Interreg
Co-funded by the European Union
North-West Europe

Bonsai

D.2.1.3 Jointly developed test plan on long-term resilience

Climate and environment

D.2.1.3 Jointly developed test plan on long-term resilience

Version:

Final

Authors:

Peter Boone (STOWA), Ilona Evers (HHNK), Jan-Willem Nieuwenhuis (NZV), Eric Visser (RU), Bart Vandevoorde (INBO)

Contributing to Activity 2.4, via Deliverables 2.4.1, 2.4.3 and 2.4.5
Activity A.2.5., via Deliverable D.2.5.2

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Table of contents

This project has received funding from the Interreg NWE programme 2021-2027

co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

INTERREG NWE BONSAI project

Climate change

Climate change is accelerating, leading to increased rainfall, drought, storms, flooding, and sea level rise, particularly impacting the NWE region with its extensive estuarine systems. How can we better prepare these areas for climate change for the long term?

BONSAI objective

The overall objective of BONSAI is to make flood defence systems in tidal estuaries of NWE more short and long term resilient against climate change by learning from sites in different climate zones over Europe and developing and sharing pro-active and responsive measures. Organisations responsible for flood resilience and societal partners in tidal estuaries in NWE are empowered through capacity building to strengthen their resilience and better act in case of flood threats caused by extreme weather events.

Main results

The main results are (1) a transnational strategy for national authorities and 3 action plans for regional and local authorities, (2) 5 solutions on increasing robustness and resilience and enhancing disaster management and (3) multiple training schemes and courses on flood disaster management and flood resilience and 1 joint transnational flood academy.

BONSAI aims

BONSAI aims to apply a holistic approach that is focusing on (short and long term) flood defence system resilience and the improved disaster management. Different NWE countries tackle these challenges from their own perspective. Transnational cooperation between the NWE regions and beyond is essential because estuarine systems and climate change transcend borders, offering opportunities for mutual learning and resilience building.

Unique approach

The BONSAI approach is unique, 1. bridging the three layers of the multi-layer water safety approach: prevention, disaster management, and spatial planning 2. simulating shifting climate zones based on the application of insights from more southern regions to northern regions and 3. focusing on increased cooperation between countries to learn from each other, north learning from south as well as south learning from north.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Test plans embedded in BONSAI

Within the BONSAI project in the second project period, Activity 2.1: Jointly Develop Test Plans for Pilots were planned. In this introduction, these test plans are put into context of the whole BONSAI project. The test plans are part of Work Package 2, pilots leading to solutions.

Following the NWE programme priority specific objective and the BONSAI project overall objective, three Project Specific Objectives (PSO) were formulated. For WP2 the project specific objective is the following:

1. Jointly develop and validate transnationally:
    a. 2 short term flood defence robustness solutions
    b. 2 long term increased resilience of flood defence systems solutions
    c. And 1 solution for enhancing disaster management for flood risk related disasters
2. Towards the end of the project, the solutions will be fully implemented by our 6 flood risk management project partners and available for other authorities responsible for flood risk management.

For project period 2 (P2), Activity 2.1 of the project work plan focuses on jointly formulating Test Plans for pilot actions yielding the following three deliverables:

- D.2.1.2: Jointly develop a test plan on short term robustness
- D.2.1.3: Jointly develop a test plan on long term resilience
- D.2.1.4: Jointly develop a test plan on disaster management

From the project organisational point of view, test plans are the foundation for achieving the PSO of WP2 and therefore the activities following A2.1 from P3 and further, being:

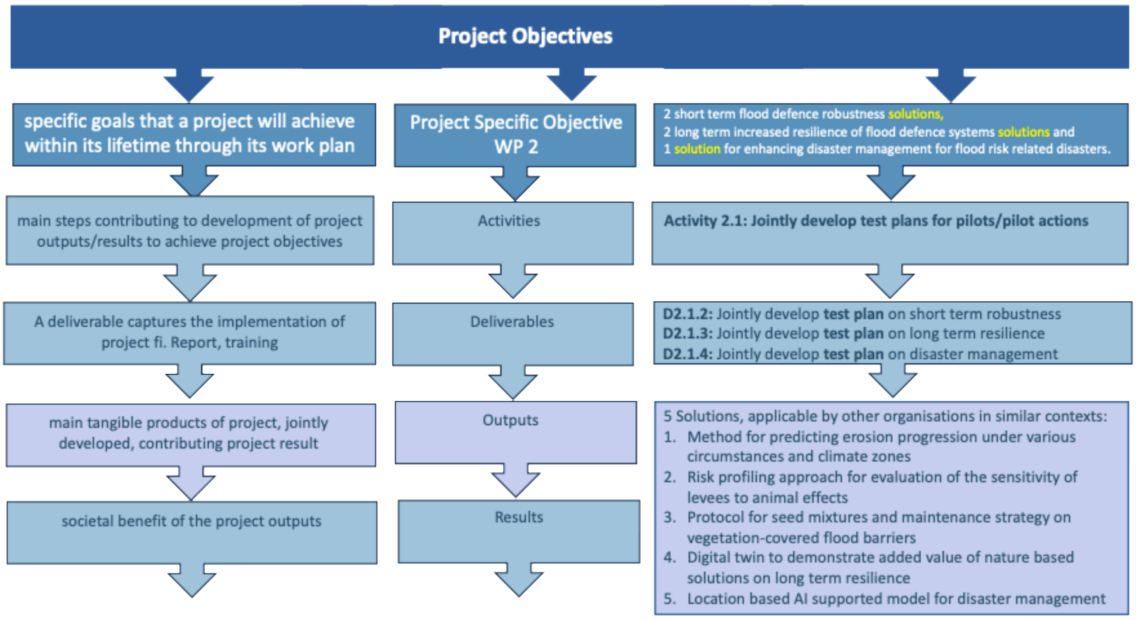
- Activity 2.2: Jointly implement pilot action for short term flood defence robustness – erosion
- Activity 2.3: Jointly implement pilot action for short term robustness – animal activity
- Activity 2.4: Jointly implement pilot action for long term resilience – biodiversity/vegetation
- Activity 2.5: Jointly implement pilot action for long term resilience – nature based solutions
- Activity 2.6: Jointly implement pilot actions for disaster management

These activities and their deliverables are envisioned to yield the following Outputs, namely 5 Solutions, applicable by other organisations in similar contexts:

1. Method for predicting erosion progression under various circumstances and climate zones;
2. Risk profiling approach for evaluation of the sensitivity of levees to animal effects;
3. Protocol for seed mixtures and maintenance strategy on vegetation-covered flood barriers;
4. Digital twin to demonstrate added value of nature-based solutions on long term resilience;
5. Location based AI supported model for disaster management.

Underneath a summarising figure is enclosed.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]



This test plan, on long term resilience, focuses on biodiversity/vegetation and nature-based solutions whilst incorporating relevant pilot actions of follow up activities A.2.4 and A.2.5.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

1 Introduction

1.1 General objectives

Besides an increase in mean sea level rise, climate change creates the potential for more high energy storms and extreme weather events, thereby increasing the probability of extreme loading conditions for levees. BONSAI aims to help areas in North-West Europe to prepare for climate change in the long term. The BONSAI approach thereby applies a multi-layer defence approach covering different topics. This specific document focuses on the topic of long-term resilience with a specific focus on nature-based solutions and effects of climate change on the protection layer of the vegetation on dikes in estuaries.

The strategic objective of BONSAI to promote climate change adaptation and risk prevention via the tactical objectives:

- Learn from different climate zones
- Develop solutions on short term robustness
- Develop pro-active response measures on climate change and biodiversity, and solutions for long term resilience

The sections below describe how these tactical objectives have been translated into operational objectives of the running brigade on long term resilience.

1.2 Objectives of the work on long term resilience

Pilot actions within BONSAI are performed based on test plans. The two pilot actions dedicated to increasing long term resilience of flood defence in the light of climate change will be executed following the Testplan for Actions on Long Term Resilience:

- part 1 covers Activity 2.4 - Jointly implement pilot action for long term resilience - biodiversity/vegetation
- part 2 covers Activity 2.5 - Jointly implement pilot action for long term resilience - nature based solutions

In **Activity 2.4**, five deliverables (D2.4.1 – 2.4.5) will lead to a protocol for seed mixtures and maintenance strategy on vegetation-covered flood barriers to improve resilience to drought and flood-induced erosion.
These deliverables will be reached through work at various pilot sites, reference sites and additional locations. Most of this work is described in **Chapter 2** (Biodiversity and Vegetation), and in one section of **Chapter 3** (Growing dike; 3.6.5 Monitoring vegetation development).
Activity 2.4 will be done by RU and INBO and aims to understand how vegetation on dikes will change in this era of climate change, and how a resilient vegetation can be applied to safeguard a future protective and biodiverse green cover on the estuarine dikes. This will include learning from present vegetation on dikes in warmer and dryer European climate zones, and testing responses of current plant species to increasing intensity of drought events. Seed mixtures of various species composition will be tested for their resilience in

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

such drier conditions. Finally, the effect of soil improvement on establishment of newly sown vegetation will be tested on dike plots with various treatments of soil types and seed mixtures.

In **Activity 2.5**, four deliverables (D2.5.1 – 2.5.4) will lead to jointly developed solutions (O3). These deliverables will be reached through work at the pilot sites Meegroeidijk and Oeverdijk. This work is described in **Chapter 3** (Growing dike) and **Chapter 4** (Foreshore dike).

The work involving the Growing dikes (Meegroeidijk) is led by NZV, and aims to gather more insight in how dikes can be fortified by the application of sludge. This includes monitoring and analysis of the influence of a variety of parameters on vegetation development and sediment stability on such dikes (effect of salinity of the top layer and thickness of the sludge layer on vegetation regrowth, build-up of structure in-situ). The work at the Foreshore dike (Oeverdijk) is led by HHNK, and is a nature-based solution designed for combining an innovative flood defence with an ecological compensation area. This system aims to safeguard the long-term resilience of both water safety and biodiversity, with monitoring of ecological functioning included in the project.

The work that will be performed towards developing a Digital twin (D2.5.4) will not be described here as yet, as this does not concern field-based actions.

2 Biodiversity and vegetation

contributing to Activity 2.4, via Deliverables 2.4.1, 2.4.3 and 2.4.5

2.1 Purpose

The objectives of the partial test plan for long-term resilience of dikes via biodiversity and vegetation are:

1. to evaluate how a drier future climate in NW Europe may affect vegetation development and floral diversity on estuarine levees (dikes), by describing vegetation and sampling rooting patterns at dikes across a range of climate zones in Europe. This will allow us to learn which characteristics plant species on dikes need to survive harsh drought spells, and how this knowledge can be applied to our future dike vegetation (RU in the lead).
    - to experimentally apply drought stress to established simulated NW European vegetation types and determine the effect of this environmental stress factor to above (leaves) and below-ground (root) biomass production and overall performance of various (functional groups of) plant species. This will predict which plant species and/or vegetation types wil be the most resilient to increased occurrence of drought spells in a future climate (RU in the lead).

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

- to inquire if various soil types and seed mixtures can be used as an adaptation measure to keep levees resilient against climate change. To evaluate this measure several seed mixtures are used on two types of improved soil and compared with non-improved soil. The improvement of the soil consist of a lime treatment (INBO in the lead).

2.2 Choice of locations

For objective 1, we will take measurements of vegetation and topsoil at virtuall all designated test and reference sites. The selected sites are: Falsterbo (S), Meegroeidijk (NL), Oeverdijk (NL), Vlassenbroek (B), Caen to Ouistreham (F), and Camargue (F). Marnewaard has not been selected, since this is not a formal primary or secondary water safety levee. Additionally, more southerly situated dike vegetation will be sampled to compare the situation in NW Europe to sites exposed to a warmer and/or drier climate already in the current situation. The exact locations need to be established during a field visit, but anticipated locations are the dikes along the Loire river (F), in the Gironde area (F), along the coast of the Cantabrian Sea and rivers in this region (E and P), estuaries of the Douro and Tagus rivers (P), and the Guadalquivir estuary (E).

For objective 2, a drought experiment with multiple seed mixtures has been set-up at the experimental dikes, located at the Radboud University, Nijmegen (NL). Below is a detailed description of the construction of these dikes, and the experimental procedure of imposing drought. Additionally at the levees along the Schelde estuary several vegetation types occur which have different erosion resistance properties. To test the impact of drought on those erosion resistance an in situ drought experiment is set up.

For objective 3, at pilot site Vlassenbroek, an experiment with multiple seed mixtures has been set up. These seed or grass mixtures are sown on two types of improved soil. One soil type is treated with lime, the other with a lime based binder. The third soil type is a normal clay cover.

2.3 Set-up of pilots, sampling, surveys and measurements

2.3.1 Field survey of dike vegetation along a climate gradient in Europe (Objective 1)

At each test site and additional location, at least three homogeneous plots with a permanent vegetation cover will be chosen for vegetation survey and determination of rooting characteristics (protocols, see Appendix). If the vegetation appears heterogeneous, the number of locations will be expanded accordingly to cover the variation in vegetation types.

2.3.2. Nijmegen model dikes (Objective 2)

In the summer of 2022, four small-scale dikes (l: 30m, w:3.8m, h: 70 cm) were constructed at the facilities of the Radboud Greenhouse and Experimental Garden (Figure 1;

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

https://www.ru.nl/en/research/research-facilities/plant-and-animal-models/greenhouse; coordinates 51.8228, 5.8731). Vegetation surveys and rooting samples will be taken at the 80 plots on these dikes.Construction followed the guidelines for inner slopes of Dutch river dike, using soils that originated from a dike reconstruction near Nijmegen. First, a layer of clay (40 cm; 35% sand, 20% silt, 45% clay) was deposited and compacted, followed by a sandy clay top soil layer (30 cm; 55% sand, 20% silt, 25% clay) (Figure 2). On each dike, 20 experimental plots (l: 200 cm, w: 100 cm) were created (totalaing 80 plots), with a 30 cm buffer zone between each plot. To avoid root growth from one plot to another, a steel plate (l: 200 cm, h: 30 cm) was inserted in the middle of each buffer zone. In two of the four dikes, a transparent acrylic tube (ø 70mm) was placed belowground at the centre of each plot for minirhizotron scanning. The tube was angled in such way that the scanning depth ranged from 5 cm at the lower end, to 25 cm at the highest point (Figure 2).

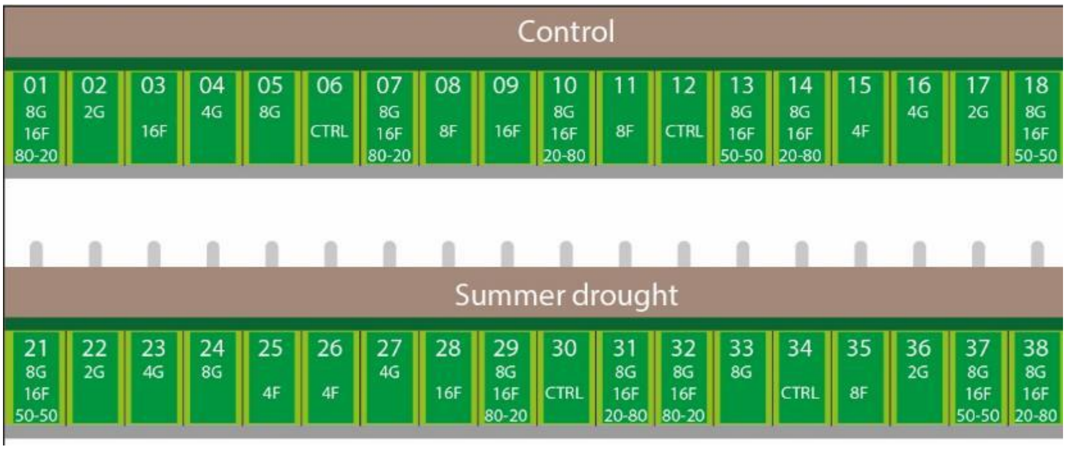
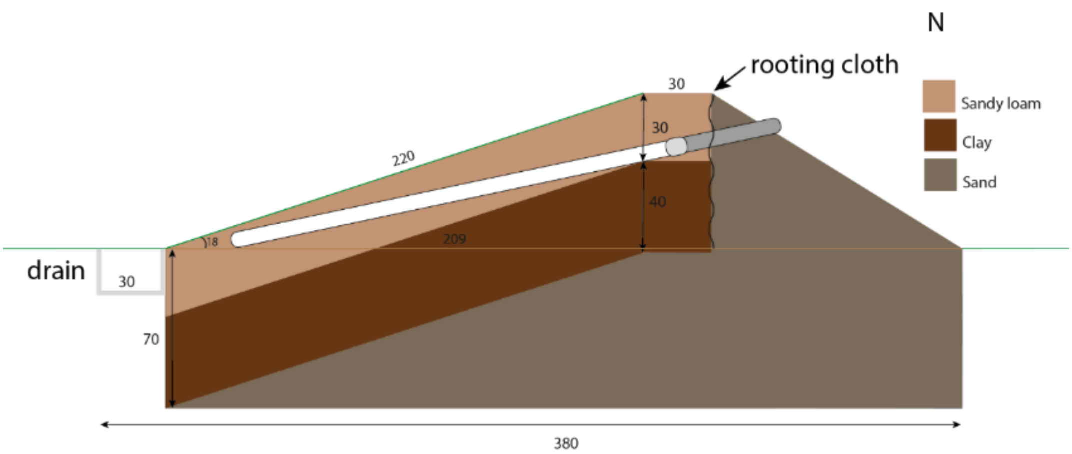


Figure 1. *A cropped schematic overview of a part of two experimental dikes. Indicated in dark green are the sown seed mixtures, where CTRL indicates the control mixture of three grass species, G shows plots with 2, 4 or 8 grass species, F shows plots with 4, 8 or 16 forb species, and indications like 20-80 show the weighed ratio of seeds for grass: forb species in the seed mixture with all grass (8) and forb (16) species present. Light green strips are the buffer zones; black lines indicate the steel plates. The light brown rectangle indicates the north-exposed side covered with rooting cloth. The grey rounded rectangles in the lower dike indicate the upper end of the root scanning tubes.*



This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Figure 2. Schematic cross section of the south-exposed small scale river dikes. Different colours indicate soil types, with dark grey as sandy soil; the dark brown as the clay layer, and light brown indicating the sandy loam top soil layer. The transparent part of the acrylic root scanning tube is depicted by white, and the rear end is shown in grey. Rooting cloth is installed to prevent plant growth from the north-exposed part of the dike. A concrete drain is installed at the bottom end for water drainage. The horizontal green and brown line indicate ground level. Units are in centimetres.

In October 2022, 80 plots were sown semi-randomly with the ten seed mixtures, to obtain two replicas of each mixture per dike. All seed mixtures consisted partly of commercial D2 mixture, which is a conventional seed mixture used for decades in the Netherlands, consisting of the three grass species *Lolium perenne* (10%), *Poa pratensis* (30%), and *Festuca rubra* (60%). In two sets of three seed mixtures, the species richness of grass species (two, four and eight species) and forb species (four, eight and sixteen species) was increased. In the third set of three mixtures, the ratio of seed weights of grass species: forb species was varied in the most species rich mixture (i.e., D2 with eight grasses and sixteen forbs) in three ratios: 80:20, 50:50, and 20:80. The unaltered D2-mixture was used as a control (**Table 1**). Grass and forb species were selected based on vegetation surveys of Dutch river dikes and results from previous experiments (**Table 2**). Grasses were combined based on belowground biomass accumulation, and were combined to create an evenly distributed root column. For the three grass seed mixtures, grass seeds were weighed based on germination rates from previous experiments to a predicted plant biomass ratio of 1: 1 with the species from the D2 mixture. Forbs were divided into four categories: Asteraceae, legumes, rosette forming species, and others (**Table 2**). In the seed mixtures containing four and eight forbs, we randomly selected either one or two species from each functional group to create unique plant combinations across the functional groups. In all forb mixtures, we used a grass species : forb species ratio of 80: 20.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Table 1. Overview of the ten seed mixtures, with seed contents and ratios.

Seed mixture	Contents	Seed ratio
1. D2 + 2G 2. D2 + 4G 3. D2 + 8G	D2 and two grass species D2 and four grass species D2 and eight grass species	50: 50 50: 50 50: 50
4. D2 + 4F 5. D2 + 8F 6. D2 + 16F	D2 and four grass species D2 and eight grass species D2 and sixteen grass species	80: 20 80: 20 80:20
7. D2 + 8G + 16F (20:80) 8. D2 + 8G + 16F (50:50) 9. D2 + 8G + 16F (80:20)	D2, eight grass species and sixteen forb species D2, eight grass species and sixteen forb species D2, eight grass species and sixteen forb species	10:10:80 25:25:50 40:40:20
10. D2 (control)	*F. rubra*, *L. perenne*, *P. pratensis*	60:10:30

Table 2. List of plant species in the seed mixtures, sorted by functional group.

Grass	Forb	Legume
Agrostis capillaris	*Achillea millefolium*	*Lotus corniculatus*
Alopecurus pratensis	*Centaurea jacea*	*Medicago lupulina*
Anthoxantum odoratum	*Crepis biennis*	*Trifolium pratense*
Arrhenatherum elatius	*Daucus carota*	*Vicia cracca*
Bromus hordeaceus	*Galium mollugo*	
Poa angustifolia	*Hypochaeris radicata*	
Schedonorus arundinaceus	*Leucanthemum vulgare*	
Trisetum flavescens	*Picris hieracoides*	
	Plantago lanceolata	
	Ranunculus bulbosus	
	Rumex thyrsiflorus	
	Taraxacum officinale	

Additionally, 25 sites are selected along the Schelde estuary, preferably 5 of each vegetation type (Table 3). On those sites the impact of drought on the vegetation will be experimentally simulated by a shelter. On each site a treated and a non-treated plot are selected. Of each plot the vegetation is investigated as described in Annex 1.

Table 3: Overview of the included vegetation types of the survey along the Schelde estuary.

Vegetation type
Type 1 Species-rich grassland
Type 2 Species-rich *Arrhenatherum*-grassland

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Type 3 Species-poor *Arrhenatherum*-grassland
Type 4 Deteriorated *Arrhenatherum*-grassland
Type 5 Stinging Nettle vegetation

2.3.1 Vlassenbroek soil improvement tests (Objective 3)

The test site of Vlassenbroek consists of 11 test strips (B to L, strip A is not included in the experiment) (Figure 2). Strips B to G have an improved topsoil. Strips B to D are improved with a lime based binder whereas strip E to G are improved with lime or with lime based binder. Strips H to L have a topsoil of normal clay.
Several seed or grass mixtures are sown in may 2020. D1-mixture consists of *Lolium perenne* (40%), *Festuca rubra* (25%), *Poa pratensis* (25%) and *Trifolium repens* (10%). Mixture 75/25 consists of *Lolium perenne* (75%) and *Poa pratensis* (25%) and mixture 100 consists of 100% *Poa pratensis*. In strip K an unknown mixture is sown whereas no seed mixture is sown in strip L where spontaneous colonization is applied.
Each year the strips are mown twice, the first time at the end of June or the beginning of July; the second time mid October.
In each strip or treatment three plots are situated. In these plots the vegetation development is monitored from 2021 to 2025 by yearly making a vegetation relevé. The biomass is measured in these plots and also the erosion resistance. The cover of the vegetation is used as a proxy of the erosion resistance.
Root density is measured in the plots by taking 4 soil cores of 20 cm of the topsoil. These cores are sliced in parts of 2,5 cm. In each part all roots with a length of 1 cm or more are counted.
Further details of the vegetation survey are given in Annex 1.

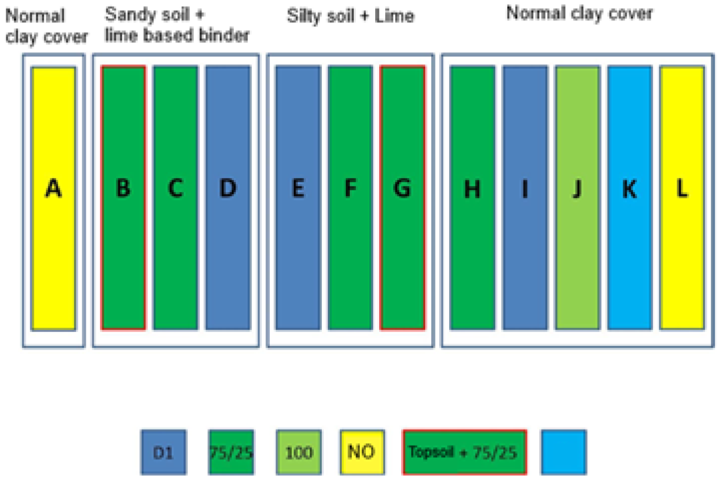


Figure 1 Several seed or grass mixtures (D1, 75/25, 100) are applied on the test strips with an improved soil (B to G) or with a normal topsoil (H to L) at the pilot site in Vlassenbroek.

2.4 Test Parameters

The following test parameters will be recorded:

Vegetation surveys

- Plot ID, size of plot
- X-Y coordinates upper left corner and lower right corner.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

- time, date and year, name of the surveyor, photograph
- Maximum and average height of the vegetation (in cm)
- Relative areas covered by vascular plant species, mosses, and plant litter (in percentages)
- Total cover (%).
- List of vascular plant species with their cover and phenology

Surveys are preferably taken in the period when grasses are flowering, to facilitate species determination, and before mowing or grazing.

A vegetation survey protocol has been produced according which a description of the vegetation will be made (see appendix(?)). In short, the following steps are needed:

- a 2 x 2 meter plot of homogeneous vegetation (size may vary if needed to obtain a homogeneous plot) is set out on the dike.
- X-Y coordinates are recorded of the upper left corner and lower right corner.
- Plot ID, time, date and year, name of the surveyor are recorded, and a photograph of the plot is made.
- Maximum and average height of the vegetation are recorded, and the relative areas covered vegetation of vascular plant species, by mosses, and by plant litter, are estimated (in percentages), as well as total cover.
- A species list of vascular plant species is made, including their cover according to the decimal scale of Londo, and their phenology.

Rooting patterns and soil characteristics

- Plot ID, X-Y coordinates
- root biomass of coarse and fine roots in the five soil layers: 0–5 cm, 5–10 cm, 10–20 cm, 20-30, and 30–40 cm
- soil texture (ratio of lutum, silt, and sand)
- local cover

Roots are sampled by collecting a core of the upper 40 cm of the soil profile using a corer with an internal diameter of 4 cm. The core is then sectioned into five depth intervals: 0–5 cm, 5–10 cm, 10–20 cm, 20-30 cm, and 30–40 cm with a sharp knife. Each segment is stored in a labelled plastic sample bag in cool conditions and later frozen at –20 °C until laboratory analysis. A separate soil sample is taken and stored for analysis of texture. Cover of vegetation of the exact sampling spot is recorded.

The frozen soil segments are thawed and washed over a sieve. All lignified components of the belowground biomass (coarse roots) are separated from non-lignified parts (fine roots), and both fractions are dried and weighed separately. It should be noted that in the uppermost layers, horizontal rhizomes (technically part of the stem) typically are present and included in the coarse root fraction.

2.5 Roles and Responsibilities

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Team Members	***Role***
Project Leads Eric Visser, Bart Vandervoorde and Peter Boone	Oversee entire test plan execution, report on results
Field Technicians and post-doc post-doc Anna Visscher	Implement test setup and monitoring
Data Analyst Anna Visscher, Eric Visser, Bart Vandevoorde	Compiles and analyzes collected data, prepares draft report
Botanical expertise Eric Visser and Bart Vandevoorde	Verifiy determination of species

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

2.6 Risk Assessment & Mitigation

2.6.1 Unpredictable weather

Field work during extensive period of rains is not possible for safety reasons (slippery dike slopes, trampling of vegetation), but typically some flexibility will be taken in the planning of field work to mitigate this factor.

Weather is not an interferring factor for the experiment in Nijmegen, since rain-out shelters enable drought exposure independent of precipitation, and the control treatment can be irrigated in case of dry weather.

2.6.2 Equipment failure

Equipment typically is available with some redundancy. Extensive core sampling of roots in heavy soil may lead to damaged or blunt steel corers. Therefore, at least 8 corers will be available, and a visit to the local blacksmith has previously shown to fix broken or ruptured parts of this equipment.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

2.7 Data Analysis Plan

2.7.1 Statistical comparison between test units and controls

- The data set from the climate gradient will typically be analysed with linear mixed models.
- The data set from the experimental dikes at Nijmegen and from the experimental test sites of the Schelde allows for ANOVA type of analysis, with drought (Y/N) and seed mixture as fixed variables and possibly control plots as contrast. Analysis of the effect of the number of species could be approached with a linear mixed model, or linear regression analysis. A comparable type of analysis will be conducted on the data from Vlassenbroek.

2.7.2 Time series analysis of performance parameters

Data from the Nijmegen dikes will be compared among various years (at least two), to allow statements on the change in vegetation and root development during subsequent summer droughts.

2.7.3 Thresholds for defining failure or success

No matter what outcome these analyses have, the gain of knowledge on variation in dike vegetation development and rooting patterns across Europe will be valuable. Also, the data retrieved from the experimental plots in Nijmegen have already resulted in valuable insights since the start of the experiment, and "failure" is therefore not considered an option.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

2.8 Reporting & Documentation

2.8.1 Frequency of reporting

Reporting is due in period 7 of the project (end of 2027).

2.8.2 Reporting format

Reporting takes place as a report containing the main questions, an explanation of the setup of sampling, data visualisation and analysis, and conclusions based on the data.

2.8.3 Integration with broader BONSAI-project outcomes

The data set will help to interpret erosion tests on the pilot sites, since vegetation cover and root biomass (strongly) contribute to the erosion resistance of the top layer of dikes. The integration of plant biodiversity in this aim for a strong cover and rooting of the vegetation will explore the potential of using nature-based solutions to build long-term resilience into our dikes.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

3 Growing dike (Meegroeidijk)

3.1 General description of the pilot site and tests

The principle of the Meegroeidijk is that the dike is enlarged by oversurfacing with sludge, see Figure 2. The main goals are to follow the sealevelrise or compensate the soil subsidence.

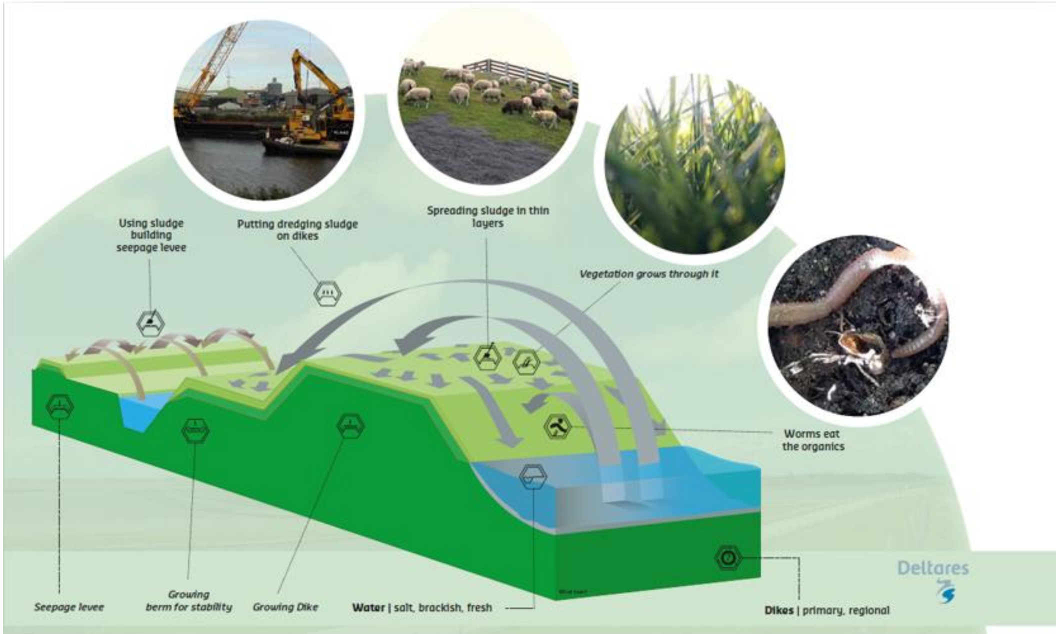


Figure 2 The principle of the Meegroeidijk

The aspect of the Meegroeidijk is being tested on three different locations. These were selected for their diversity, in order to optimize knowledge development and ensure maximum applicability to (Dutch) flood defenses. The pilots differ in:

- Saline clay-rich silt and, potentially, fresh organic silt from rivers and waterways;
- Geometry;
- Vegetation;
- Location and subsoil conditions

The first one is situated at the Westpolder in the northwestern part of Groningen in the Netherlands. This is seadike which is still in function, see Figure 3. At this location salt sludge will be placed on the dike. This will be done several years. The pilot site is devided in several plots. They differ in the thickness of the layer and if a seedmixture is added to the sludge or not. For this two mixtures have been selected.

Figure 3 seadike Westpolder at the Groningen northcoast

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Another pilot site is located more in the Western part of the Netherlands approximately 5 kilometers northeast of Alphen aan de Rijn (coordinates: 52°16’00.57”N, 4°70’08.09”E), see Figure 4. This dike is situated in a peat meadow area and is mostly build up from peat itself which makes it vulnerable for long dry periods. At this location fresh water sludge will be deposited with a rather high organic matter. One of the specific aspects which will be determined is the impact on the humidity of the dike. For this moisture sensors will be placed in the different plots where either sludge is being or not being deposited.

Figure 4 local dike near Alphen aan de Rijn

The third pilot side is situated at wastewater purification system Nieuwveer (coördinates 51°63’12.9 “N 4°70’80.6 “E) which is located about 10 km north of Breda in the Netherlands, see Figure 5. At this location trenches have been filled with sludge combined with several grass seedmixtures which differ from composition. By this means a prefab grass revetment will be produced. The final goal is to find out which combination of sludge and seedmixture results in the best grass/vegetation revetment.

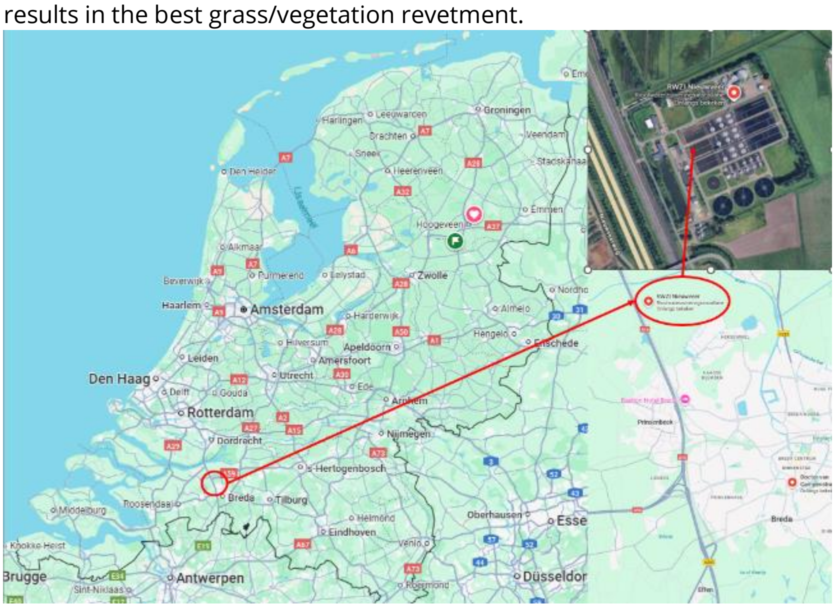


Figure 5 Testlocation wastewater purification system Nieuwveer

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

3.2 Aim and site suitability

The aim in the content of short term robustness is to gather knowledge on the effect of sludge being put on top of the grass revetment of a dike. Will it die or reveal itself? Is this depended on the type of sludge and/or the thickness of the layer? To get answers to these questions several aspects will be taken into acount such as fresh- or saltwater sludge, the organic matter content and the thickness of the layer of sludge by which the dike is . During the project regulary information of the development of the vegetation will be gathered and analysed. Also the weather conditions will be measured. At the end of the project the strength of the erosion resistance of the vegetation will be tested with grass pulling test.
The pilot site at the Westpolder can be visited by public all year round. Many people travel along by bike. Especcially at this pilot site a billboard will be placed to give more information about the project. The other pilot sites are situated on private property and cannot be visited everyday. For this fieldtrips can be organized.

3.3 Contribution to overall objective

By testing the effect of sludge with different characteristics and difference in layers knowledge will be gathered about the impact of oversurfacing a dike with sludge.
Because of BONSAI a special seedmixture, which resulted from the project Future Dikes, can be tested in the Netherlands and at the site of CEREMA. Also the seedmixture which is regularly being used in the Netherlands will be tested on this site. By comparing the development of the vegetation the sustainability in relation to climate change can be determined.

3.4 Link with other pilot activities

The grass pulling tests will be done with the same instrument that is being used in Vlassenbroek. This will also be done as much as possible with the monitoring of the development of the vegetation. By this results from the Meegroeidijk and Vlassenbroek can be compared.

3.5 Description of survey performed. (Link to the test and reference site characterization)

In 2022 the possibility to use sludge from the harbour of Lauwersoog for the principle of Meegroeidijk has been tested with small and medium scale experiments, see Figure 6. One of the questions to be answered was how quick the sludge would dry completely and much would remain of the original thickness. This was followed up by an experiment at the pilot site Westpolder where in 2023 sludge was being sprayed against the dike, see Figure 7. This was done in layers of 2 cm’s respectively 5 cm’s. At some plots the normally used D1 seed mixture was added. Sometimes the sludge was prewashed with fresh water, see Figure 8. The vegetation survived well but there was hardly any difference found in the remaining thickness of the layers[1].

[1] *For the final results of this project see: TKI - report Meegroeidijk Lauwersoog 11209071-000-ZKS-0002, 28 August 2023*

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Figure 6 Small scale and medium scale tests

Figure 7 Spraying sludge and its result at the Westpolder in 2023

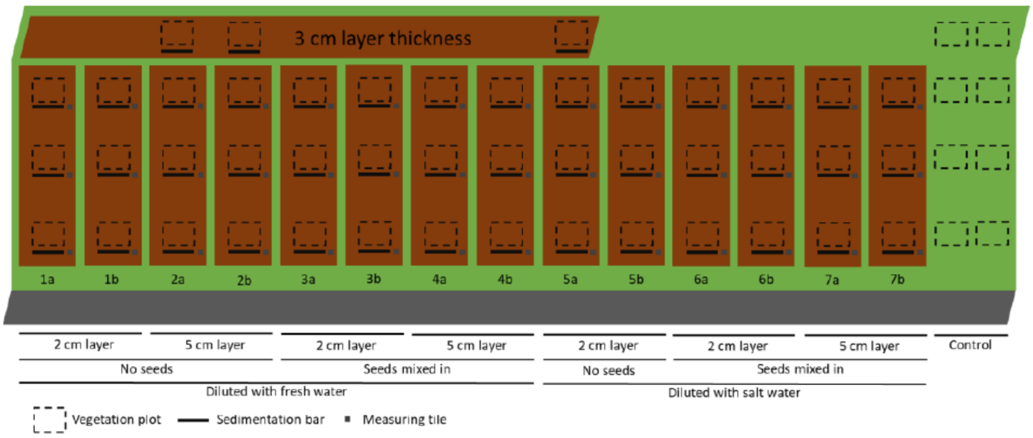


Figure 8 Overview of testplots

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

3.6 Test protocol

3.6.1 Methods of oversurfacing

At the pilot site Westpolder the means to oversurface the dike with saltwater sludge has been tested in September 2025. For this a sludge was being dredged from the harbour of Lauwersoog, transported to the dike. Finally a manure injector has been used to oversurface the dike. By this method the aim was to get a layer that would be of the same thickness all over the slope or the crest of the dike, see Figure 9 and Figure 10. This will also be done in 2026 and optionally in 2027.

Figure 9 the usage of the manure injector to oversurface the dike

Figure 10 The results of oversurfacing the dike with saltwater sludge

At the pilot site nearby Alphen aan de Rijn the impact of oversurfacing the dike will tested in a different way. At this location the idea is to bring sludge on top of the dike straight from the neighbouring waterway. This will only be done in 2026 but in much thicker layers of approximately 10 cm and 20 cm.

3.6.2 Monitoring layer thickness development

During the time the thickness of a layer of sludge will become less. As known the final result depends on the amount of organic matter. The saltwater sludge used at the Westpolder hardly contains any of this in contradiction to freshwater sludge used near Alphen aan de Rijn. To gather information about the development a Sedimentation Erosion Bar , see Figure 11 is used. At least at the Westpolder pilot site information will be gained by using a drone,

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

see Figure 12. By comparing the measurements which are taken several times a year the development can be determined.

Figure 11 Sedimentation Erosion Bar

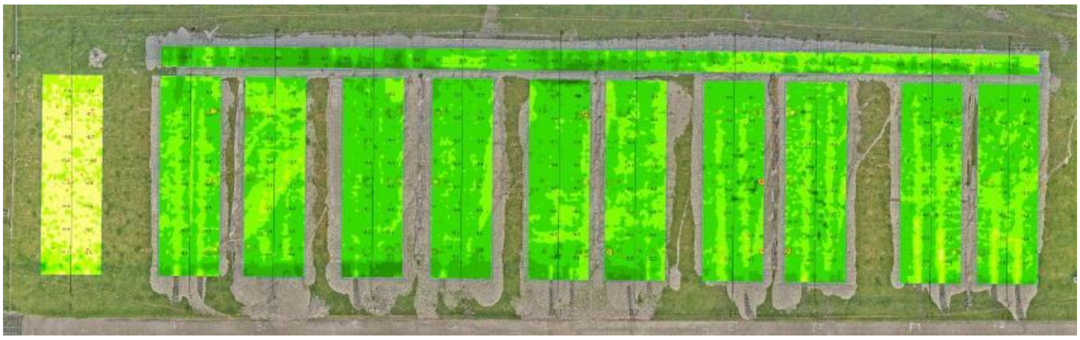


Figure 12 Results from a drone flight

3.6.3 Mutual connection between several layers of sludge

At September 2027 trenches of approximately 80 cm deep will de dug in several of the plots at pilot site Westpolder. The intention is to see if the different layers can be seen as separate layers or if they some sort of became one single layer. By using the Torvane tests the mutual connection can be tested. These tests will also be done in the wall of the trenches. Also the possible impact on structure formation can by this way be examined.

3.6.4 Grass pulling tests

The maximum allowable tensile force on the grass cover can be assessed using a turf puller, see Figure 13. For the execution of the grass pulling tests four pins are anchored horizontally into the sod at 4 cm below the surface, to prevent the pins from tearing through the sod. In order to insert the pins into the sod, the soil has to be removed from at least two sides of the frame. When soil is removed at all sides of the grass sod, only the bottom of the sod will resist against the applied force. When the soil is only removed at two sides of the grass sod,

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

the bottom and the two other sides will provide resistance against the uplifting force. Because of this, it is not possible to test the strength of an intact grass sod with this device[2].

Figure 13 turf puller and 'results' of the test in the reference plot

At the pilot site Westpolder 40 tests have been done in the reference plot. In September 2027 this will be repeated. At that moment grass sod pulling tests will also be executed in several plots where the dike has been oversurfaced with sludge. This activity will also take place at the pilot site near Alphen aan de Rijn. The aim is to do these as well at the pilot site Nieuwveer. This depends though on the development of the vegetation.

3.6.5 Monitoring vegetation development

At all three locations the development of the vegetation will yearly be monitored. This will be done by using an internal standard method so that the results can be compared with the measurements at the other BONSAI pilot sites. In September 2027 also a monitoring of the root density in the different test stretches will be executed.

3.6.6 Impact on drought

At the pilot site nearby Alphen aan de Rijn the impact of sludge on the humidity of the dike will be tested. For this moisture sensors will be placed in the different plots where either sludge is being or not being deposited. This will start in 2026. To be able the impact well local weatherdata will also be collected.

3.6.7 Greenhouse gas fluxes

Sludge will finally develop into clay. During this process though climate gasses like carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), will develop / come free due of oxidation. It is not known yet which will come free at what time and how large the concentration will be. To investigate and quantify the greenhouse gasses the Microportable Greenhouse Gas Analyzer (MGGA) will be employed. This is a portable in situ gas monitoring system that measures concentrations of greenhouse gasses collected in a small chamber placed on the surface where the emissions are to be measured, see Figure 14. The chamber is connected to the machine forming a closed circuit. Air is circulated through the machine, which measures the greenhouse gas concentrations by infrared detection every second.

[2] *For a further description of the method see paragraph* ***Error! Reference source not found.***

This project has received funding from the Interreg NWE programme 2021-2027

co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

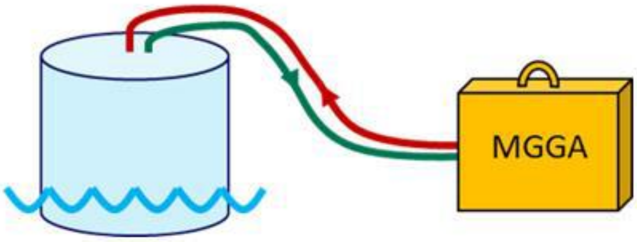


Figure 14 Microportable Greenhouse Gas Analyzer

The fluxes can be positive in case the concentration is increasing, meaning emissions of GHG, or negative, meaning that the concentration is decreasing due to uptake and absorption processes. On this basis, the rate of GHG emission or uptake is determined. This device produces multiple measurements per second that can be visualized in real-time, allowing for the immediate detection of potential leakages that could affect the results. The MGGA is adaptable to various environments and weather conditions, making it suitable for deployment on different soil types and water bodies. Figure 6.10 shows a schematic representation of the MGGA with the cylindrical greenhouse placed on the surface whose GHG fluxes need to be measured. measurements will be taken by This will at least be tested at the Westpolder and probably also at the pilot site near Alphen aan de Rijn.

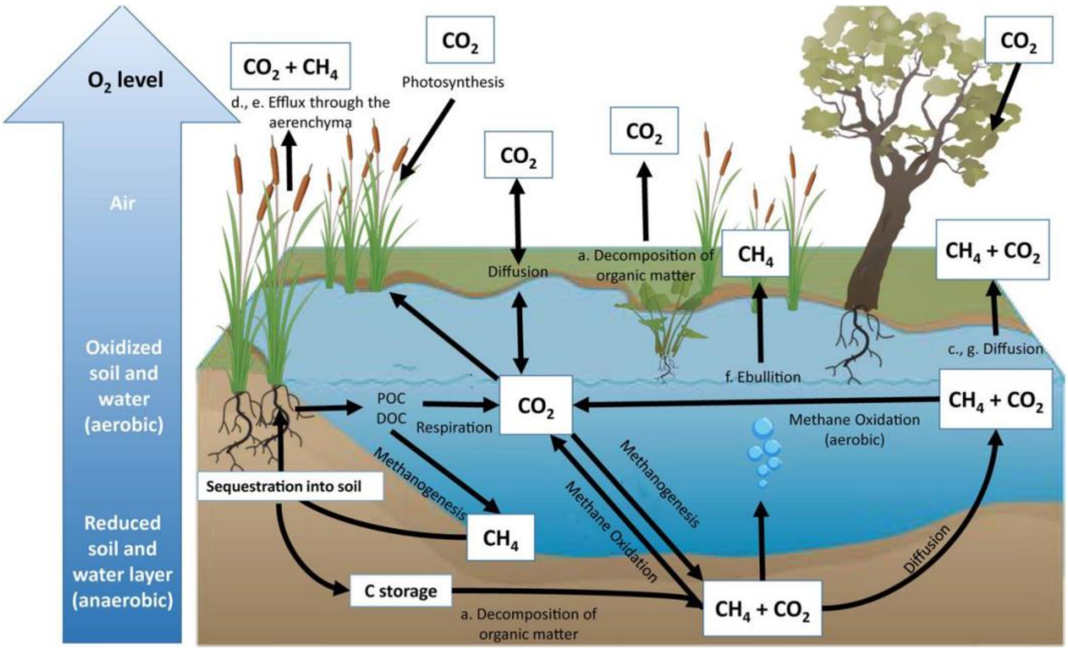


Figure 15 the storage of greenhouse gasses in sludge

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

4 Foreshore dike (Oeverdijk)

Contributing to activity A2.5 via deliverable D 2.5.2

4.1 Introduction Oeverdijk

The Oeverdijk was recently developed using a new dike reinforcement concept in a freshwater lake environment, being a sandy solution replacing an old peat and clay levee.

The Oeverdijk in Hoorn is a nature-based solution designed for water safety. In addition, the Oeverdijk hosts a ecological compensation area. This compensation has been established as part of the High Water Protection Programme (HWBP) along the stretch from Amsterdam-Noord to Hoorn. A permit for the required flora and fauna activities was granted through the creation of this ecological compensation area. The Oeverdijk, including the internal water system, covers approximately 61 hectares (Figure 1).

Figure 1: Oeverdijk Hoorn

The purpose of the Oeverdijk is to safeguard the long-term resilience of the system—both in terms of water safety and biodiversity. This report outlines the monitoring of biodiversity developments on the Oeverdijk.

Various ecological monitoring activities are carried out on flora and fauna to fulfil different objectives. A number of these activities are part of the ecological compensation requirements listed in the area's management and development plan. Additional monitoring is carried out for the BONSAI project. Only the monitoring efforts

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

relevant to BONSAI are described in this plan of action. Table 1 provides an overview of all monitoring activities on the Oeverdijk and point out those included in BONSAI.

4.2. Set-up of monitoring, and measurements

Several ecological monitoring programmes are conducted on the Oeverdijk; these are summarised in Table 1. The following chapters describe the monitoring activities that are relevant to the BONSAI project.

Table 1. Overview of ecological monitoring at the Oeverdijk

Monitoring	Executed by	Purpose
Grass snake	HHNK	BONSAI
Lichens	BLWG	BONSAI
Structural habitat elements	HHNK	BONSAI / Development plan
Terrestrial plants	HHNK	BONSAI / Development plan
Breeding birds	KNNV Hoorn	BONSAI / Development plan
Butterflies, dragonflies, bees, hoverflies	Natuurlijke Zaken	BONSAI / Development plan
Aquatic plants	Watersystems	Development plan
Fish	Watersystems	Development plan

The results of the monitoring support ecological management of the Oeverdijk and the data helps to build a general ecological profile of the site. This profile can be compared with similar sites in different climate regions within the BONSAI project. Such comparisons allow us to learn from colleagues in neighbouring countries and improve future ecological monitoring for comparable nature-based solutions.

4.2 4.2.1.Grass Snake Monitoring

4.2.1 Breeding heaps

Five artificial breeding heaps for grass snakes have been constructed on the Oeverdijk. These are monitored annually in October. Monitoring involves carefully dismantling the heaps, first removing larger branches and then combing through the organic material to search for grass snake eggs. The total number of eggs found serves as the success indicator for each heap for that year. Locations of several heaps are shown in Figure 2, and an example heap is shown in Figure 3.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Figure 2: Locations of breeding heaps

Figure 3: Breeding heap on the Oeverdijk

4.2.2 Winter stay

Six winter stays for grass snakes have been constructed on the Oeverdijk. Their locations are shown in Figure 4, and Figure 5 shows one of the installed winter stay. These winter stays are also monitored yearly.

Monitoring is carried out between March and September. Between mid-March and July, each transect is visited four times under favorable weather conditions for reptile detection. In August and September, each transect is surveyed three more times, with a greater likelihood of observing juveniles. Visits are spaced out across both periods, ideally with a two-week interval (minimum of five days).

Cold springs may reduce the number of suitable monitoring days. In such cases, monitoring may need to be conducted later in the season (e.g., late June or July). Monitoring is only conducted on days with favorable reptile activity conditions, typically sunny days in April and May.

During prolonged warm periods, reptiles are primarily active during early morning and late afternoon, and surveys are scheduled accordingly. No monitoring takes place on very hot days (≥ 30°C), during rainfall, or on sunless days with strong winds.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Figure 4: Locations of winter stays

Figure 5: Winter stay on the Oeverdijk

4.2.3 Sensors

In addition to the winter stays on the Oeverdijk, several winter stays were also installed along other sections of the HWBP project of Amsterdam Noord to Hoorn. These winter stays, such as the one shown in Figure 6, are equipped with temperature and moisture sensors to determine whether the microclimate meets the habitat requirements of the grass snake.

These sensors were installed by the project alliance, and the water authority is working to gain access to the data.

Figure 16: winter stay build into the new dike

4.2.4 Lichen Monitoring

The development of lichens on the Oeverdijk will be monitored in 2026 and 2032, using the same methodology in both years.

The most promising locations for lichen development are the six grass snake winter stays constructed from Norwegian stone and/or sandstone.

For each stay, a complete list of mosses and lichens will be compiled, including abundance. Although the rest of the Oeverdijk appears less suitable for lichens, colonisation may occur on areas of bare soil and on basalton revetments. All potentially suitable locations will therefore be inspected, and occurrences of rare or Red List species will be recorded. Data will be entered into VERA and published in the National Database of Flora and Fauna (NDFF).

4.3 Structural Elements

Structural elements will be monitored following the requirements listed in the management and development plan for the ecological compensation area. The percentage cover of each structural element is estimated in the field. Appendix 1 contains the field form used for these

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

surveys. These measurements will be repeated yearly during the development phase, for a minimum of three years.

Additionally, the area is photographed using a drone. It is not yet certain whether these aerial images can be used to support the structural assessment.

4.3.1 Terrestrial Plant Monitoring

Terrestrial vegetation across the Oeverdijk is monitored by submitting annual observations to the National Database Flora & Fauna (NDFF). Ecologists from the Hollands Noorderkwartier Water Authority contribute significantly to these records. The NDFF is also supplemented by observations from a wide range of users, including naturalists and professional ecologists using the Obdensify field app.

Each year, the NDFF data for the Oeverdijk are queried and compared to the target species established in the development plan. A quality assessment is then assigned. Target species and assessment criteria are included in Appendix 2.

4.3.2 Breeding Bird Monitoring

Breeding bird monitoring will be conducted by volunteers from the local nature association KNNV Hoorn. The specific methods to be used are still under consideration.

4.3.3 Butterflies, Dragonflies, Bees and Hoverflies

This monitoring follows the official SNL monitoring protocol. Three fixed transects of approximately one kilometre each have been digitally mapped on the Oeverdijk. These routes remain identical throughout all project years.

Each transect is surveyed three times per year—in spring, early summer, and late summer. All visible butterflies, dragonflies, bees, and hoverflies are counted while walking the transect at a steady pace under suitable weather conditions. Dragonfly monitoring is supplemented by larval sampling following SNL standards.

As the method is weather-sensitive, annual fluctuations may occur. However, the systematic approach ensures robust long-term trend insights.

All observations are digitally recorded, quality-checked, and stored in a central database. Records are submitted to the NDFF and forwarded to the Dutch Butterfly Foundation for national trend analyses.

Annual reports (years 1 and 2) include distribution maps for characteristic species and habitat descriptions with management recommendations. A final report in year 3 synthesises all data, answers the key research questions and presents multi-year trends.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

4.4 Integrated monitoring

The Oeverdijk consists of a profile of sand that is constructed in front of the old dike. It will take over the entire function of water safety.

The required volume of sand for the safety profile must be present during the planning period (until 2071). If the available volume falls below the critical volume, the shore embankment will in principle be rejected and maintenance (int het form of sand replenishment) will have to be carried out.
The Alliance has been commissioned to design a safe dyke for the next 50 years. The manager only allows regular maintenance. For the Oeverdijk, this effectively means the desire to arrive at a design that requires as little maintenance as possible, minimizing the risk of additional sand replenishment. For this reason, a wear layer has been included in the design to enable the dynamic behavior of the Oeverdijk without directly affecting the total sand volume in the safety profile.

4.4.1 Reason for monitoring sand and water

At present, there is no clear-cut method for arriving at a realistic estimate of the volume of sand required in the war layer. This is because insufficient knowledge is available about the dynamic behavior of a sandy foreshore in a lake situation. In order to gain more insight into this, the daily behavior of a sandy reinforcement was investigated by means of a test section, the pilot sandy foreshore reinforcement Houtribdijk. Although this project has yielded a great deal of new knowledge, it is not yet possible to translate the results directly into the design of the shore embankment.

In order to arrive at an estimate of the required wearing course volume, the dynamic behavior of the embankment was investigated using a model. Monitoring is therefore crucial to understanding the behavior of the embankment and ensuring water safety.

Monitoring within projects is often carried out on a small scale and only set up at the end of a project. We start earlier by using drones and possibly cameras for both ecology and sand monitoring. For both types of monitoring, we will come up with a proposal for a portal for sharing data, both internally within Bonsai and externally.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

4.5 Data gathering

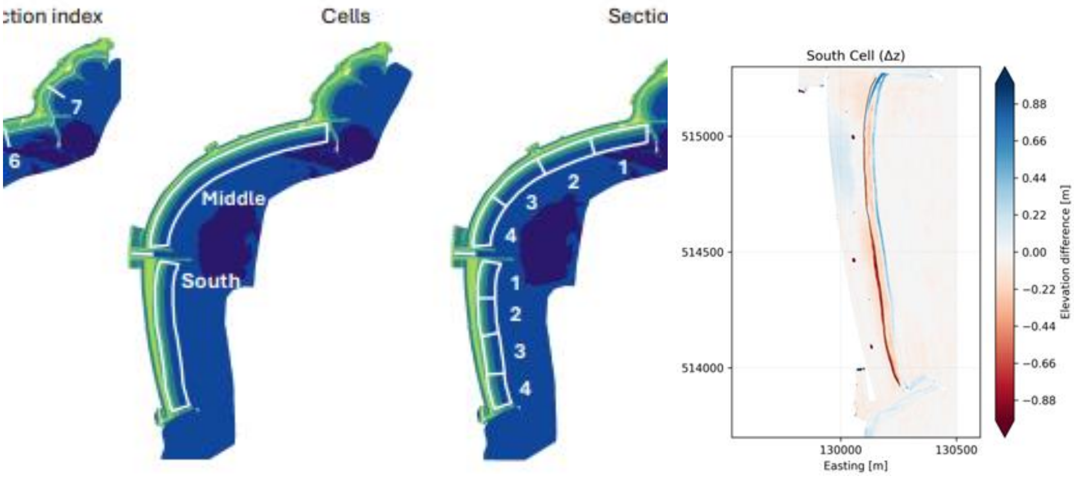
In collaboration with Boskalis, the measurement data from the measuring buoy has been requested. This includes water pressure, water height, wind speed and wave direction. In combination with the bathymetry data, we should ultimately be able to say something about the erosion that is occurring.

Measuring buoy

- Objective: to develop a clearer understanding of the required sand maintenance volumes and nourishment frequency by improving insight into the hydraulic boundary conditions and advancing erosion-modelling approaches
- Realized data acquisition from measurement buoy in cooperation with civil engineering Contractor.
- Data in combination with bathymetry potentially allows for enhanced modelling of erosion processes, morphology and required sand nourishment
-

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Further filtering and assessing data quality required for eventual model input
In combination with bathymetry data acquirement a first attempt at comparing expected erosion versus actual occurring erosion
Comparing design parameters vs actual occurring parameters. Which design choices were made and why, and how do these design choices compare to the actual observed values



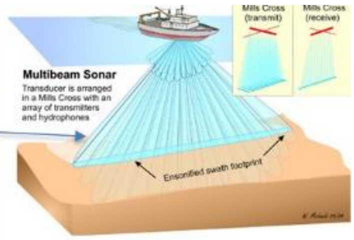
Indicative products from the Oeverdijk, if analysis and bathymetry data is successfully completed. Pictures created by Puck van de Ven, 2025

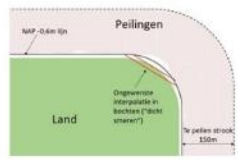
4.6 Data management

4.6.1 External data management and data capture

In 2025, we inventoried the available external data. We completed the data transfer from external to internal storage and created a reference to this data within our Geographic Information Systems (GIS).
During the inventory, it became clear that the Alliance is currently collecting geometry characteristics of the above-water surface on a quarterly basis. This process will continue until the end of 2026, after which we will take over the monitoring.
Currently, the Alliance is not collecting bathymetric data (under-water characteristics). This data is necessary to create an integral elevation model of the situation. Therefore, it is now crucial that we issue a market consultation for this data collection (starting in 2026). Due to procurement regulations, we will approach three identified suppliers for this tender.

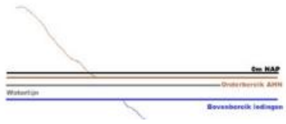
This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

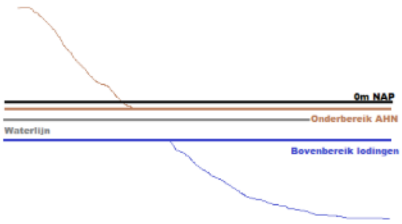




Bathymetric tender

- Defined project area and measurement interval
- Defined data quality standards
- Identified potential contractors for data capture





4.6.2 Data pipeline development

Regarding the development track for the data analysis pipeline, the first step is to assess the quality of the external data, including the need for noise reduction and classification. Following this we will design the data pipeline. This design will define which variables we will calculate and how we must process the raw data to derive the desired insights.

Once the design is complete, we will begin the automation phase. The preferred approach is development in open source Python, which will facilitate easy sharing within the BONSAI community and beyond. As a backup, we are considering a combination of FME and Arcpy. However, this option is less preferred than open source Python due to the licensing requirements..

4.6.3 Planning Q1 – Q2 2026

- Asses external data quality
  - Noise reduction
  - Classification
- Design data-pipeline
- Start with automating data pipeline
  - FME / Open-source Python

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

4.7 Development of recreational use of the site

4.7.1 Integrated Development of the City Beach and Flood Defense in Hoorn

The combined realisation of the city beach and the reinforced flood defense along the Markermeer represents a strategic, future-oriented investment in Hoorn's spatial quality, safety, and economic vitality. By integrating water safety measures with recreational and ecological enhancements, the project delivers broad societal value and aligns with the municipality's long-term ambitions for sustainability, livability, and regional attractiveness.

4.7.2 Water Safety and Climate Resilience

The strengthened flood defense meets the latest national safety standards and significantly improves Hoorn's resilience to rising water levels and extreme weather events. The integration of the dike reinforcement with the city beach development ensures a coherent, multifunctional waterfront that protects residents and infrastructure while enhancing spatial quality.

4.7.3 Ecological and Landscape Benefits

The new sandy foreshore and gradual land-water transition create valuable habitats for flora and fauna, contributing to a more diverse and robust ecosystem. The redesigned waterfront strengthens Hoorn's identity as a historic water-oriented city and improves the overall landscape experience for residents and visitors.

4.7.4 Recreational Value and Quality of Life

As the largest lake-side city beach in the Netherlands, the area provides accessible, high-quality recreational space for all age groups. Facilities for swimming, water sports, walking, sports activities, and relaxation support healthier lifestyles and meet the growing demand for outdoor public spaces. The proximity to the city centre enhances Hoorn's appeal as a vibrant place to live and visit.

4.7.5 Economic Impact and Tourism Development

The renewed waterfront attracts both regional visitors and tourists, generating increased spending in hospitality, retail, and recreational services. New business opportunities arise through the beach pavilion, rental services, and event programming. The project strengthens Hoorn's position as a distinctive destination within Westfriesland and the broader Markermeer region.

The integrated development of the city beach and the reinforced flood defense delivers substantial benefits across water safety, ecology, recreation, and economic development. It positions Hoorn as a resilient, attractive, and forward-looking city, prepared for the challenges and opportunities of the future.

4.8 Roles and Responsibilities

Team Members	***Role***
Project Leads Ilona Evers	Oversee entire test plan execution, report on results
Field Technician Jeroen van Ruitenbeek	Implement test setup and monitoring
Data Analyst Sem Jongejan	Compiles and analyzes collected data, prepares draft report

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Ecologist Floris Marsman	Interprets animal-related impacts and biodiversity

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Annex 1

Vegetation survey protocol used at the site of Vlassenbroek (an adapted version will be used in the European wide surveys)

How to survey levee vegetations?

Bart Vandevoorde, Eric Visser & Peter Boone

1. Inleiding

Om een objectief beeld te krijgen van de vegetatiesamenstelling en -kwaliteit op de dijken worden vegetatieopnames gemaakt (zie 2). Een vegetatieopname kwalificeert en kwantificeert de vegetatie in een afgebakend proefvlak dat representatief is voor de aanwezige vegetatie.
Op basis van deze vegetatieopnames kan de vegetatie waar deze opnames zijn gemaakt, toegekend worden aan een bestaande vegetatietypologie of kan er met deze vegetatieopnames een lokale typologie worden opgesteld.
Aanvullend kunnen variabelen gemeten worden zoals de bedekking van de vegetatie als proxy voor de erosiebestendigheid, of de biomassa, of de wortellengtedensiteit, etc.
Een vegetatiekartering uitvoeren laat toe om een beeld te krijgen van de verspreiding van de vegetatietypes op de dijken (zie 3).

2. Vegetation relevés

Om de dijkvegetatie te kwalificeren worden de principes van de Frans-Zwitserse school (Braun-Blanquet-methode) gevolgd. Die stellen dat vegetatie-opnames gemaakt worden in homogene vegetaties waarbij de grootte van het proefvlak zo wordt gekozen dat de soortenrijkdom weinig of niet veel meer toeneemt bij het vergroten van de oppervlakte (Schaminée *et al*., 1995).

a. Afbakening proefvlak

Vegetatieopnames worden gemaakt van proefvlakken. Afhankelijk van de vraagstelling wordt het proefvlak gesitueerd op de kruin, landzijde, rivierzijde of teen van de dijk maar telkens in een homogene vegetatie.
Alle proefvlakken hebben een grootte van 2 x 2 m en liggen parallel aan de kruin (Figure 17), al kan de vorm worden aangepast in functie van de vraagstelling of in functie van de

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

homogeniteit. De XY-coördinaten van de overstaande hoekpunten worden nauwkeurig ingemeten met behulp van een RTK-GPS.
De proefvlakken worden random gelokaliseerd en geïnstalleerd in een homogene vegetatie. Het aantal proefvlakken is afhankelijk van de vraagstelling en van de variatie in de vegetatie.

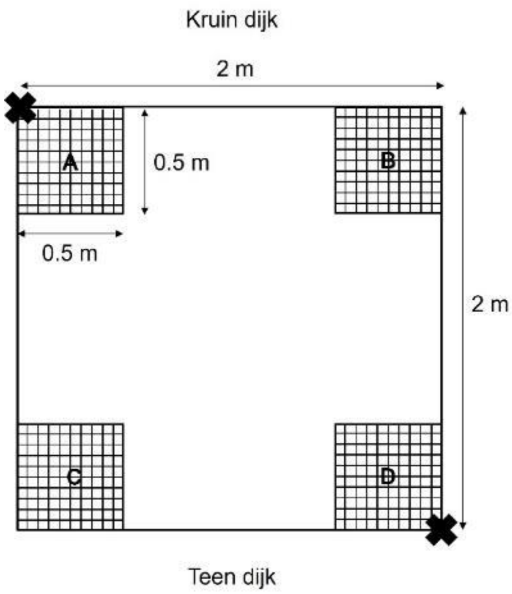


Figure 17 Standaard van een proefvlak van 2 x 2 m, welke parallel aan de kruin is gelegen. In de 4 hoekpunten worden de meetpunten van 0,5 x 0,5 m gelegd (A, B, C, D), ter bepaling van de biomassa en om de bedekking te meten. Met een kruis zijn de hoekpunten aangegeven waarvan de XY-coördinaten bepaald worden.

b. Maken vegetatieopname

i. Tijdstip van de vegetatieopname

Het tijdstip of het moment in het seizoen van de vegetatieopname is zeer belangrijk. De opname zou moeten gebeuren op het moment dat de meerderheid van de soorten een maximale bedekking heeft bereikt.
Voor graslanden in gematigde streken situeert dit moment zich in mei-juli maar optimaal is de periode tussen midden mei en eind juni.
Ook wordt rekening gehouden met het beheer. Bij voorkeur wordt de opname gemaakt voor elke vorm van beheer is toegepast. Dit is vanzelfsprekend bij maaibeheer maar ook bij begrazingsbeheer wordt de vegetatieopname best gemaakt voor er begrazing is.

ii. Vegetatieopname

Bij het maken van de eigenlijke vegetatieopname worden zowel kopgegevens als soortgegevens genoteerd. Kopgegevens zijn beschrijvende data van het proefvlak maar evengoed data omtrent de vegetatie in zijn geheel. Zoals de naam aangeeft betreffen soortgegevens data op soortniveau.
Kopgegevens:

- Naast datum en auteur wordt aan elke vegetatieopname een uniek nummer toegekend, bijvoorbeeld EV26/001 of PB26/001. Dit uniek nummer bevat bijvoorbeeld de initialen van de auteur, het jaartal en een volgnummer. Ook het nummer van het proefvlak wordt genoteerd.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

- Ook wordt een foto gemaakt van het proefvlak waarbij identificatiegegevens op een bordje genoteerd en gefotografeerd worden (Figure 18).
- Aansluitend wordt in procenten de bedekking van de verschillende aanwezige vegetatie- of structuurlagen ingeschat (boom-, struik-, kruid-, mos-, algen-, strooisellaag), net als de totale bedekking. De totale bedekking wordt over de lagen heen ingeschat en is 100% verminderd met de bedekking van onbedekte bodem. Deze bedekkingen zijn een rechtstreekse schatting van het percentage in sprongen van 10%, 5% en 1%, waarbij op de uiteinden van de schaal kleinere sprongen genomen worden. Dit resulteert in 0, 1, 2, 3, 4, 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 85, 90, 95, 96, 97, 98, 99, 100 (INBO, 2023).
- De gemiddelde hoogte van de kruidlaag wordt ingemeten. Het gaat hier om een schatting van de vegetatiehoogte. In het proefvlak wordt volgens een rasterpatroon op 10 locaties het hoogste plantendeel gemeten. Dit uitmiddelen geeft de gemiddelde hoogte aangezien de gemiddelde maximale plantenhoogte per rastercel een gemiddelde hoogte voor het volledige proefvlak oplevert (INBO, 2023).
- Vervolgens wordt per vegetatie- of structuurlaag een volledige soortenlijst gemaakt van alle terrestrische vaatplanten, mossen en lichenen[3].
- Binnen elke laag wordt voor elke soort of taxon de bedekking[4] ingeschat met de schaal van Londo (1976) (Figure 19). Ook wordt per soort of taxon de fenologie genoteerd (Figure 20). Als er een soort meerdere waarden voor fenologie heeft, wordt de meest voorkomende toegekend.

Figure 18 Voorbeeld van overzichtsfoto van het proefvlak met identificatiegegevens op een bordje.

[3] Alle soorten worden per laag in rekening gebracht die door verticale projectie van de bovengrondse delen een bedekking hebben in het proefvlak. Dit betreft niet enkel in het proefvlak wortelende planten maar ook soorten die buiten het proefvlak wortelen maar waarvan delen boven het proefvlak hangen zoals een overhangende tak.
[4] De bedekking van een soort is het aandeel van het proefvlak dat ingenomen wordt als alle bovengrondse plantendelen van de betreffende soort verticaal geprojecteerd worden in het proefvlak.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

DECIMAL SCALE			Braun-Blanquet scale
symbol	coverage	supplementary symbols	
·1	<1%	• = r (raro) = rare, sporadic p (paululum) = rather sparse a (amplius) = plentiful m (multum) = very numerous	+
·2	1-3%		1
·4	3-5%		
1	5-15%	1- = 0.7 = coverage 5-10% 1+ = 1.2 = coverage 10-15%	2
2	15-25%		
3	25-35%		
4	35-45%		3
5	45-55%	5- = coverage 45-50% 5+ = coverage 50-55%	
6	55-65%		4
7	65-75%		
8	75-85%	(coverage >5%: abundance not indicated)	
9	85-95%		5
10	95-100%		

Figure 19 Decimale schaal van Londo (Londo, 1976) (deze schaal kan nog verder gedetailleerd worden door aan de codes 2, 3, 4, 6, 7, 8 en 9 een + of - toe te kennen).

Code	Verklaring
-	n.v.t.
+	Dood
0	niet genoteerd
Dis	uitgezaaid (oude bloeistengels nog aanwezig)
Fl	Bloeiend
Fr	met vruchten
K	Kiemplant
Kn	Bloemknoppen
sp	Sporenvormend
V	Vegetatief

Figure 20 Fenologiecode (INBO, 2023).

c. Biomassabepaling

De biomassa van de vegetatie wordt ingemeten in de 4 hoekpunten van 0,5 x 0,5 m in het proefvlak (A, B, C, D in Figure 17). Of er worden 4 meetpunten random gelokaliseerd in het proefvlak. Als de biomassameting in deze proefvlakken herhaald zal worden in kader van een monitoring, wordt best gekozen voor de hoekpunten omdat dit praktisch herhaalbaar is.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Indien het een eenmalige survey betreft, wordt gekozen voor random gelokaliseerde meetpunten.
In deze 4 hoekpunten of meetpunten van het proefvlak wordt de bovengrondse biomassa weggeknipt tot op ca. 2 cm hoogte en verzameld. Strooisel, gedefinieerd als liggend afgestorven plantenmateriaal niet vasthangend aan de moederplant, wordt niet verzameld. Ook terrestrische mossen en korstmossen worden niet verzameld, tenzij ze doorgroeien tot tussen de hogere planten (> 2 cm hoog).
Het plantenmateriaal van de 4 meetpunten wordt apart verzameld en zo snel mogelijk overgebracht naar het labo, waar het wordt gedroogd in een droogstoof bij 70 °C tot er geen gewichtsverlies meer is (Moore & Chapman, 1986). Het gewogen drooggewicht wordt uitgemiddeld per proefvlak en verrekend naar g/m² of naar ton drooggewicht (DS) per hectare.

d. Inmeten bedekking

Dezelfde 4 meetpunten van 0,5 x 0,5 m als voor de biomassabepaling worden gebruikt voor het meten van de bedekking (A, B, C, D in Figure 17 of random). In deze meetpunten is de bovengrondse biomassa reeds weggeknipt tot op ca. 2 cm hoogte (zie c).
Voor het inmeten van de bedekking van de vegetatie wordt een raster van 0,5 x 0,5 m gebruikt met rastercellen van 0,05 x 0,05 m (Figure 21 links). Elk snijpunt binnen het raster, in totaal 81, stelt een datapunt voor. Ter hoogte van elk snijpunt wordt een pin of staafje neergelaten en genoteerd of dit een hogere plant (V), mos (M), strooisel (S) of kale bodem (K) raakt (raammethode volgens Sýkora & Liebrand, 1987). Het procentueel aandeel hogere plant (V) geeft een waarde voor de bedekking binnen het meetpunt.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

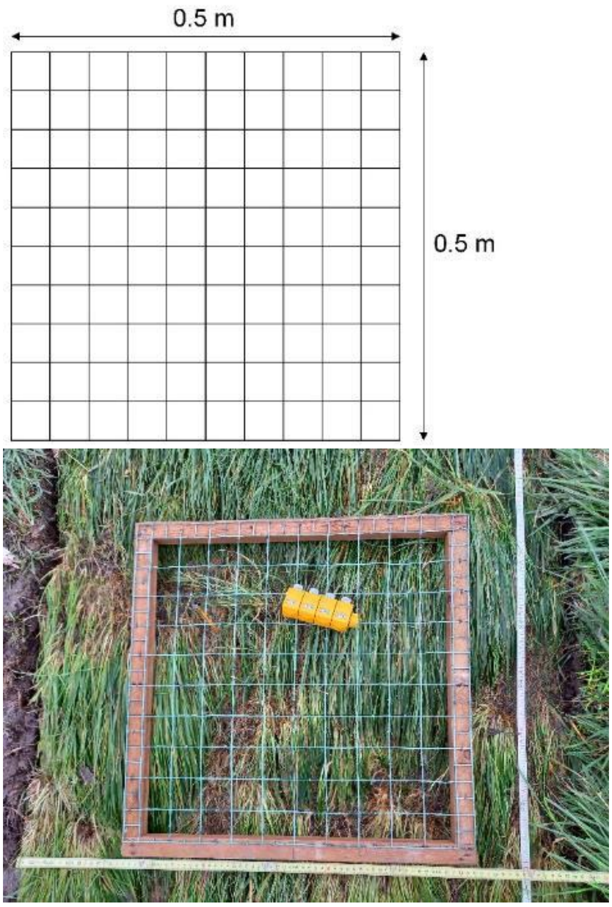


Figure 21 Raster van 0,5 x 0,5 m met 100 rastercellen en 81 snij- of datapunten om de bedekking van de vegetatie in te meten.

e. Bepalen worteldichtheid

De erosiebestendigheid wordt niet enkel onrechtstreeks bepaald door de bedekking te meten maar ook door de worteldichtheid te bepalen met behulp van de handmethode. Hiervoor worden per proefvlak 4 cores van de bovenste 20 cm genomen (diameter 3 cm), telkens random gelokaliseerd in de 4 kwadranten (Figure 22). Elke core wordt verdeeld in substalen of partjes van 2,5 cm waarin de duidelijk zichtbare wortels met een minimumlengte van 1 cm worden geteld (Sprangers & Arp 1999; VTV, 2007). Zowel dode als levende wortels worden geteld. Lange wortels van verschillende centimeters worden als individu geteld en niet per centimeter zoals Schaffers *et al*. (2010) suggereren.
De staalname gebeurt in de periode midden december en midden maart. Als de staalname buiten deze periode gebeurt en toetsing aan literatuurgegevens is gewenst, dan is een correctie nodig om het seizoenseffect te compenseren (Schaffers *et al*., 2010).

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

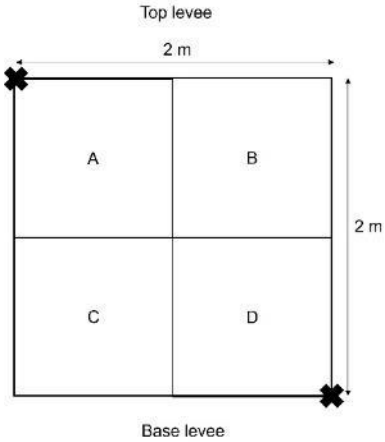


Figure 22 Proefvlak met 4 kwadranten waarin per kwadrant een random staal wordt genomen.

3. Vegetation mapping

Om een beeld te krijgen van de ruimtelijke verspreiding van de vegetatietypes op de dijken wordt een vegetatiekaart gemaakt. Een vegetatiekaart is opgebouwd uit veelhoeken of polygonen die telkens een homogene vegetatie-eenheid omvatten en waaraan een karteringseenheid zoals een vegetatietype is toegekend. Afhankelijk van de vraagstelling gebeurt de kartering op de kruin, landzijde, rivierzijde of teen van de dijk.
Bij de kartering kan gebruikt gemaakt worden van een recente orthofoto waarop de verschillende homogene vegetatie-eenheden worden onderscheiden (Figure 23). Aan elke onderscheiden vegetatie-eenheid wordt een vegetatietype toegekend. Ofwel wordt hiervoor een bestaande typologie gebruikt ofwel wordt er op basis van gemaakte vegetatieopnames een lokale typologie opgesteld en toegepast.
Indien geen orthofoto's beschikbaar zijn, kan bij het karteren de grens tussen de verschillende homogene vegetatietypes worden afgelopen en ingemeten met behulp van een RTK-GPS. Door verschillende types grenspunten te onderscheiden (S, T, Q, C) en telkens te noteren welke vegetatietypes ze begrenzen is het mogelijk om achteraf in een GIS deze puntenkaart om te zetten in een polygonenkaart (Figure 24).

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

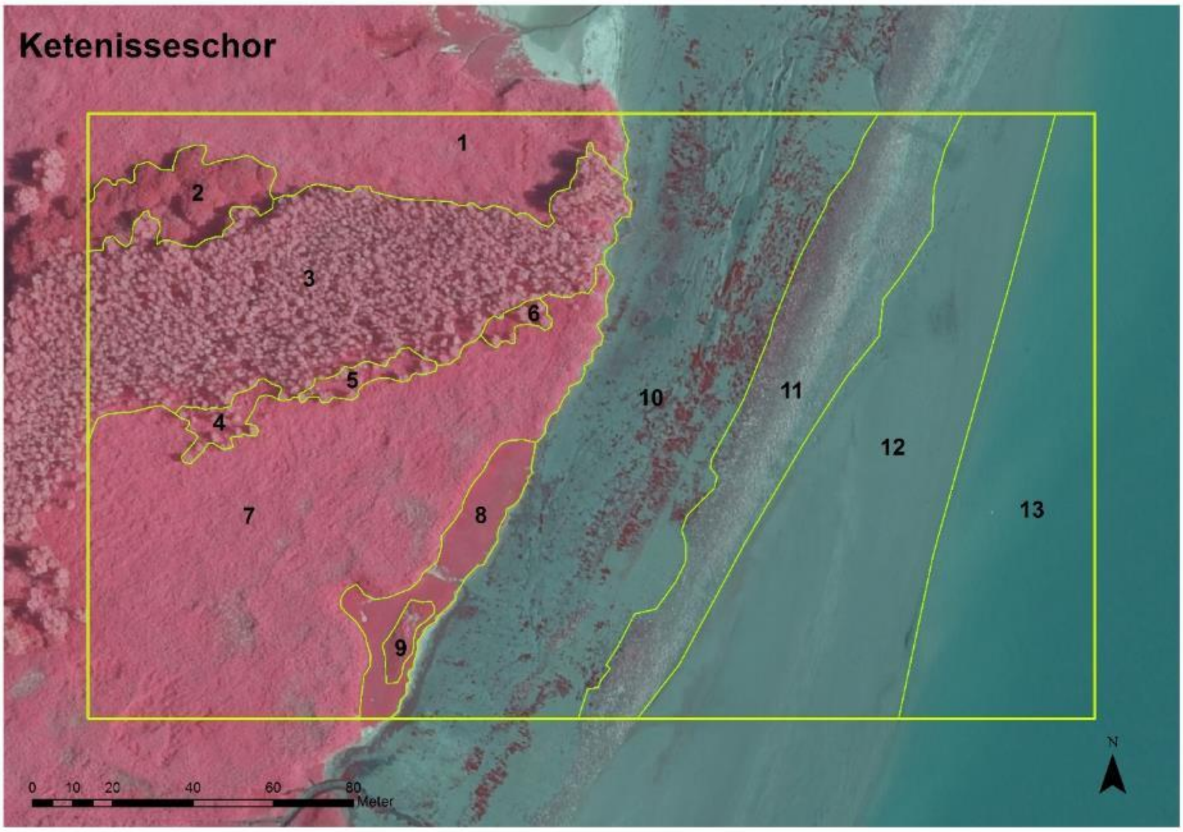


Figure 23 Voorbeeld van een FCIR-orthofoto, gebruikt als basis voor het maken van een vegetatiekaart.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

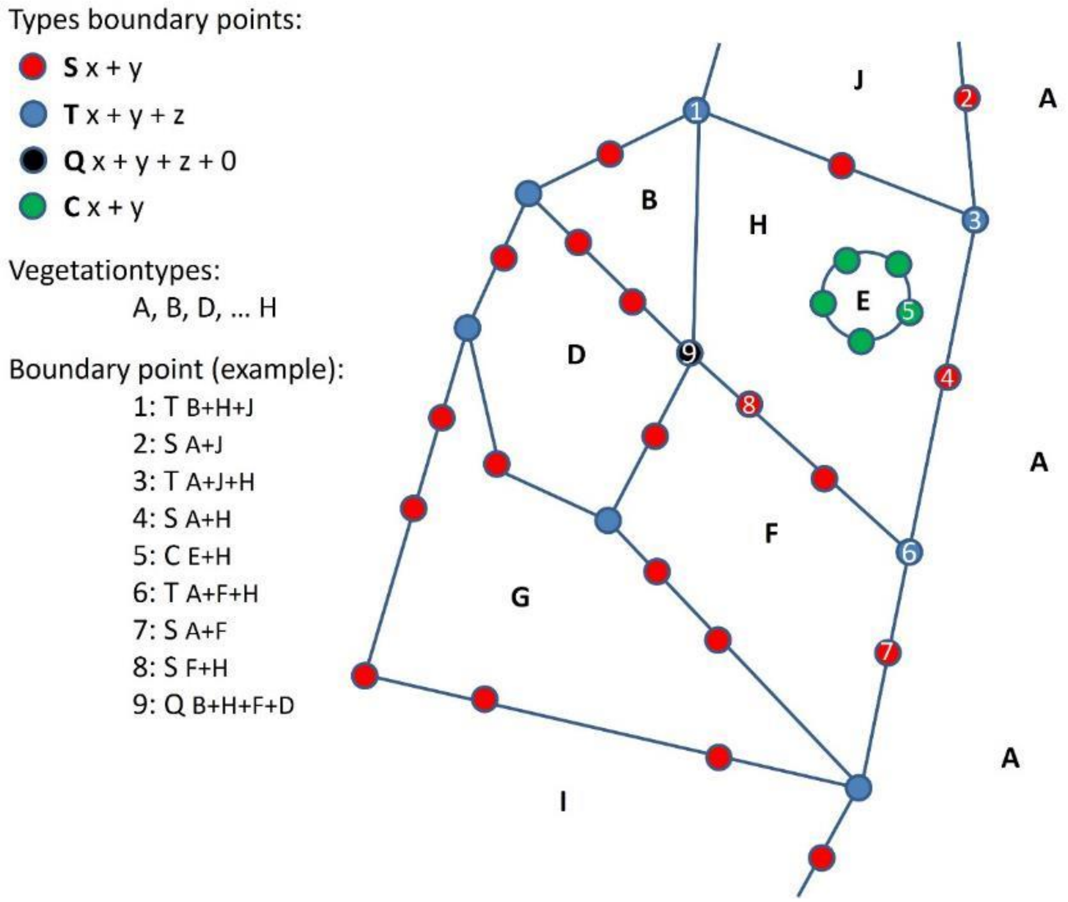


Figure 24 Bij het karteren worden de grenzen tussen de verschillende vegetatietypes (A, B, D, ...) ingemeten. Verschillende types grenspunten worden onderscheiden. Type S vormt de grens tussen 2 vegetatietypes, type T tussen 3 vegetatietypes en type Q tussen 4 vegetatietypes. Type C is een grenspunt tussen 2 vegetatietypes waarvan de ene polygoon volledig binnen de andere ligt.

4. References

INBO (2023). Klassieke vegetatieopname in een proefvlak aan de hand van visuele inschattingen van bedekking van soorten in (semi-)terrestrische vegetatie (versie 2023.3). Standaard Veldprocedure 401, Instituut voor Natuur- en Bosonderzoek, Brussel.

Londo G. (1976). The decimal scale for releves of permanent quadrats. Vegetatio 33(1): 61-64.

Moore P.D. & Chapman S.B. (1986). Methods in Plant Ecology. Second edition. Blackwell Scientific Publications, Oxford, 588 p.

Schaffers A.P., Frissel J.Y., van Adrichem M.H.C. & Huiskes H.P.J. (2010). Seizoensverloop in de doorworteling van dijkgrasland. VTV-toetsing buiten het winterseizoen nader bekeken. Alterrarapport 2014, Alterra, Wageningen

Schaminée J.H.J., Stortelder A.H.F. & Westhoff V. (1995). De vegetatie van Nederland. Deel 1 Inleiding tot de plantensociologie: grondslagen, methoden en toepassingen. Opulus Press, Uppsala, Leiden, 296 p.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Sprangers J.T.C.M. & Arp W.A. (1999). Toetsingsparameter dijkgrasland –indicatorsoorten dijkgraslandtypen en worteldichtheidbepalingen (handmethode). Rapport IBN-DLO, Wageningen.

VTV (2007). Voorschrift Toetsen op Veiligheid Primaire Waterkeringen. Iov. Ministerie van Verkeer en Waterstaat Directoraat-Generaal Water, Den Haag.

Sýkora K.V. & Liebrand C.I.J.M. (1987). Natuurtechnische en civieltechnische aspecten van rivierdijkvegetaties. Landbouwuniversiteit Wageningen, 194 p.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Annex 2

Protocols to be used by partners at the pilot sites when erosion measurements are about to be started

Vegetation data to be collected at each erosion test site (sod quality)

We propose to largely use the methods described in the *Guideline for Assessing Grass Covers on Dikes*, used by Dutch water authorities, but then apply them in a somewhat more quantified way:

- percentage of vegetation cover and open soil, defined as fractions of grass, forb (non-grass), and moss, and of open soil, adding up to 100% of the total area of 30 x 30 cm
- sod quality, defined as sod with closed rooting, open rooting or fragmentary rooting
- type of soil, ideally as % lutum/silt/sand – total 100%, but otherwise in categories like clay(ey), sand(y), loam(y), or combinations of those – e.g., loamy sand, sandy clay

Protocol for Bonsai teams

- Determine the place of the sod quality plot(s), representative for the dike as a whole and as close as possible to the location of the erosion test; note down the GPS coordinates, and details on cardinal orientation (N/S/W/E), slope (in °; level is 0 °), and average height of vegetation cover (in cm).
- Set out a square plot of 30 x 30 cm with 4 short poles or sticks (if these are 30 cm, they can be used to determine the size of the plot).
- Make clear pictures of the situation of the entire dike, a picture of the vegetation and one of the plot.
- Estimate the percentages of open soil visible, versus vegetation. Then decide how much of the visible vegetation cover contains of moss, grass and other plants (forbs). Write these four values down, make certain that they add up to 100%.
- Cut a sod of approximately 0.25 × 0.30 m, using a spade, and lift it as a turf block with a thickness of about 10 cm.
- Determine the quality of the root sod according to the following criteria:
  - Dense root sod:

    It requires some effort to pull apart a sod block (approx. 0.25 × 0.30 m²). A block from a densely rooted sod generally remains largely intact when detached from the subsoil with a spade.
  - Open root sod:

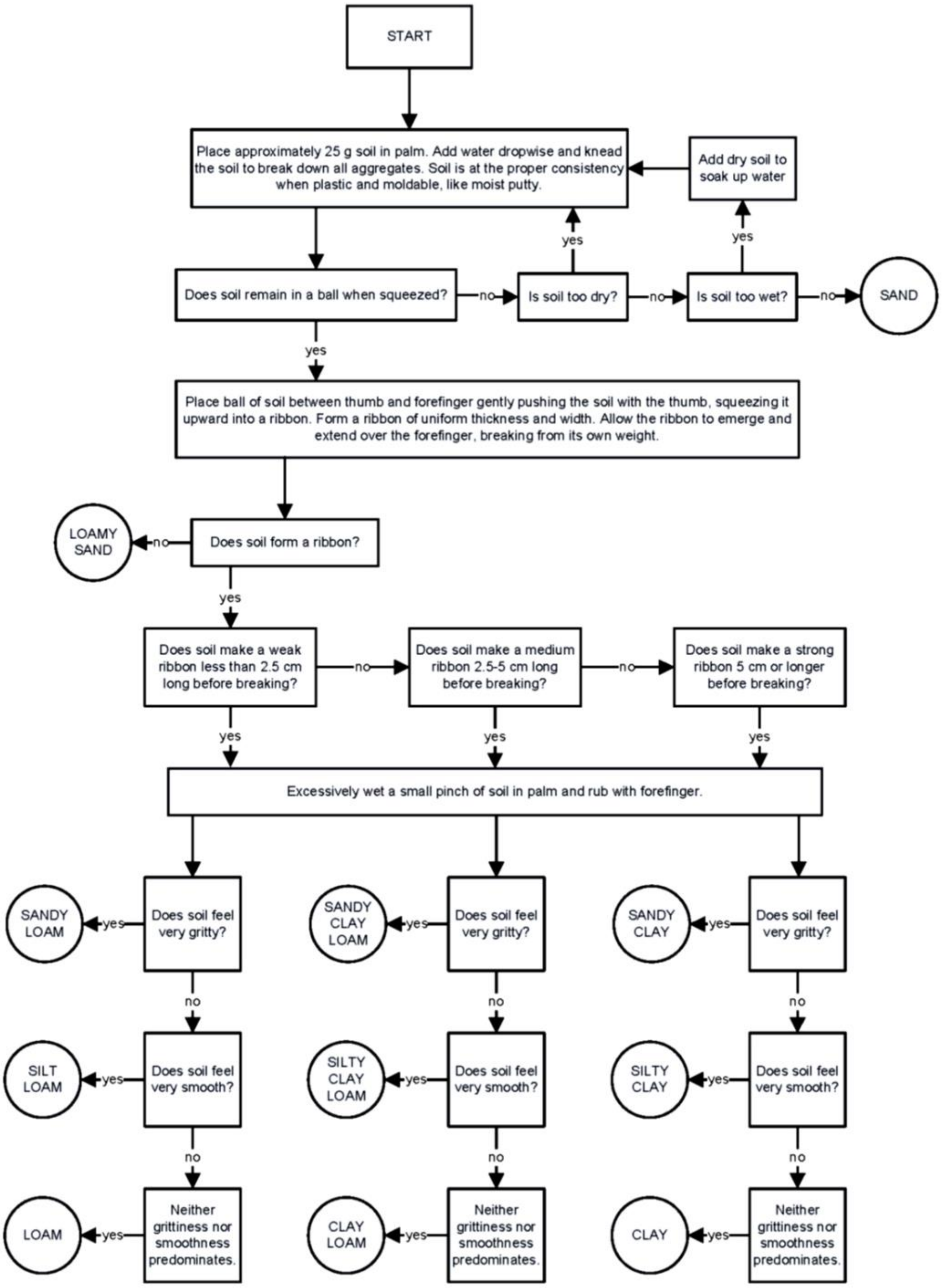
    An intact sod block (approx. 0.25 × 0.30 m²) can only be extracted with considerable care using a spade (except in cases of moist, clayey soil compacted by foot traffic or during cutting).
  - Fragmentary root sod:

    It is nearly impossible to extract an intact sod block (approx. 0.25 × 0.30 m²) from the soil surface (except in cases of moist, clayey soil compacted by foot traffic or during cutting).
- Take some soil from the sod, remove coarse materials, and determine the texture of the soil, according to the diagram *Guide to texture by feel*. Ideally, have a sample analysed for soil texture at a soil laboratory.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Guide to Texture by Feel

Modified from S.J. Thien. 1979. *A flow diagram for teaching texture by feel analysis.* Journal of Agronomic Education. 8:54-55. https://www.nrcs.usda.gov/sites/default/files/2022-11/texture-by-feel.pdf



Reference:

Abbreviated translation of Eisen Grasbekledingen by Infram BV, now Infram Hydren, 2017 (https://www.handreikinggrasbekleding.nl/sites/default/files/2023-09/Rapport-eisen-grasbekledingen-v2.0-incl-bijlage-Infram-2017.pdf)

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Definition of “closed,” “open,” and “fragmentary” vegetation

The quality of the grass sod can be classified into three categories - **closed, open, and fragmentary** - primarily based on the density of the root network. A closed grass cover refers to a sod with dense rooting.

According to the *Technical Report on Assessing Grass Covers on Dikes* (Deltares, 2012), as adopted in Section 6.4.2 of the Dutch *Guideline for Assessing Grass Covers on Dikes*, the following guidance applies when evaluating grass cover quality:

The common vegetation types corresponding to the three sod-quality categories can be identified through visual inspection. Such an inspection involves estimating the coverage of a recently mown dike slope while walking over the grass cover and, particularly when the grass height exceeds approximately 0.1 m, regularly examining in more detail the density of vegetation at the soil surface.

The representative plant spacing serves as the criterion for determining the degree of openness of the vegetation. This spacing is visually estimated as the average distance (within an area of approximately 0.3 × 0.3 m^2) between plants emerging from the soil. Grass cover with a given plant spacing can generally be recognized while walking over the slope, but requires periodic checks during the inspection round by directly observing the soil surface.

If there is doubt about the quality of the root mat, verification can be performed by extracting a sod sample from representative sections with similar appearance. This check may be necessary because above-ground plant parts do not always accurately reflect rooting density. Additionally, this inspection provides information on any irregularities in sod structure and soil composition, which should be recorded where relevant.

The vegetation characteristic of the three sod-quality categories is described as follows:

I. Closed Grass Sod:

Visually appears as a continuous grass cover dominated by grass blades, with a representative plant spacing of less than approximately 0.1 m, which may increase to 0.2 m over no more than 10% of the surface. No more than two shallow (less than 0.1 m) damages per square meter larger than 0.15 × 0.15 m^2 are permitted, and on average over 25 m^2, no more than five such holes.

II. Open Grass Sod:

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Visually appears as a continuous grass cover dominated by grass blades, with a representative plant spacing of less than approximately 0.1 m, which may increase to 0.25 m over no more than 25% of the surface. Damage limits are the same as for closed sod.

III. Fragmentary Sod:

Slope vegetation with more than 25% of the surface having plant spacing greater than 0.25 m, typically consisting of individual, isolated plants or clumps, possibly interspersed with smaller ground-cover plants that do not form a closed grass cover.

Management practices are also the dominant factor influencing the roughness of a grass-covered dike slope. A closed grass sod will not develop if the microrelief (within 0.1 m²) exceeds approximately 0.1 m. Therefore, a visually sufficiently smooth slope is a prerequisite for achieving a closed grass sod, in addition to its effects on hydraulic conditions.

i. **Grass Sod Quality Categories**

Sod Type	Vegetation Appearance	Plant Spacing	Damages
Closed Sod	Continuous vegetation cover dominated by leaves	Less than approx. 0.1 m, no more than 10% of the surface up to 0.2 m	- Shallow damages max. 0.10 × 0.15 m (L×W) - Max. 2 per m² and avg. max. 5 per 25 m² - Microrelief not greater than 0.1 m (surface)
Open Sod	Continuous cover dominated by leaves	Less than approx. 0.1 m, no more than 25% of the surface up to 0.25 m	- Shallow damages max. 0.10 × 0.15 m (L×W) - Max. 2 per m² and avg. max. 5 per 25 m²
Fragmentary Sod	Vegetation with only individual,	More than 25% of the	*(Not specified)*

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Sod Type	Vegetation Appearance	Plant Spacing	Damages
	isolated plants or clumps, possibly interspersed with smaller ground-cover plants that do not form a closed grass cover	surface with plant spacing greater than 0.25 m	

Simple Field Test for Assessing Sod Quality

If there is uncertainty about the grass sod quality based on visual inspection, the quality of the root mat—and thus the sod—can be easily verified by extracting a sod sample at a representative location within a section of the slope considered homogeneous.

Using a suitable spade, cut out a piece of sod approximately **0.25 × 0.30 m**, lifting it as a turf block with a thickness of **70–100 mm**. The rooting quality is classified as follows:

- **Dense root sod:**
  It requires some effort to pull apart a sod block (approx. 0.25 × 0.30 m²). A block from a densely rooted sod generally remains largely intact when detached from the subsoil with a spade.
- **Open root sod:**
  An intact sod block (approx. 0.25 × 0.30 m²) can only be extracted with considerable care using a spade (except in cases of moist, clayey soil compacted by foot traffic or during cutting).
- **Fragmentary root sod:**
  It is nearly impossible to extract an intact sod block (approx. 0.25 × 0.30 m²) from the soil surface (except in cases of moist, clayey soil compacted by foot traffic or during cutting).

ii. **Root Sod Quality Assessment**

Sod Type	Rooting (Visual)	Root Interruption	Sod Block
Closed Root Sod	Densely woven roots	Nowhere greater than 20 cm	- Largely intact when cut - Requires some effort to pull apart
Open Root Sod	Open rooting (widely woven)		- Sod can only be cut carefully

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]

Sod Type	Rooting (Visual)	Root Interruption	Sod Block
	with local compaction		- Sod falls apart when detached from subsoil - Block falls apart with little force
Fragmentary Root Sod	Fragmentary rooting (widely woven), only local compaction	Often absent over more than 20 cm	- Almost impossible to extract an intact sod block

The above serves as the guideline to be followed. In short, the target condition is a uniform slope with good grass coverage, where the plant spacing is less than 0.1 m. The guideline refers to grass blades; however, the focus is on the rooting of the sod. This rooting can also be supported by herbs in addition to grasses.

This project has received funding from the Interreg NWE programme 2021-2027
co-funded by the European Regional Development Fund under subsidy contract No [NWE0400542]