparts and concrete revetments.

In order to grow mangroves, an inventory was made between 2004 and 2009 on the bathymetry and historic sediment distribution of the major affected rivers of Vietnam: the Mekong and Saigon in the south and the Red River in the north and coastal shifts in the past. Next to this, a new approach was developed by the Botanic Garden in cooperation with the Department of Coastal Engineering, both of Delft University of Technology and shared with its Vietnamese partners, the Water Resources University in Hanoi and the Southern Institute of Water Resources in Ho Chi Min City. The new approach had its origin in the discovery of mica deposits on the remnant pockets of beaches. Mica is a mineral that floats on water and is known to have an origin in acid rock formations. Because all the above-mentioned Vietnamese rivers originate or pass through acid mountains or rock areas in the hinterland, we can be assured that deposits of mica, at the highest tide level in a predominant clay rich suspension on the coast of the South China Sea, are a perfect indicator of the influence of river systems and so provide for future possible outbuilding or reclaiming of land formations into the sea.

In coastal systems, the sea can bring materials with the tide and waves in the upper current and can take the same materials also with the tide and waves in the undercurrent. Building up land or reclaiming historic depositions by the sea involves obstructing the undercurrent with a bar of rods. The width of the bar is correlated to the grain size of deposition. So first we capture sand or larger particles until the shore is shallow enough with a very gentle slope of maximum 3 degrees angle. Then we put in out sticks to stop the deposition of materials and to regulate equilibrium of sand or grain between sedimentation and erosion. The same process will repeat until a stepwise structure of deposited material has built up into the sea. As soon as the sea is shallow enough with grain or sand, as a second step of building with nature, the space of the bar will be reduced to capture the smallest materials such as silt and clay. This also will grow in clay or silt deposition on top of the grain or sand layer and regulated in the same manner until the clay or silt layer is about 30 centimetres thick.

Figure 2: Third-succession remnant mangrove forest in front of a sea rampart

The young clay or silt layer of 30 centimetres will be planted with pioneer mangroves *Rhizophora apiculata* (red mangrove) and/or *Sonneratia caseolaris (*crab apple mangrove). Because of continuous sedimentation the young plants roots in an oxygen rich clay or silt, but this soon becomes deficient in oxygen. When the oxygen level in the soil is almost zero, the plants start to produce stilt pneumatophores. Pneumatophores are essential for respiration and help to break up waves and diminish wave impact. Other species such as Avicennia *alba* (grey mangrove) with partial stilt growing pneumatophores are also suitable additions in the pioneer mangrove vegetation. *Avicennia alba* can also form pencil-like pneumatophores and is perfectly suitable for the second succession of the young mangrove forest. After three years of development, the second succession of mangrove vegetation can be introduced and these can eventually take over from the pioneer mangroves. Pioneer mangroves need, and can only grow in, dynamic tidal systems.

As the primary mangrove forest matures, tidal impact reduces over time and provides perfect conditions for the second succession of mangrove vegetation. Mangroves of the second succession of vegetation, with only pencil-like pneumatophores, capture silt and clay very efficiently. Thus species like *Sonneratia alba* (mangrove apple) and *Avicennia marina* var.

intermedia (guave mangrove) contribute very much to building on soil sedimentation until the effect of the tide varies ten centimetres or less and other stepwise successions follow after.

The third succession begins with the introduction of *Avicennia officinalis* (white mangrove) and *Ceriops tagal* (Indian mangrove), both with very short and dense pencil-like pneumatophores, and also *Nypa fruticans* (mangrove palm), *Sonneratia griffithii* and *Rhizophora mucronata*. The fourth and final low saline and inland environmental mangrove forest consists of shrub and small tree species such as *Bruguiera cylindrica*, *Xylocarpus granatum*, *Lumnitzera racemosa*, *Ceriops decandra*, *Camptostemon schulzii* and *Aegialitis annulata* and in addition *Phoenix paludosa* (mangrove date palm), *Xylocarpus mekongensis* and *Exoecaria agallocha*. The final succession of mangrove forest is dependent on low tide effects, because otherwise the mangrove forest would die and be overgrown with obligate land and fresh water plant species.

Following the stepwise succession of reclaiming land from the sea with mangroves, we create a very sustainable natural coastal defence for nearly the whole shoreline of Vietnam, resulting in an annual saving of 7.8 billion Euros for the maintenance of sea ramparts, concrete revetments and sea walls on very unstable clay soils. With a single investment of 1.1 billion Euros by the Vietnamese Government to execute this ‘building with nature’, coastal defences have reclaimed historic land areas and contribute to wildlife restoration, with at least an 800 year long-lasting permanent coastal defence at nil cost. As mentioned earlier, a single clay or soft soil dike at a height of typhoon level, as the Dutch have had along their former Zuiderzee (Southern Sea) for 800 years, will be the smartest solution for any coastal defence in the tropics on clay rich estuaries and shores.

***Vetiver zizanoides*, *Ammophila arenaria* and the new Water Garden**

As mentioned in the introduction, *Vetiver zizanoides* and *Ammophila arenaria* are extremely suitable in water management projects. The first example is in the tropics and subtropics and the latter in dune building in the Netherlands. *Vetiver zizanoides* forms a matrix root system and can be seen as very cheap bench defence systems in rivers and canals.

Ammophila arenaria helps together with a native pioneer *Elythrigia juncea* subsp. *boreoatlantica* (sand couch), to fix sand in a ‘building with nature’ project to create a double coastline and a new inner sea. A big dam is built perpendicular to the current along the shore, shaping a hollow and moves the current more outward into the North Sea. A sand-sucking motor piles up huge masses of sedimentation at the tip of the dam and sand will be spread and taken by the predominant current along the shore. This is deposited in a narrow beach-line and beach ridge parallel to the old beach ridge line and it encloses a partial inner sea. Both plant species capture sand on the beach and create primary dunes and eventually mature full-sized dunes form.

The predominant western wind will diminish the height and transport the sand upon the second, inland dune ridge. As a result, the second and present coastal defence dunes will become higher and adapt in a cheap and ‘building with nature’ way to protect the Netherlands from future sea-level rises.

This and other ‘building with nature’ water management projects involve the use of gabions, open structured reinforcement blocks, soft slope beaches, also *Phragmitis australis* (common reed) as a barrier to dune growth, and *Populus nigra* (black poplar) gallery forest along rivers and larger brooklets or creating floating artificial islands with plants to form floating gardens. This will be explained and demonstrated in the new Water Garden next to the existing Delft Botanic Garden.

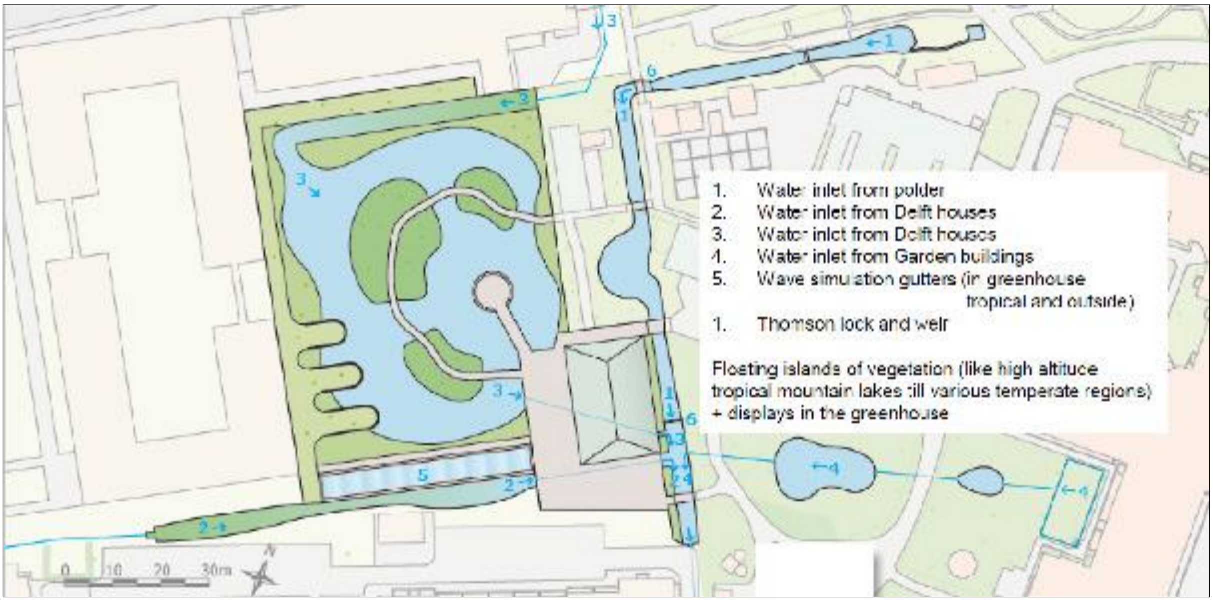

Figure 3: Layout of the Delft Water Garden

Literature

Christensen, S. M., Tarp, P. & Hjortsø, C. N., 2008. Mangrove forest management planning in coastal buffer and conservation zones, Vietnam: a multimethodological approach incorporating multiple stakeholders. *Ocean & Coastal Management* **51** (10) p.712-726.

Hogarth, P.J. 1999. *The biology of mangroves*. Oxford University Press, Oxford, UK.

Phan Khanh Linh, 2012. *The Mekong deltaic coast: past, present and future morphology*. Thesis. Delft University of Technology, Delft, The Netherlands.

Hong, Phan Nguyen & San, Hoang Thi, 1993. *Mangroves of Vietnam*. IUCN. Bangkok, Thailand.

Tomlinson, 1986. *The botany of mangroves.* Cambridge University Press, Cambridge, UK.

Waterman, R.E., 2008. Integrated coastal policy via building with nature. *Coastal ocean space utilization*. Building with Nature/R.E. Waterman, Delft, The Netherlands. pp.262-281.