Wave attenuation with willow woodland

- *Type: services delivered by organisms;*
- *Application: in fresh to moderately brackish waters, on land that is submerged seasonally or during spring tides;*
- *Species: among others, willows, poplars, rushes, reeds, lythrum salicaria;*
- *Contributes to:*
  - Natura 2000 habitat [4]: 'Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)';
  - Natura 2000 species [5]: species including fish, marsh birds, insects, mammals;
  - Water Framework Directive (WFD) [6]: rivers, transitional waters, lakes;
- *This measure can contribute to the National Ecological Network (EHS).*

Willow woodlands act as natural breakwaters and therefore contribute to flood risk management. They should be located on a natural embankment (see Natural embankment fact sheet) and be combined with a hard dike. These are known as 'hybrid' solutions. Meadows with willows in front of dikes attenuate waves and so the dike does not need to be as high.

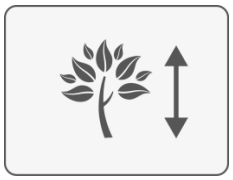
Studies have shown that a strip of willows one hundred metres wide can reduce the height of one-metre-high waves by 80%[2]. This means that dikes can be kept quite a lot lower. In some cases, planting willows makes it possible to replace stone revetments on dikes and to use a cheaper revetment of clay covered with grass. The location and size of the woodland will depend on the prevailing direction of the waves and the wave pattern.

As well as attenuating waves, willow woodland can also provide added value in terms of leisure and biodiversity. Using willow forests enriches the landscape by introducing a natural feature that has cultural and heritage value. The beaver is one of the most eye-catching species that feels at home in submerged willow woodland.

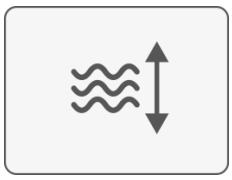
Specimen projects:

- Noordwaard. Creation of willow woodland in front of a dike to break waves.

Spatial aspects



Tree height



Submersible area required

A maximum of 10-60 days of flooding a year

Services[3, 8, 9, 10]

Ecosystem services generate benefits if people can exploit the services and capitalise them.

Erosion control

Well-positioned willow woodland can reduce wave impact during high water and also absorb tidal energy, preventing bank erosion.

Cleaning

Willow woodland can have a positive effect on water quality by furthering the precipitation of sediment so that water becomes clearer. Willows are also sometimes used to remove heavy metals from the ground[7].

Biodiversity

Willow woodland forms a habitat for flora and fauna where land and water meet, and where there used to be only traditional, hard banks.

Water dynamic

A fully-grown willow woodland mitigates currents and waves locally. Research in the Noordwaard polder has shown that waves can be reduced by 80%.

Uptake of particulate matter

It is known that woodland captures particulate matter. This means that willow woodlands contribute to improving air quality.

Carbon capture

Willows produce large amounts of biomass annually, capturing CO_2 as a result. In that way, willows can help to mitigate climate change.

Urban climate

Green areas reduce the urban heat island effect by approximately 0.6 degrees per 10% increase in the green area.

Benefits and cost savings [8, 9, 10]

The ecosystem services referred to before generate benefits if people can exploit the services and capitalise them.

Landscape enrichment

Willows enrich the landscape and also have cultural and historical value (willow meadows are a centuries-old tradition in marshy areas).

Leisure value

The improvement in aesthetic value means that willow forests afford numerous opportunities for leisure activities (sailing, walking, cycling).

More appealing habitats

Willow woodlands fit in better with the landscape than traditional hard flood defences. For example, when they were used at Fort Steurgat (Werkendam), it was possible to build the dike lower and therefore to preserve the view from the homes located behind the dike.

Education

The enrichment in terms of nature and the cultural heritage of a particular area can serve an educational function. Children and adults come into contact with nature in the immediate vicinity.

WFD objectives

The construction of nature-friendly banks is one of the main WFD measures. A willow woodland can serve as a WFD bank when it is submerged regularly. Falling trees and dead trees in the water are appealing locations for fish and macro-fauna. Combining objectives makes it possible to make major savings.

Natura 2000 measures

The network of Natura 2000 areas is strengthened. Natural embankments provide habitats for Natura 2000 habitat species. Combining objectives results in savings because it is probable that other measures will no longer be needed.

Implementation of measures for flood risk management

The height of a dike is calculated on the basis of factors such as water levels and wave height. Willow woodlands are effective breakwaters (reducing wave impact by up to 80%[2]) so that dikes can be built lower. In the Noordwaard polder near Fort Steurgat, the dike was raised one metre less than originally planned. In addition, the dike can be covered with clay rather than a stone revetment [1].

Both costs and benefits are location-specific and difficult to extrapolate. Cost-benefit analyses will therefore have to be conducted for each individual location.

Implementation costs

The wave-attenuating flood defence consists of a combination of a dike (4.8 metres above NAP) and willow woodland that is approximately one hundred metres wide. The willow woodland can consist of *Salix alba*, *S. viminalis*, and *S. triandra*, varieties that can grow well when water levels are high and that can cope with waves. Approximately four trees are planted per square metre. The dike is covered with clay to strengthen it. The willows make it possible to dispense with rock revetments, saving on construction and maintenance.

Current information indicates that the cost of building a flood defence of this kind is EUR 1550 less per metre than it would be with a traditional dike.

We can adopt the following amounts (taken from a quotation submitted in 2008) as guidelines for the cost of planting one hectare of willow woodland:

- Planting willow woodland: approximately EUR 6000;
- Maintenance 1st two years: approximately EUR 1750;
- Maintenance per two years after 2nd year: approximately EUR 2000.

Income may also be generated using the biomass of the harvested wicker. This could amount to EUR 750 per hectare per two years.

Management and maintenance

For optimal management (the maintenance of the wave-attenuation function), pruning every two or three years is optimal. This keeps the woodland dense and healthy enough. Half of the trees will be pruned on each occasion so that the breakwater function of the woodland will be maintained after pruning. The dike itself requires little maintenance: it needs only mowing.

Willow meadows are ideal habitats for beavers. Additional checks are therefore needed to monitor damage to the willows. Beavers can severely deplete the number of trees per square metre of woodland and that can adversely affect the intended breakwater function.

Physical boundary conditions

A willow woodland as a breakwater is useful in the river area when a dike has to be raised or strengthened in response to the height of the waves.

Size

The size of a willow woodland for attenuating wave impact depends on the pattern and height of the waves. A hundred metres of willow woodland can reduce waves with a height of 100 centimetres by 80 centimetres, assuming a density of four trunks per square metre.

Flood duration

The design guideline for flood duration is 10 to 60 days a year (cumulative). A shorter period of time will result in other types of tree becoming more dominant. If there is

more flooding, there will be fewer trees over time, and the area will start to become marshy.

Salinity

Willows cannot survive in salt water. They can manage short periods of brackish conditions.

Other boundary conditions

Rather than willows, other robust bankside plants can be used. For example, salt marshes and mangroves can deliver comparable ecosystem services in salt and tropical environments, as can natural embankments with reeds and rushes in the Netherlands (see Natural Embankments fact sheet).

Potential sites

The best conditions can be found on the higher sections of river banks that are only submerged when water levels are high. Areas outside the salty coastal zone should also be selected. The woodlands can be planted behind and in front of dikes: they can be planted behind a dike as long as they are within the reach of the river water dynamic. This can be achieved by, for example, building culverts below the dike.

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10. *Ruijgrok E.C.M. Kentallen waardering natuur, water, bodem en landschap; hulpmiddel bij MKBA´s. Ministry of Agriculture, Nature Management and Food Safety. GV706-1-1/ruie/1.*