2022

A proposal for the new monitoringsplan

Reinders, Eline

Waterschap Vallei en Veluwe

1-1-2022

Inhoudsopgave

1. Introduction

Levees play an important role in blocking water and flood prevention. In general, a levee is a human-made weir made of sand, clay, and grass. Approximately, the first levees in the Netherlands date back to the 11th century but it is guessed that the first levees were already created during roman times. In many parts of the Netherlands, the sea level and ground level are at the same height. Originally farmers started to build levees to gain more land for livestock and to keep these lands dry. During the golden age, the Netherlands became very prosperous, and the population rapidly grew. Due to the success of the Netherlands and its increasing population, large-scale hydraulic engineering works such as land reclamation, polders, and large-scale peat extraction were organized. In the beginning, these hydraulic structures were made of wood but over time, levee builders started switching towards stony materials to strengthen levees (van der Veeken, et al., 2015).

The flood of 1953 showed the Netherlands the importance of the protection of levees. This flood was the biggest natural disaster in the Netherlands in the 20th century. A heavy North-western storm in a combination with spring tide caused large parts of the Netherlands to be underwater. In total 1.836 people and ten thousands animals died. At 150 different places, the levees broke due to a large amount of water. In South-West Netherlands, the levees were too low and too weak. In previous years, the regional water authorities had not maintained the levees enough which caused instability of the levees. Since the flood, strict measurement was made for primary flood defences. So was a Delta height created to protect the Netherlands against future storm surges (Rijkswaterstaat, sd).

So, the past learned in the Netherlands that the resilience of levees is important for uncertain future changes in coastal processes. Coastal resilience has morphological, ecological, and socio-economic components (Klein, et al., 1998). Resilience thinking is a part of natural hazards research, in the study of environmental and social impacts of climate change (Nicholls & Branson, 1998). A part of the morphological and ecological components is grass cover.

Grass cover has the function to offer the levees an erosion-resistant layer and encourage the development of nature. Figure 1 shows that the soil near the surface of the top layer has a high root density, is elastic under moist conditions, and is porous. The clay layer lying underneath is stiff and less permeable. The deeper parts of the layers in a levee are more sensitive to erosion than the upper layer. The reason that the upper layer is more resistant to erosion is because of the high root density and irregular bed structure, this layer is also called the sod (Technische Adviescommisie voor de waterkeringen, 1999).

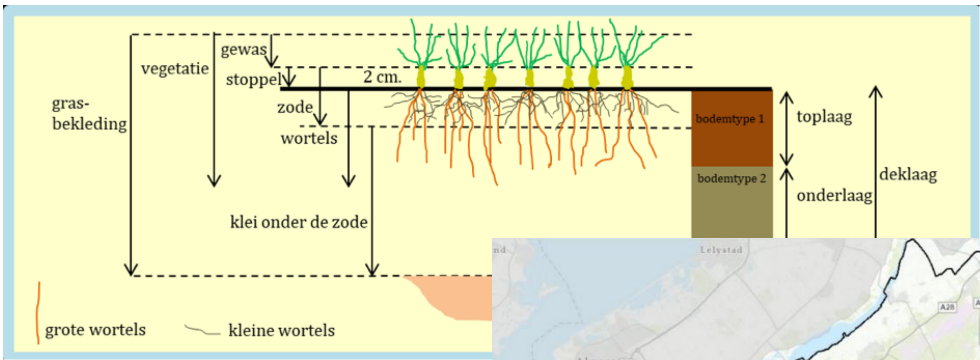

Figure 1, overview of how the coating on a dike is

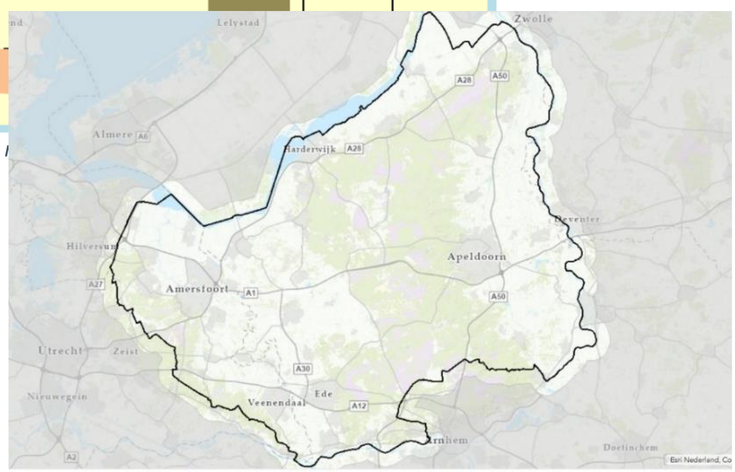

Figure 2 shows the area that is under the care of Waterschap Vallei en

Veluwe (WSVV). The area is the size of 245.644 ha and has a circumference of 273 km. The primary and regional flood defences are in total 248 km long (Waterschap Vallei en Veluwe, 2021). The levees in this area all need to be maintained, specifically grass cover. WSVV has a monitoring plan to check the quality of grass cover. However, over time climate conditions change introducing changes in the water levels, gale winds, wave action, peak precipitation, and temperature. Additionally, the vegetation types change, and new goals of the direction from Waterschap Vallei en Veluwe can influence the monitoring of the grass cover. To have a relevant monitoring plan, it needs to be updated every few years. To create a complete monitor plan several aspects need to be taken into consideration. The safety of the levee is the first aspect. The safety of the levee includes vegetation and stability. Secondly, nature is an aspect of the monitoring plan. Biodiversity, species richness, and maintenance all play an important role in the quality of the levee. The last aspect is the agricultural use of the levee.

In this research report, the three different aspects are analyzed, and how they can be applied in a monitoring plan. The direction team has prioritized biodiversity as a goal of the water authority. Therefore, biodiversity will be a factor included in the different aspects. For each aspect, desk research is performed, and interviews were executed. Each chapter ends with a summary.

1.1. Research questions

The main question of the research is:

What monitoring plan suffices as much as possible to all the different aspects; safety, nature, and agricultural use in order to create a high-quality grass cover on the levee?

In order to answer the main question, the sub-questions are:

1. *What lessons can be learned from the current monitoring plan regarding grass cover on levees?*
2. *What is the optimal safety situation on a levee?*
3. *How can nature thrive on a levee?*
4. *How can a levee be used for agricultural use?*
5. *What needs to be adjusted to the quality of the current monitoring plan in order to meet the different aspects analyzed in the previous research questions?*

Would it be useful for WSVV to share its database with the national database?

6. *How is the database from WSVV currently used?*
7. *How is the national database currently used?*
8. *How well does the database from WSVV fit with the national database standards?*
9. *Which adjustments would be needed to meet the national database standards*

10. *Which determination apps can be used to identify vegetation types?*

2. Methodology

This chapter presents the method applied during the research. The areas of study are explained. Furthermore, the research design and approach will be elaborated, and the research collection methods used during data collection are provided. Explanations will also provide how data was collected and analyzed.

2.1. Research design

During this research, a qualitative approach was used to answer the main research question ‘What monitoring plan suffices as much as possible to all the different aspects; safety, nature, and agricultural use in order to create a high-quality grass cover on the levee?’ A part of the qualitative approach was interviews with experts related to the area of water safety, flood defences, and ecology. The interviews were mostly held after the completion of the literature research to ask more in-depth questions. The selection of ‘experts’ to interview was based on the questions that arose during the literature review and suggestions from other experts. The literature review was designed based on the factors of safety, nature, and agricultural aspect. First scientific articles were analyzed to identify the aspects associated with safety, nature, and agricultural use and then elaborated. After the analysis of the scientific articles, questions were formed and linked to the appropriate expert. Summaries of the interviews can be found after the literature reviews.

2.2. Data collection

Before the interviews, a list of questions was prepared. These questions were based on findings in the literature or other questions needed to answer the research questions. During the interviews, notes were taken and asked more questions if needed. The questions asked during the interviews were open questions. The selection of experts to interview was based on questions associated with the literature review, or suggestions by colleagues/ other experts. The answers and thoughts of the experts are included in the summaries, conclusion, and final recommendation. The interviews were often also linked to another or new aspect that needed to be reviewed in the report. This approach was used to answer the main research question, but also to answer the questions on the national database from Wageningen University. Besides the interviews, various monitoring plans, grass tests, and ecology reports from other water authorities were used during the research. These reports were analyzed and summarized to compare them with the monitoring plan from Waterschap Vallei en Veluwe.

2.3. Data processing

After determining what aspects needed to be discussed in the research report, appropriate literature reports were searched to elaborate on them. The notes made during the interviews are summarized and inserted after the related literature review. Names of ‘experts’ are not mentioned in the report, however, the functions of the ‘experts’ can be found at the beginning of the summaries from the interviews.

3. Monitoring plans

To determine the quality of grass cover on a levee, a monitoring plan is used by water authorities. These plans differ per water authority, as each area requires different attention points. However, this does not mean the different water authorities cannot learn from each other. Overall a monitoring plan is based on visual aspects. To determine what the differences are between various water authorities, first the monitoring plan of WSVV is described. Then a short description of monitoring plans from Wetterskip Fryslãn, Waterschap Aa en Maas, Waterschap Rivierenland, and Waterschap Rijn en Ijssel. All the monitoring plans can be found in 'W:\BWS\Algemeen\Medewerkers\Stage\Eline Reinders'.

3.1. The current monitoring plan of WSVV

The monitoring plan of levee vegetation from Waterschap Vallei en Veluwe was developed in 2015, in order to establish a general measure standard for all of the embankments managed by the organization. The goal of the monitoring plan is to make a judgment about the quality of the grass cover as a measure for the safety of a levee and other functions, based on a grass test and the development of the turf. See Annex 1.1 for the official 2015-2022 monitoring plan of WSVV in Dutch.

The starting points of the monitoring plan are monitoring based on safety contribution, and maintenance consequences. The intensity of monitoring of the turf is depending on the importance of the grass cover for the levee and its current condition of it. This includes the safety interest of the turf is determined by the admissibility of the transshipment flow, the build-up of the levee, and the safety norm; The current quality of the turf determines how intensive the monitoring will be; lastly, local damage in grass cover due to high water or other threats from outside such as animal engraving requires input for emergency measures. The intensity of monitoring also depends on the secondary goals of grass cover on levees and the changes in management efforts when there is a lack of monitoring. This means that in many areas on levees there are also objectives regarding traffic, nature, and recreation that are also included in the maintenance method; the reached quality image of the turf is an assessment criterium under the maintenance contract on a part of the levee's; when there is insufficient maintenance the accessibility, inspectability, maintainability decreases resulting in needing more enforcement and regulating.

Besides the starting points, a new judgment method for the grass test is in development. The deterministic method to judge the strength of the turf is described in the voorschrift voor toetsen op veiligheid (VTV2006) and the WBI (Wettelijk Beoordelings Instrumentarium).

3.1.1. Monitoring area

The areas that are monitored are divided based on the starting points mentioned above. These are:

1. Primary flood defences
    - Annual assessment: cover percentage, species richness, unwanted species
    - 3-yearly assessment: rooting (grass test), and quality image
2. Regional flood defences
    - 2-yearly assessment: cover percentage, species richness, unwanted species
    - 4-yearly assessment: rooting (grass test), and quality image
3. Other flood defences
    - 3-yearly assessment: cover percentage, species richness, unwanted species
    - 6-yearly assessment: quality image
4. New turfs on flood defences

- Yearly two times an assessment on cover percentage and unwanted species

5. Inside slope or outside slope
    - In case of excess height and clay deck >0.8m thickness only judged in the outside slope on cover percentage, species richness, and rooting.

3.2. Monitoring plans of other water authorities

The water authorities that are contacted are Wetterskip Fryslãn, WDO Delta, Aa en Maas, Rijn en Ijssel, and Waterschap Limburg.

3.2.1. Aa en Maas

The monitoring plan of Aa en Maas is executed by Ecologica. The goal and motivation for this monitoring plan come from the inventory of 2008, in which goal species and types of species were counted. Additionally, the water authority wants to gain insight into the obtained effects of the implemented management. The methodology is determined by the results from 2008. The starting point for the monitoring plan come from Aa en Maas, and Brabantse Delta.

Between 2008 and 2016, Aa en Maas used the existing vegetation types to perform vegetation mapping. Over the entire section, the presence and abundance of attention- and problem species were determined. All these species were noted in the GPS. For some of these dike sections, the vegetation type was determined with the help of vegetation recordings. Alongside the vegetation recordings, the water authority placed as pilots six permanent quadrants (PQs). The PQs were placed on the outside slopes of the dikes where there were safety risks (problem species, short grass, empty spots in the cover). On the inner slope of the dike, the PQs were placed in locations with a low botanic value but that have the potential to grow in a more valuable vegetation type.

Since 2016, Aa en Maas determined the vegetation types per hectometer section to note distinctions of changes and shifts of the vegetation types. The vegetation typology is based on the VTV.

Aa en Maas conducts once every five years what the vegetation is on the dikes. Besides using vegetation recordings, the water authority placed more PQ locations in 2017. The attention points which were considered for placing the PQs locations were:

- Recently changed management technique
- Good comparable inside- and outside slopes
- Division over the different management techniques
- Division over the present vegetation types,
- Preference for outside slopes due to erosion resistance.

Due to the mapping of problem species requiring intensive work, as minimal as possible species are noted as a GPS-coordinate in a map. For Aa en Maas, these rare and problem species are Japanese Knotweed, giant hogweed, meadow chervil, and Rapunzel clock. The moment to map these problem species is at the period when most of these plant species are visible.

To test the erosion resistance of the dikes, the method from ‘Handreiking toetsen grasbekleding op Dijken t.b.v. het opstellen van het beheerdersoordel (BO) in de verlengde derde toetsronde’ is used. Inside this method, three different categories are applied. A closed grass sod, an open grass sod, and a fragmented grass sod.

3.2.2. Rivierenland

The monitoring plan of Rivierenland was executed by Natuurbalans, Cyril Liebrand. The goal of the monitoring plan is to determine the effects of phased mowing on the biodiversity of dikes. The biodiversity in the monitoring plan consists of vegetation composition and the population of invertebrates. The most important variables in the monitoring plan are the conditions of the location, current vegetation composition, and operational technique. Some of the preconditions are phased mowing has to be executed with the right technique and at the appropriate moments during the entire monitoring period. The entire process needs to be according to the standards of the water management requirements. Furthermore, locations are spread over the management area and are representative of the region. Another condition is that dike projects are not part of a dike improvement project in the coming five years. There are sufficient references to follow developments when there is no phased mowing applied. Lastly, bees can easily move, and the research needs to be finished in 2025.

Rivierenland will monitor 40 transect locations that have been included in earlier monitoring so that long-term developments can be followed. From the perspective of biodiversity, several species such as ground beetles, and spiders are included. To determine the quality of flora and fauna, 60 testing areas are set out. Based on vegetation types, and goal species from earlier research, data will be gathered.

A part of the research locations consists of reference locations so that the national trends can be followed. Due to climatic conditions, the composition of plant- and animal populations can be influenced. The reference locations have a management that is applied at the same time on both slopes of the dike. Due to phased mowing being applied at almost every location, the managers are asked if the dike on the reference locations double-sided during the second phase of the mowing period can be mowed.

Yearly, three times 40 transects of ~150 m2 are sampled. The locations of transects are located next to the testing locations. On these transects, for 30 minutes long all the bees and butterflies are counted and if needed taken for more research, all visualizations are digitalized. Depending on the monitoring design the transecten are performed three times a year. During the transects, the offer of flowers is also counted or guessed.

The vegetation composition is determined with PQs which have a size of 5x5 m.

3.2.3. Wetterskip Fryslãn

At the start of 2021, Wetterskip Fryslãn started focusing on the biodiversity of the grass covers in one of their pilot plots, to determine the starting points for 2022. Besides that, the water authority will look at the differences if artificial manure is added to half of the biodiversity plot. Additionally, this plot will be mowed two times, and then the crops will be shuffled. During this period, thistle control will continue. At some of the locations, Wetterskip Fryslãn uses PQs to determine the vegetation type. Wetterskip Fryslãn had no monitoring plan available but gave information on tensile tests and results from vegetation compositions.

3.2.4. Rijn en Ijssel

Similar to Wetterskip Fryslãn, Waterschap Rijn en Ijssel does not have a 'monitoring plan'. However, according to Hebert Jolink, within the theme inspections, several subjects related to dikes are highlighted in the section regarding grass cover. To monitor the quality of grass cover and its erosion resistance, Cyril Liebrand will go past every dike plot within three years to gather data on its condition. Based on the categories from VTV2006, the grass cover is judged. In general, the judgment is carried out in January or February, when the grass cover would be in its worst condition and when it has to hold the most water. The main priority for Waterschap Rijn en Ijssel is to realize an erosion-resistant grass cover. The method used by Cyril is the vegetation recordings (test sections). The results from the vegetation recordings are noted in GIS, so the water authority can act based on the data.

Currently, the water authority is focusing on increasing the biodiversity on the dikes. There is already an amended mowing schedule to preserve red-list species. However, insect populations are not a priority yet. To determine where the red-list species are located, Rijn en Ijssel developed a map layer in GIS. Most of the mowing work is executed by the water authority itself, and a small part is done by a contractor who is under the supervision of the water authority too. Based on the vegetation type, mowing time is determined. A H3/W3 is mowed in August to preserve rare plant species, however for the H2/W2 the map layer with red list species is used to determine the mowing time and which parts contain the rare plant species. Annex 1.2. shows the interview questions with answers.

3.2. Summary

Table 1 shows an overview of all the monitoring plans from the different water authorities. Not all water authorities have a monitoring plan for grass cover, but some water authorities have this in a different format.

The execution of the monitoring plan also differs for the water authorities. Some water authorities execute the monitoring themselves, whereas others let ecological bureaus execute the monitoring.

The similarity that can be found in all water authorities assessed is the focus on the erosion resistance of the dike. This is in all cases the main priority. The second priority similar to the water authorities is the increasing focus on plant diversity on dikes.

The focus on insects is not yet present in all water authorities. Some water authorities such as Waterschap Vallei en Veluwe are doing increasing research on insects in their areas. The only water authority fully including insects in their monitoring plan is Waterschap Rivierenland.

There are also differences between the vegetation measure methods of the water authorities. Some water authorities work with multiple methods, which are influenced by the location/ area, and type of vegetation.

Table 1, Overview of the water authorities

Water authorities	Monitoring plan	Execution	Focus	Plant diversity	Insects	Measure method
Waterschap Vallei en Veluwe	Yes	Intern/ Extern	Erosion	Yes	Yes	Representative field
Waterschap Aa en Maas	Yes	Extern	Erosion	Yes	No	PQs & Vegetation recording
Waterschap Rivierenland	Yes	Extern	Erosion	Yes	Yes	PQs
Wetterskip Fryslãn	Other	Intern	Erosion	Yes	No	PQs & Representative field
Waterschap Rijn en Ijssel	Other	Intern/ Extern	Erosion	Yes	No	Vegetation recordings

4. Safety on a levee

Grass cover plays an important role regarding the safety of a levee. There are several aspects of grass cover that contribute to the strength and stability of a dike. Based on a literature analysis and interviewing experts, these safety aspects are determined and how to assess these aspects.

4.1. Desk research

The grass cover has multiple functions. The primary function is to protect the dike against erosion from waves, currents, and water level differences. Figure 3 shows various failure mechanisms in a dike, some of these failure mechanisms such as erosion in the inside slope can be prevented by a solid grass cover. Besides this, ecology, landscape, agriculture, recreation, and gardens are also functions of grass cover. Soil type and its quality, cover percentage, vegetation type, and rooting all play a role in making a dike resistant to erosion.

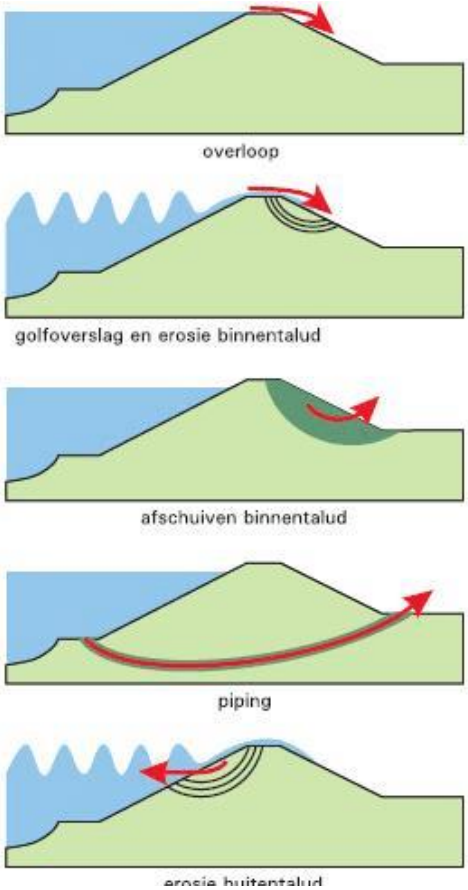

Figure 3, failure mechanisms that can lead to a levee break through.

4.1.1. Clay soil

The dikes under the management of WSVV are mostly clay soil. Clay is often firm, shape-retaining, and coherent even under the influence of water. However, the characteristics or circumstances of clay are different when used in a dike compared to when used in a horizontal field. Clay in a dike is often drier than when in a field and the differences in humidity and temperature are bigger, especially on steep slopes of a dike. Besides, clay is often available in the direct area where a new dike is built. One of the most important aspects of clay is the presence of soil structure. Larger pores can arise due to ruptures in the soil and biological activities in the ground. Ruptures can occur due to shrinking and swelling as a result due to dryness and wetness of clay. Biological activities concern the burrowing of animals (such as worms, insects, and moles) and rooting due to vegetation. Clay with a soil structure consists of an assembly of bigger and smaller, often angular chunks; also called soil aggregates. The bigger soil aggregates are often made up of smaller aggregates. The smallest aggregates can be found in and direct under the sod. In general, all dikes have soil structure in the first 1 to 2 meters of the outside of a dike. Soil structure can be a result of climate effects, weather influences, and activities from microorganisms. The effects of soil structure are in general dominating the characteristics of clay and under grass cover and will affect the functioning of a dike. The composition of clay consists of mass percentages of lutum, silt, and sand.

Clay consists of solid particles, water with diffused particles, and gasses. The fine particles that can be found in the solid particles and the water determine what characteristics clay

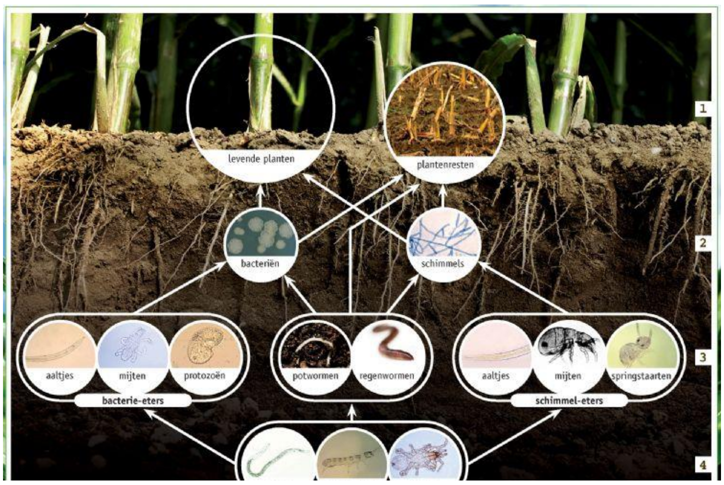

Figure 4, The soil fundamentals of clay has. The fine particles consist of various minerals such as clay minerals, quartz, various iron- and aluminum bindings, chalk, etc. Besides the minerals, there is also organic material present in the form of plant and animal organisms, fibers, active bacteria and fungi, and organic molecules. Some of the organisms present in clay soil can be seen in figure 4. Dutch clay has relatively many variations in the number of the different components that different characteristics exist, such as the difference between gray or blue clay, and older clay cover. The consistency of solid particles mostly depends on the mineralogical composition in the area where the clay is located and can change over time. The concerning minerals have an influence on the water-holding capacity of the soil and the strength of the bindings between the solid particles and therefore on the shape retention and erosion resistance. The nature and quantity of organic matter in clay change. Conversion by microorganisms reduces the quantity of organic matter. When air cannot reach the organic matter and when the temperature is less than 10° to 15°C, the conversion will be very low. With increasing air and temperatures, the conversion will be increased, causing organic matter in the upper soil to be broken down in a few years. The upper layer develops often organic matter as a result of roots, fungi, manure, and micro-organisms. Directly under the sod, a dynamic balance develops as a result of the supply and conversion of organic matter. These changes in organic matter can change bulk density, water-holding capacity, and deformation properties.

Water tension in clay above the phreatic plane is mostly negative relative to the atmospheric tension and can influence the changes in the water content of the soil as seen in figure 5. This negative water tension is usually indicated as suction voltage because clay can suck water from the phreatic plane as a result of negative water tension. Only by precipitation or infiltration of outside water, the water tension can reduce in the phreatic plane and make it locally positive. The suction voltage is decided by a dynamic balance between gravitational potential, the place height of the phreatic plane, and the form and size of the pores. Additionally, evaporation above the atmosphere also plays an important role. The rate of evaporation to the atmosphere is dependent on the relative air humidity. Due to the changes in suction voltage, there is a consistent transport of humidity through a dike body. In the winter, a dike becomes more humid even though there has been no precipitation. Whereas in the summer, the clay dries out due to humid transportation to the atmosphere. If the grass cover is wet, the water disappears through diffusion to the atmosphere and the relatively cold core of a dike. A declining water rate increases the strength of saturated clay because the clay particles will be pulled closer to each other. Besides, decreasing the water rate in a dike causes clay acts more like a plastic substance rather than a thick liquid.

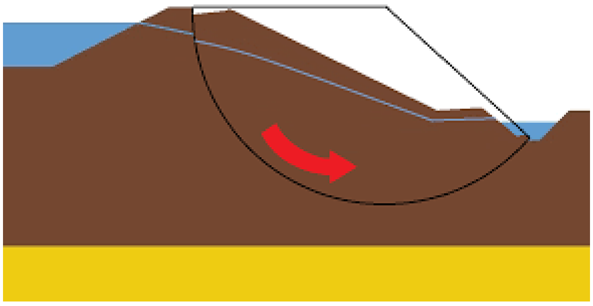

Figure 5, Phreatic line in a regional flood defense

In the form of erosion, various mechanisms need to be distinguished. A few examples are a dispersion of fine particles in water, carrying along of particles under the influence of water currents, and the forces from breaking waves as can be seen in figure 6. The way these mechanisms work on the soil depends on the load of water and the structure of the clay.

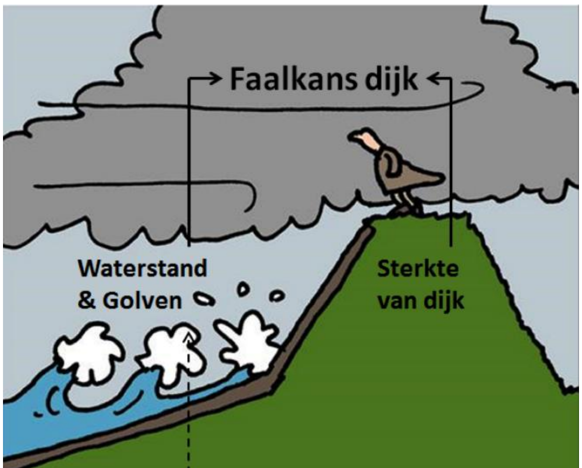

Figure 6, failure mechanism breaking waves against a dike

To give a good evaluation of clay, clay can be categorized into erosion resistance (1), mediocre erosion resistance (2), and little erosion resistance (3). These three categories are based on the Atterberg borders, which is the plasticity index that measures the differences in the water index between the yield point and rollout limit; and the sand index. Annex 2, figure 14 shows the specific demands of clay used in dikes. When inspecting, a few aspects need to be considered; the ground has to be sufficiently homogeneous considering sand and other coarse-grained inclusions, gross contaminants, and big local variation in characteristics of the clay soil. The visual judgment focuses on extreme coloring, strong different smells, homogeneity, contaminants (rubble, roots, and wood residue), sand index, chalk index, and consistency/ hardness (Van Ooijen, et al., 1996).

4.1.2. Sandy Soil

The physical properties of sandy soils (bulk density, porosity, aggregates) differ a lot due to the size and organization of the grains, type of clay, natural processes (biological activities) or human activities (tillage). Sandy soils often have high hydraulic conductivity, gas permeability, and organic carbon concentration. To maintain crop productivity of sandy soils, the use of inorganic and organic fertilizers, and irrigation are often required. Due to the specific physical properties of sandy soils, there are only a small number of sand dikes at Waterschap Vallei en Veluwe. In combination with a closed grass sod, sandy dikes can be erosion resistant. However, a bald spot in the sod can quickly cause a dangerous situation. Then again, sandy soil is preferred for growing herbs on a dike. Due to the low clay concentration, there are fewer nutrients in the soil. This makes it a more optimal environment for herbal plants (Huang & Hartemink, 2020).

4.2. Vegetation on a dike

The vegetation growing on dikes can diverge from monotone grass cover with a few plant species to strong and diverse vegetation with a lot of different grass species and herbs. The vegetation composition is determined by the substrate and maintenance. The differences in vegetation compositions are expressed in vegetation types, which show differences in coverage and rooting. With the vegetation type, the quality of the grass cover can be determined.

4.2.1. Developed vegetation types

According to the VTV2006, eight different vegetation types can occur on a dike which are presented with details in table 3, annex 2. Two important parameters to determine the quality of the grass sod are vegetation- and rooting density. Figure 7 shows that different plant species have different roots. In combination with these diverse roots, the strength of a dike can be increased. Well-developed vegetation types have optimal maintenance (conservation management). Bad or mediocre-developed vegetation types are able through optimal maintenance transform into better-developed vegetation types (Liebrand, 2022).

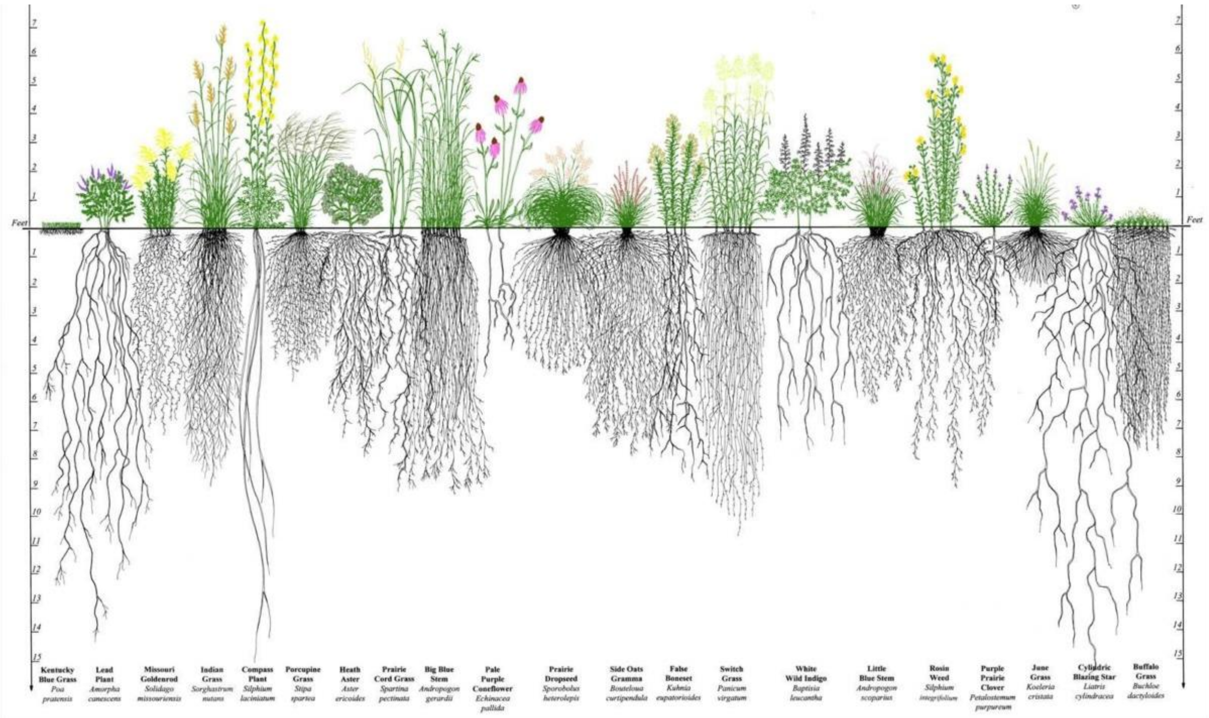

Figure 7, rooting diversity of various plants

4.2.2. Vegetation types and specie richness on soil types

The vegetation composition and types can be related to soil type, exposition, and the management of the slopes. The species richness and the specie composition are also related to the soil type, exposition, and management. Table 4 (see annex 2) shows that a 'good' vegetation type has the lowest chance to develop in heavy clay and the highest chance in sandy clay. Furthermore, the chance for a mediocre vegetation type to develop is highest in sandy clay and lowest in light clay. A bad vegetation type occurs more in heavy clay and less in sandy clay.

Table 5 (see annex 2) shows that the species richness is the highest on sandy clay and the lowest on heavy clay. Additionally, the rare threatened, and protected species percentages are bigger in sandy clay and the lowest in heavy clay. Lastly, the percentage of unwanted species is the highest in heavy clay and the lowest in sandy clay (Liebrand, 2022).

4.2.3. Vegetation types and maintenance

There are different types of maintenance to manage a vegetation on a dike. Table 6, annex 2 shows the relationship between maintenance and vegetation. The specie richness is the best when there is only mowed and disposed of one time per year and the lowest when there is extensively grazed by youngstock in combination with adding manure to the dike. However, mowing one time per year is only possible when there is a stable specie rich vegetation on the dike. The number of mowing initially depends on the biomass production on a dike. Furthermore, The average number of species is higher with mowing and disposing of one time per year compared to all the other maintenance techniques. The percentage of rare threatened and protected species is the lowest when youngstock (cows) graze on the dike in combination with manure and the highest when the dike is mowed one time in a year. Besides, the number of unwanted species is higher with extensive youngstock grazing with manure and the lowest when mowed once a year (Liebrand, 2022).

4.2.4. Problem species on a dike

On a dike, various plant species can be found that can cause a problem for safety on a dike. Some plants cause bald spots due to their shadow effect, other plants can have roots that lose up the soil, and others repress native plant species. One of these problem species visible in figure 9 is the giant Hogweed (*Heraclum mantegazzium)*. The giant Hogweed displaces native plant species, that give strength to the dike. This invasive species spread through germination from its seeds. Due to the giant hogweed producing yearly thousands of seeds, this plant spreads at a high rate. Another problem species is rapeseed (*Brassica Napus)* which is visible in figure 8. Rapeseed blooms early and is mowed when the seeds have been disposed of. In grass areas with an open cover, this plant species can spread easily. When rapeseed occurs in large quantities on a dike, light for other plants to grow will be taken causing bald spots in the grass cover. The plant species that is considered the most invasive species, is the Japanese Knotweed (*Fallopia japonica)* visible in figure 10. Once this plant is established, removing it is very complicated. Through its strong vigour, it displaces native plant species. The strong roots of the Japanese Knotweed can cause damage to the dike. Table 7 in annex 2 shows a list of all other problem species (Liebrand, 2022).

Figure 9, Giant Hogweed (Heraclum mantegazzium) (picture from WUR)

Figure 10, Japanese Knotweed (Fallopia Japonica) (picture from WUR)

Figure 8, rapeseed (Brassica Napus) (picture from Tilo Hauke)

4.2.5. Growth of vegetation

Another point that influences vegetation, is the growth of plants. Plants grow the quickest when there is sufficient sunlight, and an optimal temperature is present. When there is less sun present, the temperature is also often colder. Lower temperatures and less sun presence means less growth in plants. Photosynthesis whereby plants transform sun energy (CO_2) from the air into sugars, is less under cold temperatures. Normally these sugars are used for growth, but during colder periods these sugars are used as antifreeze, thus growth is on a stop.

The growing point of grass is a critical part, as it contains the stem cells a plant needs to grow new leaves. One-year-old species do not contain stem cells yet but are formed over the years. At the beginning of spring, the growing points become generative. This means that no new leaves will be developed but instead inflorescences with spikelets and flowers. The inflorescences are raised by stem elongation, which is in general a negative quality for grass cover. If the growing point is cut off during harvest, the plant is not able to grow back and blocks the tillage due to the working of growth substances. Dependent on the plant species is the inflorescence formation on typical demands posed regarding temperature and day length. Figure 11 shows a schematic image of inflorescence formation. Some plant- and grass species in colder climates are exposed to lower temperatures or shorter daylengths after flower initiation. These plant species will often show flowering culms the next year. However, in general, most plant- and grass species belong to moderate climates which means that to realize blooming, a certain minimal day length is required (Minderhoud, et al., 1989).

In young tissues of plants, there is evidence of higher plasticity is demonstrated in traits such as growth responses, and more NPQ activation and DNA repair. The older the plant is, the higher the loss of plasticity which decreases stress resilience but can be compensated for via the acquisition of physical or chemical defences (Rankenberg, et al., 2021). The degree of dry matter and nitrogen is positively correlated to the age of grass sod. Older grass sods are also correlated to deeper roots (van Eekeren & Bokhorst, 2010). Additionally, Faber et al (2012) found that the age of grass sod is positively related to earthworms that can be found on the soil.

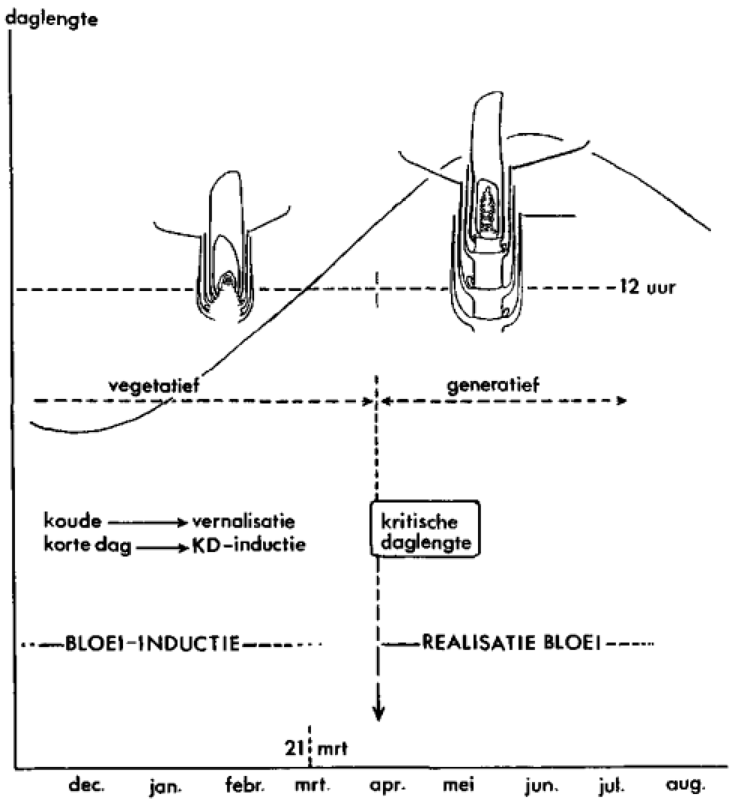

Figure 11, schematic representation of the process of inflorescence formation. The curve shows the course of the day's length. The critical day length can differ per species and genus

4.2.6. Rooting of a vegetation

The rooting of grass cover can be according to handreiking grasbekleding divided into three depth zones. Zone 1 is a closed uproot network, most of the terrain is around five cm deep, of which the first form between one year is present. Zone 2 is a rooting network that is visibly strong (diameter > 140 micrometers) with a density of 3-10 roots/ dm^2, mostly 0.2-0.4 m under the terrain surface and that has developed after one or two years. The last zone is a visibly good rooting network with a density of 0.5 till 2 roots/ dm^2, of which the zone is more than 1 m deep in a full-grown sod on clay. The first two zones can be found in the top layer. The transition between the zones is often gradual and is often associated with details of preventing sandy and clay layers, and inclusions beneath 0.3 m, with the location of some bigger cracks in the ground. The roots beneath 0.3 m prefer humid spots in the ground (for example near clay inclusions in sandy soil) when there is sufficient aeration (as long slits in clay) (handreiking grasbekleding, 2022).

Season also plays a role in the rooting of grass cover on a dike. The period with a high rooting density is between March and July (August). The period with a low rooting density is directly after the summer between September and February (Schaffers, et al., 2010). Adding manure to grass cover can negatively affect rooting. Light manure added in combination with maintenance can lead to a dense rooting network in the first five cm, however beneath the five cm, the density of rooting declines. This difference can also be seen when comparing sheep grazing and mowing maintenance. In meadow maintenance, the first soil layer (0-5 cm) has a higher number of roots but under the number is lower. Mowing maintenance results in more roots between the layer of 7-15 cm (Handreiking grasbekleding, 2022). Additionally, a good rooted soil contains diverse roots which are influenced by species diversity in the soil. Various grass- and herbal plants contain different rooting qualities. Besides, better rooting makes the grass cover less sensitive to drought (Handreiking grasbekleding, 2022).

4.2.7. Drought and vegetation

Originally a half-natural vegetation was present on dikes and plant species spontaneously grew on dikes. The established species were adapted to the surroundings of the dike and were relatively insensitive to drought due to the long roots. Currently, the dikes are sowed with a standard dike mixture of D1 or D2. These mixtures consist of species that produce a lot of mass upon and beneath the ground. Due to this, the roots grow not very long and do not root as deep. This makes the plants more sensitive to drought. Especially younger grass covers mainly dominated by Red fescue, Perennial ryegrass, and field grass coming from D1 and D2 mixtures are brown and seem to be dying. Although these mixtures do sprout and develop quickly, and often are combined with plant species with more beneficial characteristics that can take over in the long term. Older dikes with higher grass species seem to show more resistance to the drought.

The effect of drought stress in clay dikes are associated with the 'heaviness' of the top layer. A heavier top layer dries a lot out, which increases the roots dying out. Besides, a top layer with heavier clay is more sensitive to cracks. A lighter top layer dries on the surface quicker but protects the layer beneath. Clay with a mediocre weight is the best type of clay as the top layer. The roots stay intact and due to capillary working; the chance for water in the top layer stays the biggest. Besides the recovery on a mediocre top layer is the quickest due to the top layer taking up water quickly (Handreiking Grasbekleding, 2022).

4.2.8. Engravings/borrowings in vegetation

Another factor influencing concerns for the safety of a dike is animal borrowings and other engravings. Besides the damage to grass cover, these damages can influence failure mechanisms such as erosion resistance, sliding of slopes, and decreased waterproofness.

There are two divisions in engraving in dikes: engravings big and burrowing small. The risk of burrowed places is mostly erosion related. Around a burrowed place, bald spots can start developing. A big hole can cause the core to fill with water if the water level is high enough. This as a result can cause the dike to collapse. Large digging tracks can be from humans, beavers, muskrats, foxes, rabbits, etc. Human digging tracks can be related to building- or cable- and piping work, trampolines, ponds, digging by dogs (without a human interacting to stop), Users and owners not enabling actions to stop animal burrowers such as from dogs. Technical factors influencing engravings can be natural burrowers, no presence of excavation facilities, a levee too close to water, and bushes on/near the flood defence. Maintenance-related diggings can be loss of control of dug spots, insufficient mowing, or wrong design (Handreiking grasbekleding, 2022). Small digging tracks can be from mice, moles, or crayfish (Handreiking grasbekleding, 2022).

4.3. Interviews

To gain more perspective on what is found in the literature, interviews with experts are performed to discuss how the topic of the safety of levees is applied at Waterschap Vallei en Veluwe. First, the topic of failure mechanisms is discussed to find out which are the most common for the water authority. Secondly, the inclusion of soil in the monitoring plan is discussed.

4.3.1. Interview advisor assessment and management

In an interview with the advisor assessment and management, we discussed what failure mechanisms occur mostly in the area of Waterschap Vallei and Veluwe. These failure mechanisms are piping and macro stability. Piping is a failure mechanism where water with sand particles flush under the dike. On the other side of the dike, this water with sand particles comes up again. The channel underneath the dike which is created by washing away sand particles is called a pipe. This can weaken the dike and eventually can cause the dike to prolapse (Piping Control, 2022). When macro-stability occurs, the stability of 'the body of the dike' is not in balance. The strength of the soil decreases due to higher water tension in the underground and the core of the dike (Deltares, 2022). Besides a closed grass sod, no damages, and good rooting, the grass cover is not able to contribute more to prevent these failure mechanisms. Overall, there is a higher priority for safety on the outside slope of the dike. This is because the dikes from Waterschap Vallei and Veluwe are on the higher side. This makes the overtopping of waves on the inside slope a lower risk.

4.3.2. Interview planning

With an employee in planning that has knowledge in the department of soil. The topic of soil types and soil life were discussed. Heavy clay on a dike is the best for erosion resistance, however not ideal to grow a good vegetation on. In order the realize an erosion resistance dike, medium-heavy clay is the best option. The amount of soil life in a dike depends on the living environment. When there are lots of nutrients, light, water, and air there is possibly more soil life when these factors are not there. Soil life can indicate the robustness of a vegetation. When there is more soil life, vegetation can be considered healthier as it is better protected against diseases. Fully incorporating soil in a monitoring plan is probably not the best solution yet. Rather a plan of action can be created when something is wrong in the grass cover, so you would act problem-focused.

4.4. summary

Most of the dikes under the management of Waterschap Vallei en Veluwe consist of clay soil. Clay is a strong erosion-resistant soil that contains a lot of nutrients. This influences the type of vegetation growing on the dike. A desired vegetation type has the lowest chance to develop in heavy clay. If the water authority wants more specie richness and herbs growing on the dikes, the soil needs to be 'worn out'. Additionally, Soil structure has an influence on the characteristics of clay. The structure of soil is influenced by climate effects, weather influences, and activities from microorganisms. Besides the clay soil, the type of maintenance also influences the quality of the vegetation growing on a dike. Specie richness is usually the best when the vegetation is mowed and disposed of only once a year. When mowing, the period is also important. If the growing point of a young plant is cut off during harvest, the plant is not able to grow back. Inflorescence formation depends on temperature and day length.

The age of a grass sod can also relate to its vitality. The vitality can influence the response of grass cover to external and internal factors damaging the plants. Younger tissues have more plasticity, with more NPQ activation and DNA repair compared to older tissues. Although older tissues can be compensated by physical or chemical defences. The degree of dry matter, nitrogen, number of earthworms, and length of roots are also positively correlated to the age of grass sods.

5. Nature on a levee

Besides the role of safety, a levee can also hold ecological functions. Due to vegetation growing on top of the dike, the grass cover can function as a hiding space, nectar spot, breeding place, etc. Additionally, a dike full of flowers and herbs is pleasing to the eye. In this part, the function and importance of specie richness are discussed, furthermore, the animals that can be found on and in the dike are mentioned. Finishing off with native species on the dike and their relation to diversity and animals.

5.1. Desk research

Nature on a dike has a strong relation to safety on a dike. Vegetation on a levee protects against erosion from water flowing by. The more diverse the herbs and grasses are the more diverse root development in the upper layer. Diverse roots increase the strength in the upper layer, and therefore decrease erosion. Nature components consist of various factors such as the earlier mentioned plant diversity, but also insect diversity, species richness, and type of maintenance which considers the effects of mowing and sheep grazing.

5.1.1. Plant diversity on a levee

The diversity of plants can help a dike improve erosion resistance and deterioration. The stability of the dike slopes, which are covered with grassland, is important in case of heavy rainfall or when waves overtop the dike. Research from Nature Conservation and Plant Ecology group and the Soil Physics and Land Management Group at Wageningen University showed that a reduction of 75% in species numbers was associated with a doubling in erosion. This could be explained by the fact that a larger number of species means that if one species disappears, there is a greater chance it will be replaced by another species with an equivalent effect on erosion resistance. Additionally, above and under-the-ground biomasses were found to be greater where the species diversity was richer, and this too had a positive effect on erosion resistance (Berendse, et al., 2015).

Many studies showed a positive correlation between diversity and invasibility. An actual invasion of a new species, which is often non-native, is influenced by the number of propagules (a vegetative structure) entering a new environment, the characteristics of the new species, and the susceptibility of the environment. Invasibility is an emergent property of an environment and fluctuations of resources available. Disturbance, herbivory, and eutrophication (richness of nutrients in a body of water) were identified as key factors controlling invasibility. A hypothesis to explain why some communities are more susceptible to invasive species is: a plant community becomes more susceptible to invasion whenever there is an increase in the number of unused resources. The theory tests the assumption that an invading species must have access to light, nutrients, and water, and that a species will have greater success in invading a community if there is less intense competition for these resources from resident species. Heavy herbivory due to grazing or a pest outbreak, or a widespread disease among resident vegetation can also reduce resource uptake (Davis, et al., 2001). The utilization of resources (mainly light and nutrients) increases with diversity, which results in fewer resources available for invaders. This means that the invasibility decreases with increasing diversity. Local invasion resistance is to an extent determined by the presence of particular species. It can be emphasized that if these particular species are lost in grassland, the barrier for invasive species becomes smaller (van Ruijven, et al., 2003).

Up to 90% of global terrestrial plant production enters the dead organic matter pool, and decomposition and the sequestration (removing or separating a substance) of organic carbon in soils and sediments (matters that settle to the bottom) stand out as central components of a functioning ecosystem. Changes in biodiversity can alter the decomposition process. Leaf litter varies a lot in chemical composition. Some types of litter are rich in nutrients or carbon that can easily be utilized, whereas others are nutrient-poor or contain high concentrations of organic compounds. Secondary compounds in some litter types can be detrimental to microbial decomposers and detritivores consumers (cockroaches, termites, mosquitoes, etc.). Changes in the species composition and diversity of leaf litter thus profound changes in patterns and rates of leaf litter utilization and decomposition (Gessner, et al., 2010).

Soil respiration is an important pathway of the global carbon (C) cycle. It integrates root respiration and soil heterotrophic activity recycling soil carbon originating from litter, roots, and root exudates (the fluid that leaks out of vessels into nearby tissues). Soil respiration reflects the capacity of soil to support soil including crops, soil animals, and microorganisms. Several studies suggest both positive and neutral relations between plant diversity and soil respiration. There are several ways plant diversity may affect soil respiration. The most important pathway is through changes in C input into the soil. Experiments testing diversity in grassland species have shown that more diverse plant communities are often more productive, leading to increased C inputs. Although more diverse plant communities also showed higher nitrogen (N) use efficiency, in other words, the N concentration in the biomass produced decreased. The reduction of the N concentration of organic matter may negatively affect both autotrophic and heterotrophic components of soil respiration. Plants with lower leaf and root N concentrations generally show lower root respiration per unit of biomass. The shifts in productivity caused by changes in diversity can have a strong effect on soil respiration in grasslands (Dias, et al., 2010).

5.2. Animals on a levee

There are various animals on a dike. Animals can be placed on a dike for maintenance purposes such as sheep which are used to maintain the quality of grass cover, or small animals can be there for natural reasons such as a place for living, finding food, hiding, etc. In combination with the focus on plant diversity, a dike can offer a great space for all sorts of insects, invertebrates, and other microorganisms living in the soil. Although not all animal species are preferred on a dike, there are also animal species that are unwanted due to their negative effects on the safety of a dike.

5.2.1. Sheep Grazing

The grazing of sheep on sea-, lake-, river-, and canal dikes is a form of multi-functional agriculture. The maintenance is focused on the quality of the grass cover. In the Netherlands, the maintenance of grass cover on a dike is often executed by the use of sheep in combination with animal production (such as meat or wool). However, recent studies have also shown the negative effects of sheep grazing on dikes which are resulting in a decline in using sheep grazing for maintenance in the last decade. Sheep farmers often combine grazing on a dike in combination with the extraction of roughage. One of the downsides of grazing with sheep on a dike is the effect on macro homogeneity. Sheep cause walkways on a dike which in return can cause the formation of terracing on a dike. If the walkway is smaller than 20 cm, the safety and macro homogeneity of the dike are not affected that much and the dike is still considered adequate.

Figure 12, The use of sheep as form of maintenance on the Grebbedijk

An important part of performing maintenance with animals is preventing overgrazing and trampling during autumn and winter. High stocking density of sheep during the growing season in general does not cause any problems. Rather starting grazing too late or a low stocking density causes problems with the quality of the grass cover during the growing season. Due to the vegetation already being too long, the sheep cannot reach the plants which causes an increase in pol- and terrace formation. This formation can cause production losses and plants dying (Praktijkonderzoek Veehouderij Wageningen UR, 2002).

Using sheep for maintenance leads in general to a closed grass sod. However, there is often limited rooting (van Loon-Steensma & Huiskes, 2017). The reason that rooting is not preferable under sheep grazing is because sheep eat the green parts of a plant. By eating only the green parts, the source of energy production is removed which means the plant has to use reserve energy stored in the roots. The more intensive the grazing is, the lower the quality of the roots is. Although, when the grazing intensity is too low, vegetations with higher biomasses can develop, which eventually can turn into overgrowth. When using sheep, it is important to find a balance between the amount of biomass, intensity of grazing, and recovery time for the plant. Additionally, due to the grazing behavior of sheep, the vegetation structure over a dike can differ. This can be an excellent tool for realizing botanical objectives. Due to the sheep carrying seeds in their fur, well-developed plants (spines, thorns, toxic, or aromatic species) can spread over a dike. This is especially beneficial for pasture types if grazing happens at the right times. Furthermore, vegetation variation also has a favorable outcome for insects and small animals that need multiple environments in a small area (Handreiking grasbekleding, 2022).

Grazing does not immediately mean that there will be diverse plant species. On a levee, that is correctly maintained by sheep, more than 60 plant species can develop in an area of 25 m2. Extensive grazing has in general a specie richness of 26 species per 25 m2 which is relatively low. In the case of intensive grazing over a shorter period, plant species have more time to develop (when flowering and seed setting is also considered). This results in a species richness of 42 species per 25 m2. With alternating grazing, a mix of hay- and pasture species can develop, and the specie richness is comparable to when mowing only. This is around 46 species per 25 m2 (Handreiking Grasbekleding, 2022).

5.2.2. Insects on a dike

Since the last two decades, the number of insects and insect species has been declining. To increase the number of insects, water authorities have started applying flower-rich dikes. By planting herbs, and grasses that are used by insects, the living area for them can be increased. Besides, the dikes form a long line throughout the country which makes it easy for insects to move over them safely (Radboud Universiteit, 2020).

In the Netherlands, there are around 365 wild bee species, of which 79 can be found on dikes. Due to continuous levee maintenance, these bees can use the dike. The species richness and the red list species show that dike management does not have to be a negative influence on insects. By mowing and eliminating crops, depletion can occur. This increases the chance for specie- and flower richness.

If mowing is not done correctly, it can cause great damage to insect populations. A simple measurement to prevent this is adjusting the cutter bar of a mower to a higher position. Although mowing with an adjusted cutter bar can alter the vegetation type for a long time (faster regrowth of vegetation). By altering the microclimate, the competition ratios between plant species and insect species can change.

To increase biodiversity for insects, variation is important. Variation influences the flowering period, interfaces of vegetation, microclimate, and shelter- and hibernation possibilities. Phased mowing is then a real opportunity. Phased mowing can be applied to locations with relatively low biomass and high species richness. If this is not the case, it is better to reduce the biomass on the forehand so the specie richness can increase (Handreiking grasbekleding, 2022).

5.2.3. Burrowing animals

Dikes are present in various landscapes. In these landscapes, there are animals that can have a negative effect on the safety of a dike. In areas with a lot of open water, beavers and muskrats are present which cause serious damage to dikes (see figure 13). In dryer sand areas, there are rabbits, foxes, and badgers that cause problems. Recently, it has been determined that crayfish also have a negative impact on water defences because they dig holes under the waterline. The effects of animals digging can result in failure of the top layer in case of high water.

Figure 13, hole in a dike burrowed by a beaver

Most of the holes that are dug are not deep (0.1 m) and are made by mice, moles, and voles. Rabbits can be found in a dike when the clay layers are too small, or when there is not sufficient clay on a dike. These rabbit holes can go through the entire clay layer, into the sandy core of the dike. This can be dangerous when a higher current, waves, or wave overtopping is expected.

In areas with dense populations of digging animals, it is important to carry out extra controls. The longer the animal activity goes on, the higher the damage and costs. Some solutions to prevent beavers, but also badgers and foxes are: reinforcing the foreshore with rocks, protecting exterior and interior slopes by burying impermeable mesh, removal of willows (trees that attract beavers), ensuring sufficient flood-free areas where beavers and voles can go during high water, catching harmful animals, acting according to protocol when protected animal species are involved, and placing nesting boxes for birds of prey to combat mice infestations (Handreiking grasbekleding, 2022).

5.2.4. Soil life

Soil life is important for the growth and health of plants on the dike. Soil life includes all organisms that live in the topsoil (root area), such as microorganisms (bacteria, fungi, worms, larvae, and nematodes). The benefits of soil life are a positive effect on the plants growing on the dike, but also soil fertility, and soil structure. Worms and fungi make ‘hallways’ for roots to grow through, making roots grow longer. This also increases the availability of resources and the soil’s ability to hold water. Additionally, soil life breaks down dead plant material and turns it into new nutrients.

However, some species have a negative effect on the plants growing on top of the dike. The larvae from cranesbill mosquitos are one of those species. These larvae feed on the basis of a plant that they bite off and pull into the ground. In the period from August until September, the larvae mold into mosquitos and immediately lay new eggs. Another specie that has a negative effect on the vegetation cover, are Grubs. Grubs are larvae from various leaf blade beetles (May-, June-, and Rose beetles) that live underground and eat the roots of plants. Grubs have a long-life cycle that can last up to multiple years depending on the climate and what kind of specie they are. The temperature and cycle stadium also determines at what depth they live in the soil. The eggs are dropped off in the soil and preferably alongside long grasses where the top layer is relatively loose and not too dry. A humid autumn and soft winter are ideal for survival. When the larvae hedge, they make a hole in the top layer where they feed themselves with dead plant materials and roots.

The problem with these larvae is that during April/ May they start getting active and start eating the vegetation. Only in June/ July, the damage starts to be visible because the larvae have started in large numbers to cause damage. The larvae eat around the (grass)leaves or roots and with that cause bald spots where grass and plants die. This also causes the grass cover to come to lay loose and makes it more susceptible to plagues and diseases. It often can be found when there are a lot of larvae; birds, mice, moles, badgers, and wild boars will start rooting in the dike to eat the larvae. Causing even more damage (Handreiking grasbekleding, 2022).

5.2.5. Native Plant Species

In the Netherlands, around 80% of native plant species are pollinated by insects of which the bee is the main pollinator. Many insects living in the Netherlands rely on native growing species as they often cannot live off or do not like exotic plant species. Over centuries, insects and plant species have evolved together in a specific area. This means that even in a small country such as the Netherlands there is a difference between the native species growing in different locations. The disappearance of a native species can have big consequences for the insects living off it, even going as far as extinction. The extinction of an insect can then have consequences for birds, fish, and amphibians. Besides, native plant species are more resistant to climate changes, due to more variety in genetics. This makes these plant species more resilient and even better protected against heat, as these plant species originally came from South Europe. So, a way to increase bee populations can be done by sowing native plant seeds (Planten van hier, 2022). When planting new ‘native’ plants it is important to know where they come from. There can be a massive genetic difference in the same plant species when they come for example out of Romania. This can have a negative impact on the insect species living here that are not adapted to the specific genetics of the plant. If native species were to be included more on dikes in the Netherlands, the flow of water (where does the river or sea come from), and the wind is important. Therefore, it could still be okay to import ‘native’ plant seeds from Germany.

5.3. interviews

To gain more perspective on the literature findings, an interview with an ecologist was performed. The ecologist has experience with vegetation types and insect monitoring.

5.3.1. Interview with ecologist

In an interview with the ecologist from Waterschap Vallei en Veluwe, the topics of good vegetation type, soil life, sheep grazing, insects, and native autochthonous were discussed. The importance of a good vegetation type from an ecological point of view is specie richness. When there is a specie rich vegetation, it provides places for rare plant species and insects. Additionally, good vegetation is based on the stream valley flora in the Netherlands which often contains special plant species. Besides, a good vegetation type on a dike can function as a ‘green ribbon’ that offers ecological connection for plants and insects throughout the country. Some important dikes within Waterschap Vallei en Veluwe that hold important ecological functions are the Ijsseldijk, and the Grebbedijk.

The importance of realizing a H3 vegetation on dikes is the root variation that is associated with it. There are many benefits of having a good rooting network such as a higher erosion resistance, but also more biodiversity in soil life. Vegetation with one type of grass will see less diversity in its soil life compared to a vegetation with multiple types of grass and herbs. To have well-developed vegetation, first knowledge of diversity under the ground is required.

Similar to the literature, sheep grazing has more variation in structure, but the temporary impact is often big. Sheep first eat the tasty plants, which are often the flowers, and trample small plants and insects. The 'wearing out' of the soil is also difficult with sheep grazing as their manure gives back nutrients to the soil. Another influence of manure on vegetation can come from fields nearby. Wind and precipitation can carry ammonia that enters the dike. Therefore, it is important to keep mowing in order the keep the vegetation worn out.

There are ecological relations between native autochthonous plants and animals, and soil. There is more known about native autochthonous trees and bushes than plants. However, the use of these plants can be beneficial as other plant species are less adapted to the regional environment. If native autochthonous plants would be included in a seed mixture, it is better to apply it on a dike reinforcement. If it would be added to a H3 vegetation it could mess up the ecological system, there. It would be possible to add the native plant species in a H2 vegetation if it would encourage the development.

5.4. Summary

The diversity of plants can help improve erosion resistance of a dike, and soil respiration, and can contribute to higher under-the-ground biomasses. Additionally, the invasibility of unwanted species is lower when the diversity is higher. The presence of certain species in a location can also influence invasibility. It can be emphasized that if these particular species are lost in a grassland, the barrier for invasive species becomes smaller.

Sheep grazing on dikes is a form of multi-functional agriculture. The downsides of using sheep are the effects on macro homogeneity and the formation of walkways and terracing. However, in general, using sheep for maintenance leads to a closed grass sod with a dense rooting network in the first few cm of the soil layer. It is important to find a balance between the amount of biomass, intensity of grazing, and recovery time for the plant. Additionally, sheep grazing can be an useful tool for realizing botanical objectives. The intensity of sheep grazing influences the diversity of plants. Alternating grazing can lead to vegetation with 46 species per 25 m2.

Due to a decrease in insect numbers, water authorities have started making it a priority to use dikes to preserve them. Some ways to preserve insects are applying 'flower-rich dikes', phased mowing, and adjusting the cutter bar to a higher position. Insects also rely on the presence of native autochthonous plant species. Plants can adapt to the environmental conditions of a specific region, and alongside the local insects adapt. Therefore, there can be massive genetic differences in the same plant species coming from different regions.

Various animals can damage dikes. The effects of animal burrowing can result in failure of the top layer in case of high water or other failure mechanisms. In areas with dense populations of burrowing animals, it is important to carry out extra controls and apply preventive solutions.

A 'healthy' soil life can have positive effects on plant growth, soil fertility, and soil structure. The presence of worms and fungi can also have a positive effect on the growth of roots due to the creation of 'hallways'. Additionally, soil life can break down dead plant material and turn it into new nutrients. There are also unwanted soil species such as grubs and the larvae of cranesbill mosquitos.

6. Agriculture and levees

Besides the important factors of safety and nature, agricultural use on a dike also plays an important role. The dikes are multipurpose, there are bike lanes, walking routes, and roads on the top of the dike, but farmers also win roughage from the dikes. Therefore, there are a lot of parties that have different goals and purposes for the dike. In agriculture on a levee, the activities of the agriculture sector are explained as how it fits within the safety lines of the dike. Additionally, the other functions assigned by municipalities, or the direction team from Waterschap Vallei en Veluwe are too mentioned.

6.1. Desk research

Farmers often have a contract with a water authority to use the dike to win roughage. By maintaining the dike, mowing it, and following the demands of the water authority the farmers can 'use' the dike for a certain price. If it is just to win roughage and maintain it by mowing the dike. Other farmers maintain the dike by using sheep, and the roughage then is considered for the sheep. For each maintenance type, different rules are associated. However, agricultural use of the dike besides winning roughage is disappearing due to the risk of decreasing safety, and resistance in case of waves striking.

6.1.1. Sheep farming on dikes

Sheep farmers determine the use of a dike based on the dry matter (DM) production, lease conditions, and available area. The DM production is mainly determined by the N-output and growth pressure due to the drought between July and August. Grazing during winter is often not allowed (November till April). Based on the VTV2006 there are different demands for amended and intensive agricultural maintenance. Amended maintenance amounts to yearly a N-output of 70 kg per ha and intensive maintenance amounts to yearly a N-output of more than 70 kg per ha. The dikes are considered safe with this type of maintenance. Additionally, the sheep excrete manure over the dike. If the N-output decreases on a dike, the rooting increases. The best roots appear when there is zero fertilization. However, good roots can also occur when there is an N-output of 80 kg per ha on a highly loaded dike. Dikes with an average load can handle up to 150 kg N-output per ha. A high N-output results often in a closed grass sod, but not in a good rooting system. The dry matter production decreases when the N-output decreases, see table 8, annex 2.

To prevent overgrazing, there must be sufficient grassland area available. Table 9 in annex 2 shows the needed area for different dike situations per 100 ewes (female sheep) and the different N-outputs (kg/ha) which are 150(1), 80(2), and 0(3). The base of table 9 is that there is no roughage removed from the grass cover. The letter a indicates that there is permanent use, and the letter b indicates that the grazing occurs as much as possible but temporarily. Companies often combine situations a and b, even though temporary grazing is preferred.

In general, two maintenance systems can be applied with the use of sheep: grazing and standing pastures. In the case of grazing (turning) pastures, sheep are regularly moved to other parts of the dike. Standing pastures cover a large area of the dike over a longer period. If stand grazing is done correctly, the use of standing pastures can lead to a closed sod whereby grass production is higher under a drought period and the quality is improved compared to grazing pastures. When the sheep are fed extra, it can often occur that the bowl of feed is left in the same spot for a longer period of time. This causes bald spots in the grass. Besides, there are often larger damages to the grass sod in the location where the sheep are fed extra due to the sheep standing there more. If the feeding location is moved around regularly, these damages can be prevented (Praktijkonderzoek Veehouderij Wageningen UR, 2002).

6.1.2. Other usage of the dike

The use of the dike by other parties is arranged through usage agreements or maintenance agreements. Maintenance agreements are with contractors, rental agreements are for gardens (lawn) which are for private use, and rent- or lease agreements are used with sheep grazing.

Maintenance contracts are a form in which the tasks are clearly described for a contractor. The contractor can determine a price based on the maintenance agreement which the water authority has to pay. Rent agreements are short-term (often one year and at the end automatically extended) and the user can 'use' a piece of the dike can use under certain conditions. The user has to pay a small amount of money each year to be able to keep using this piece of land. Maintenance agreements are similar to lease agreements, but the conditions are stricter. Yearly Waterschap Vallei en Veluwe pays a small amount of money to the user for keeping up the maintenance. The maintenance money is often for remaining flood defences. Lease agreements are a lawfully protected form in which a piece of land from the water authority is used by a farmer for multiple years. This is mostly part of the business operations but there are certain conditions to guarantee water safety.

Supervision of users is different from supervision of contractors. Throughout the contract or agreement, there is continuous contact with the contractors to adjust certain things if needed. Supervision of users is usually done afterwards; it could be possible that damage already has occurred and need to be fixed. The quality will slowly decrease and because the water authority does not check everything regularly it could be that the decreased quality is noticed too late.

The benefits of a rent- or lease agreement for the user or farmer are related to winning roughage or garden space. For Waterschap Vallei en Veluwe, the benefits are less maintenance and steering work, but also less control of the quality.

6.2. Interviews

Waterschap Vallei en Veluwe is trying to limit sheep grazing on the dikes. To gain insight into how sheep grazing can be applied in the future and the factors that need to be kept in mind, interviews were performed with experts.

6.2.1. Expert 1.

The first interview was performed with … During this interview, the topic of sheep grazing was discussed, and how this is currently applied within the water authority.

There are some dike plots still managed with sheep within Waterschap Vallei en Veluwe. Besides the managed plots are there also private dike plots maintained with sheep? On the plots that are privately maintained, has Waterschap Vallei en Veluwe less control. Due to the risks associated with sheep management, in the future, it might be an idea to do more research and checks on the quality of these grass mats. It is possible to gather data on the rooting, intensity, type of plants, coverage, etc. from the privately owned dike plots, analyze it, and send the results back to the owners with advice on how to manage the plots in the future. This might help manage the quality of the private dike plots.

Besides from a sustainable and image point of view is sheep grazing a good opportunity. Sheep grazing is more circular and produces fewer emissions than when mowing the dikes.

6.2.2. Dike managers

The second and third interviews were performed with two dike managers from Waterschap Vallei en Veluwe. During these interviews, the use of the monitoring plan was discussed.

The first dike manager did not use the monitoring plan a lot. The monitoring plan was rather for the contractor, who also writes a monitoring plan alongside a piece of advice. Due to the dike manager not using the monitoring plan a lot, he did not miss information in it. However, the dike manager mentioned that he would like an app where the condition of dike plots can be tracked with pictures. So, the dike plot would not have to be in a bad condition to note the state of quality. When monitoring, the dike manager pays the most attention to erosion resistance, so a closed grass sod, and then to biodiversity. According to the dike manager is the concept of 'biodiversity' not always good for a dike because when there are many different plant species, unwanted species are also more likely to be present.

The second dike manager also does not use the monitoring plan. According to the dike manager, the choice of using the monitoring plan less is because most dike plots are already becoming a better quality. Additionally, some parts of his dike are new and then the priority is mostly to get grass growing and get them green. The biggest issue the dike manager has is getting rid of unwanted species. Information about unwanted species and how to get rid of them is also something that he would like to see back in the new monitoring plan. Mowing two times per year is not always enough according to the dike manager as some plants are still able to seed before these moments. When monitoring, the dike manager pays the most attention to closed grass sod and the rooting network.

The second dike manager also has plots that are managed with sheep. According to the dike manager is sheep grazing sometimes the only solution as the mower is not applicable for all dike plots. The mower cannot mow a dike when it is too steep, or when there is a biking lane on top of it. The dike manager mentioned that with sheep grazing, the grass sod becomes more closed compared to mowing the grass sod. The best way to apply sheep grazing is with 100 sheep quickly over the dike. Only when it rains, do extra checks need to be done for damaged spots.

6.3. Summary

For sheep farmers, the use of a dike is determined by the DM production, lease conditions, and available area. Based on the VTV2006 there are different demands for amended and intensive agricultural maintenance. Amended maintenance amounts to a yearly output of 70 kg per ha and intensive maintenance amounts to a yearly N-output of more than 70 kg per ha. If the N-output from sheep manure decreases on a dike, the rooting increases. Preferably, temporary sheep grazing is applied on a sufficient grassland area. If done correctly, the use of standing pastures can lead to a closed sod whereby grass production is higher under drought periods and the quality is improved compared to grazing pasture.

Other uses of the dike besides agricultural use are maintenance agreements with contractors, rental agreements for gardens (lawns), and rent-or-lease agreements. Depending on the type of agreement a price is determined which is paid or received by Waterschap Vallei en Veluwe.

7. The national Database

Almost all water authorities collect data on the grass sods on dikes to gain perspective on their safety status. Each water authority does the collection of data differently, as it is also applied differently. However, most times this data on the grass sods is kept by the water authorities themselves to make an assessment for the coming years, but then not further used. Some scientists from Wageningen University started a national vegetation database to collect data on vegetation in Dutch landscapes. On the website from the database, people can select an area and see what type of plants grow there. External parties are able to share their collected data on this website. The purpose of this chapter is to see whether it would be beneficial for Waterschap Vallei en Veluwe to share their collected data on the vegetation growing on dikes with the national database. First, the current database used at Waterschap Vallei en Veluwe will be explained, then the national database, and lastly a summary with a conclusion and recommendation.

7.1. Database WSVV

The monitoring plan for the grass sods on a dike also needs to be executed. Part of the inspections is done by the area managers, whereas the other parts are done externally. The name for the collection of the data is also called 'the grass test'. The goal of the grass test is to gain information on the condition of the grass sod so that an impression can be given of the actual safety of the dike and other functions. Concretely the grass test concerns measuring the cohesion between the top layer and root penetration of the sod, and a recording of the vegetation to assess whether the requested quality has been achieved. The activities regarding the grass test concern:

- Execution of the grass test according to the WBI2017
- Determining the quality of the sod (if possible supplemented with a test of the degree of root penetration)
- Inventory of vegetation type
- Coverage

During the execution of the grass test according to the WBI2017, the three quality classes are used to assess the sod and the coverage. The three quality classes are fragmented, open, and closed. Dike plots need to qualify as at least a classification of 'open'. The classification 'open' translates in general to a vegetation type H2 with a coverage of at least 70%.

7.2. National database

To gain insight into the national vegetation database (LVD), a meeting with Mr. van Rooijen and Mrs Grashof-Bokdam was planned. During this meeting, the purpose, users, benefits, and measurement methods of the LVD were discussed.

The LVD is a data file on plant growth in the Netherlands. The archive consists of around 650.000 recent and historical vegetation descriptions (or vegetation recordings). The data available covers 65 years of vegetation field research and covers a whole variety of vegetation types. The vegetation types include aquatic and terrestrial vegetation, well-developed plant communities, but also depleted plant communities. The observations concern cultured landscapes, half-natural, and natural landscapes. Additionally, the LVD can visualize the spreading of plant communities.

There are all sorts of parties working with the LVD. Some of these are provinces for the mapping of nature areas, Staatsbosbeheer, Natuurmonumenten, and Defensie, but also parties with input from other databases. There are not yet water authorities that use the database, however, there are ecological bureaus that share the data gathered in the area from certain water authorities. All the recordings can be seen on the website. It is also possible to request certain data with the approval of the owner of the data.

The main benefits of working with the LVD are the deeper analysis of the type of vegetation (structure and functions of a habitat type), and environmental indications such as nitrogen uptake. Additionally, if used with a permanent squared method, the development of vegetation can be tracked. There is not a specific measurement method required, however, most times the Braun-Blanquet is applied. The measurement methods can differ, but certain aspects need to be included in order to apply them in the LVD. It is important to include the size of the measurement plot, but it also needs to be fully covered.

7.3. Summary

If Waterschap Vallei en Veluwe wants to share its data with the LVD, extra data needs to be collected. Currently, the water authority looks at the coverage of the grass sod, vegetation type, and the overall quality of the sod. This is not enough to share with the national database. The size from which the data is collected needs to be mentioned, as all the specific plant species growing in the test plot. Table 2 shows a short overview of the requirements from the LVD, and to which Waterschap Vallei en Veluwe already suffices.

There are many benefits to working with the LVD, especially as the organization tries to grow more aware of its footprint. A deeper analysis of vegetation can be made alongside environmental indications. In combination with a permanent squared method, the development of vegetation also can be tracked. Besides, with the help of the LVD, certain research aspects that the water authority normally would not do can be performed.

If the water authority would share their data, the current grass test would have to expand and more data needs to be collected. This needs convincing of the external party involved and more time in data collection.

Table 2, an overview of the most important requirements from the LVD and what is already done at Waterschap Vallei en Veluwe

Requirements LVD	Waterschap Vallei en Veluwe
Mentioning size	
Closed sod	X
Type of vegetation	X
Plant species	

8. Conclusion

The main purpose of this research was to find out what monitoring plan suffices as much as possible to all the different aspects; safety, nature, and agricultural use in order to create a high-quality grass cover on a levee that can be used in the coming years. The most important factor associated with all these terms is the preservation of biodiversity.

After comparing different monitoring plans from other water authorities with the monitoring plan from Waterschap Vallei en Veluwe the main difference was the specificity of the plans. Some of the monitoring plans clearly state what type of measurement method is used and the number of plots. Some of the water authorities do not have a 'monitoring plan' but describe it in another form. The measurement description from Waterschap Vallei en Veluwe was small and unclear what type of measurement method is applied. Additionally, some monitoring plans contain a research question with sub-questions. It is noticeable that these monitoring plans contain more focus on what the goals and objectives are and how the 'desired' situation will be achieved with all its limitations and costs.

The optimal safety situation on a levee should be focused on H3 vegetation where possible but in general a closed (or at least open) grass sod with a rooting deeper than 5 cm. Not all locations can grow H3 vegetation due to the placement of the dike, soil type, and type of maintenance. Therefore, to ensure a safe dike, closed grass sod should be the biggest priority.

As biodiversity is one of the priorities of Waterschap Vallei en Veluwe, the concept is intertwined with maintenance on a dike. The importance of biodiversity is related to increased erosion resistance, and the positive influence on insect populations. Biodiversity is rather a big term, therefore in the monitoring plan this is more focused on specie richness, and insects. Phased mowing is important to preserve insects and red-list plant species and should be applied where possible. Additionally continuing with research on native autochthonous plant species could also help contribute to preserving local insect species. The category 'insects' is still unclear and whether soil life is included in this category. Out of the literature review and interviews came that soil life does have an impact on the growth of the vegetation and the quality of the soil.

For now, sheep grazing cannot be ruled out immediately as a type of dike maintenance. Besides the privately used plots, there are also dike plots that are hard to manage through mowing. On the plots hard to manage, sheep grazing is at times the only solution. To ensure the safety of the dike, the quality should be checked regularly for quality and other damages as a result of sheep grazing. For the private plots clear agreements should be made about how it should be managed and what type of sheep grazing is the best for the dike plot.

So, to conclude, a monitoring plan that suffices to the aspects of safety, nature, and agricultural use to create a high-quality grass cover on a levee is a monitoring plan that focuses on H3 vegetation as the main priority of a closed grass cover and good rooting network. Continuing with phased mowing could help preserve rare plant species and habitat space for insects. Sheep grazing should only be allowed as the main method where it is not possible to apply mowing as maintenance in combination with an appropriate contract.

9. Recommendation

The recommendation based on the conclusion is to start the new monitoring plan with a research question to give more structure to the new monitoring plan. This can also help focus on other objectives such as including specie richness, insects, and overall biodiversity. Furthermore, the focus regarding a safe grass sod should be on a closed (or at least open) grass sod, and then where possible a H3 vegetation. Focusing first on safety and then specie richness can help maintain safety but also increase the focus on biodiversity-related objectives. Furthermore, I would not yet advise to include soil life fully into biodiversity-related objectives, however, I would advise to perform more research regarding the effects of soil life on vegetations. Phased mowing can help realize goals related to insect preservation, and preserving red list and other rare species. Therefore, I would advise to continue with this maintenance technique. Phased mowing is not possible at every location, which means maintenance will be performed with sheep grazing. In the cases of sheep grazing, appropriate contracts need to be drafted with the owner of the sheep to ensure the safety and other goals of Waterschap Vallei en Veluwe. Additionally, 'pressure grazing' is then the best method to be applied with sheep. Two grazing periods in the summer, and between those grazing periods, recovery time for the plants.

Advise on other possible research topics will be related to soil life and native autochthonous plant species. An example of a research question could be the differences in soil life between a H1 vegetation and a H3 vegetation. It would also be an idea to make an inventory of the native autochthonous plant species in the operation area from Waterschap Vallei en Veluwe.

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Annex 1: monitoring plans water authorities

In annex 2, the monitoring plans that are used in this report are visible.

1.1. Monitoring plan Waterschap Vallei en Veluwe

Uitgangspunten

1. *Het monitoren is gebaseerd op 1) veiligheidsbijdrage (gebaseerd op risicoprofiel dijk) en op 2) beheersgevolgen:*
   - Ad 1: De intensiteit van monitoring hangt af van het belang van de grasmat voor de dijk en hoe de huidige toestand (uitgangspositie) is:
     - Het veiligheidsbelang van de grasmat wordt bepaald door het toelaatbaar overslagdebiet, de opbouw van de dijk en de veiligheidsnorm.
     - De reeds aanwezige kwaliteit van de grasmat bepaalt hoe intensief de monitoring is; Bij hoge bestaande kwaliteit, hoef je minder vaak te controleren.
     - Grasbekleding draagt volgens de studie VNK slechts beperkt bij aan de faalkans van de dijkring. Lokale schade die bij hoogwater ontstaat vraagt wel veel inzet voor noodmaatregelen ten koste van dijkbewaking.
   - Ad 2: De intensiteit van monitoring hangt ook af van de nevendoelen van de dijkbekleding en de verandering van beheersinspanning in het geval monitoring uitblijft:
     - Op veel dijken gelden naast de veiligheidsdoelstelling ook doelstellingen op gebied van verkeer, natuur en recreatie, waarop de onderhoudsmethode is aangepast en een hoger kwaliteitsbeeld geldt.
     - Het bereikte kwaliteitsbeeld van de grasmat is beoordelingscriterium bij de onderhoudscontracten op een deel van de dijken.
     - Bij onvoldoende onderhoud neemt de toegankelijkheid, inspecteerbaarheid en onderhoudbaarheid af, zodat meer handhaving en regulering nodig is.
2. *De beoordelingsmethode voor grastoets is in ontwikkeling.*
   - De deterministische methode voor bepaling van de sterkte van de grasmat is beschreven in het Voorschrift voor Toetsen op Veiligheid (VTV2006) en verandert. Voor de vierde landelijke veiligheidstoets (2011-2022) is in het Wettelijk Toets Instrument de methode aangepast en versimpelt. De breektoets gericht op de graspol is minder arbeidsintensief en vervangt de steekmethode die gericht is op de doorworteling. De bedekkingsgraad van de grasmat zal het doorslaggevend criterium worden en vraagt een globalere aanpak.
   - Inzichten in de erosiebestendigheid tegen golfoverslag zullen tot andere eisen aan de grasbekleding leiden. Waar relevant vertalen we dit in aanpassing van de benodigde veiligheid in het kwaliteitsbeeld.

- De kwaliteit van de bekleding is onderdeel van de zorgtaak van het waterschap, waarover we verantwoording afleggen aan het bestuur. Hieruit volgen ook de rapportages aan de ILT en de Provincies.

opgave

Het areaal dat we monitoren is ingedeeld op basis van bovengenoemde uitgangspunten.

A. Primaire waterkeringen
   - jaarlijks beoordeling bedekking, soortenrijkdom en ongewenste soorten;
   - 3-jaarlijks beoordeling doorworteling (grastoets) en behalen kwaliteitsbeeld.

B. Regionale waterkeringen
   - 2-jaarlijks beoordeling bedekking, soortenrijkdom en ongewenste soorten;
   - 4 jaarlijks beoordeling doorworteling en behalen kwaliteitsbeeld.

C. Overige waterkeringen
   - 3 jaarlijks beoordeling bedekking, soortenrijkdom en ongewenste soorten;
   - 6 jaarlijks beoordelen behalen kwaliteitsbeeld.

D. Nieuwe grasmatten op waterkeringen
   - jaarlijks 2 maal beoordeling bedekking en ongewenste soorten.

E. Binnentalud of buitentalud
   - Bij overhoogte en kleidek >0,8m dikte wordt alleen buitentalud beoordeeld op bedekking, soortenrijkdom en doorworteling.

Organisatie

De monitoring gebeurt cyclisch en richt zich op twee facetten, namelijk de kwaliteit van de grasmat en de kwaliteit van het onderhoud. Dit betekent dat we 5 activiteiten uitvoeren, die verschillen in frequentie en benodigde expertise.

Methode

Het oordeel over de kwaliteit grasbekleding bestaat uit 3 activiteiten:

1. bepalen bedekking van de grasmat per oppervlak;
2. beoordelen soortenrijkdom en ongewenste soorten;
3. meten samenhang toplaag en doorworteling graszode.

Het oordeel over kwaliteit van het uitgevoerde onderhoud bestaat uit 2 activiteiten:

4. vaststellen of het onderhoud conform contract is uitgevoerd;
5. beoordelen of het gevraagde kwaliteitsbeeld is bereikt.

werkzaamheden

Activiteiten 1, 2 en 4 zijn globaal van karakter en door automatisering van de registratie eenvoudig uit te voeren door gebiedsbeheerders van afdeling *BWS*:

- bedekking en soortenrijkdom bepalen: 25km per dag, inclusief rapportage, globaal iedere 1,5km een onderzoekslocatie op binnen en buitentalud;
- beoordeling onderhoud op basis van contracten: maximaal 50km/dag, inclusief verwerking en rapportage.

Activiteiten 3 en 5 vragen specialistische kennis en vraagt onafhankelijkheid bij de beoordeling van het uitgevoerd onderhoud. De afdeling *Planvorming* gebruikt eigen (ecologische) expertise of die van andere waterschappen of huurt capaciteit in:

- beoordeling samenhang en doorworteling: 10 proeven per dag, met rapportage;
- graslandtypering en opname vegetatie tbv kwaliteitsbeeld: 30 locaties per dag op een afstand van maximaal 20km/dag nabij de locaties van de grastoets.

In de tabel staat met drie gradaties aangegeven hoe intensief en in welk jaar de dijktrajecten gemonitord worden. Die is ingedeeld in grastoetslocaties en vegetatie beoordelingslocaties, die gebaseerd zijn op verschillende aspecten:

- de toetsscores van de monitoring 2008-2014;
- de nieuwe dijktrajecten (intensief 2 maal per jaar beoordelen);

- verschil in status (Primair intensiever monitoren dan Overige waterkering);
- de benodigde monitoring van eigen onderhoudswerk.

Annex 1.2. Interview Waterschap Rijn en Ijssel

1. **Jullie hebben geen monitoringsplan, waar kijken jullie naar om de gras mat te kunnen beoordelen?**

Cyril Liebrand, gaat binnen drie jaar op alle dijken en elk jaar pakt hij een derde deel van de jaar en kijkt naar binnen en buiten talud (bedekking kwaliteit). Om de kwaliteit van de wortels te toetsen wordt er een plag gestoken. Als er geen gesloten gras mat is maar wel gesloten wortel zode wordt het gezien als een gesloten gras mat. De controle wordt gedaan als de dijk op zijn slechts is, dus rond januari/ februari. Maar over het algemeen wordt er eerst bekeken of de grasmat erosie bestendig is.

2. **Wat is voor jullie de reden dat er geen monitoringsplan is?**

Hoe de grasmat wordt beoordeel is onderdeel van thema inspecties, waar bepaalde onderverdelingen van dijken uitgelicht worden (zoals de grasmat).

3. **Kijken jullie nog naar andere factoren gerelateerd aan de grasmat zoals biodiversiteit of insecten?**

Rijn en IJsel kijkt verder nog naar de ontwikkeling van soortenrijke vegetaties, hieraan worden de maai tijdstippen aangepast. Volgend jaar begint een nieuw vegetatie onderzoek. Jaarlijks wordt dan een derde van areaal onderzocht. Met insecten wordt verder nog niks mee gedaan. Om de biodiversiteit te controleren, zorgt het waterschap dat het maai regiem goed wordt gedaan.

4. **Hebben jullie een lijst met de waargenomen rode lijst soorten?**

De rode lijsten soorten worden bekeken/ gecheckt op de maaikaart, er is een map laag met de rode lijst soorten. Deze kaart is ingeladen in GIS. Op deze kaart zijn er cirkels zichtbaar om de rode lijsten, zodat er in de praktijk rekening houden.

5. **Wat is de meet methode die jullie gebruiken om de vegetatie vast te leggen?**

Maaien en afvoeren, om zo de grasmat te verschralen. In sommige gevallen wordt de biomassa laten liggen, zodat er organische stoffen blijven liggen. Rijn en IJssel heeft een eigen onderhoudt team die een groot deel zelf maait, de rest wordt gemaaid door een aannemer maar die is onder toezicht van het waterschap zelf. H3 vegetaties worden gemaaid in Augustus (dus laat, want dan zijn de rode lijst soorten al uitgebloeid), dus dan hoeft er geen rekening gehouden worden met rode lijst soorten. Als er een H2 vegetatie type is, wordt er wel goed bekeken wanneer het juiste maai moment is. Verder werk Cyril met proefvakken, om vegetatie typen te bepalen. De Kwaliteit van de vegetaties worden ook met de vakken, genoteerd op een app (GIS).

Annex 2: demands for clay soil in dikes

Erosion resistance category	**Limit values for classification tests (all numbers are mass percentages towards the dry mass)** **W_l = yield point** **I_P = plasticity index** **I_P = 0.73*(W_l -20) is the so-called A-line in a plasticity diagram.**	
1. Erosion-resistant clay	W_l and I_P and Sand index	> 45 > 0.73*(W_l -20) < 40
2. Mediocre erosion-resistant clay	W_l and I_P and Sand index	< 45 > 18 < 40
3. Little erosion-resistant clay	W_l and I_P and Sand index	< 0.73*(W_l -20) < 18 > 40

Figure 14, an overview of the demands for clay used in dikes

For all clay in dikes applies:

Organic matter index < 5

Salt index (NaCl g/l soil moisture) < 4

Water index by processes: Coatings: $I_c \geq 0.75$

Core: $I_c \geq 0.60$

And also:

Chalk index (HCl mass loss): <25

No extreme coloring when digging or drying

No different strong smell
(rotting eggs, oil- coal like)

Table 3, Possible vegetation types on dikes including cluster, vegetation type and description, an indication of maintenance, coverage, rooting and quality of the grass sod

Cluster	Vegtype	Description	Maintenance	Coverage	Rooting	Quality grass cover
Pioneer	P	Pioneer vegetation	D	Mediocre-bad	Bad	bad
Meadow	W1	Meadow- ryegrass	D/C	Good	Bad	bad
	W2	Low-species comb grass	B	Good	Mediocre	Mediocre
	W3	Species-rich comb grass	A	average	Good	Good
Roughness	Ru	Rough hay land	D	Very bad	Very bad	Very bad
Hay land	H1	Low-species hay land	D	Bad	Bad	Bad
	H2	Average-species hay land	B	Mediocre	Mediocre	Mediocre
	H3	Species-rich hay land	A	Average	Good	Good

Table 4, the relation between soil type and vegetation type expressed in chances

Soil type	Lutum-%	Chance for good vegetation type-%	Chance for mediocre vegetation type-%	Chance for bad vegetation type-%
Sandy clay	<8	28	68	4
Light clay	24-35	24	53	23
Heavy clay	>50	6	60	34

Table 5, the relation between soil type and species richness; the average part of rare species, threatened, and protected species; and the average part of unwanted species

Soil type	Lutum-%	Specie richness	Rare species-%	Red list species-%	Protected species-%	Unwanted species-%
Sandy clay	<8	38.4	5.91	3.33	0.78	1.26
Light clay	24-35	34.3	2.43	2.83	0.10	2.45
Heavy Clay	>50	29.2	1.20	0.94	0.01	3.00

Table 6, the relationship between maintenance and specie richness; the average part of rare species, threatened, and protected species; and the average part of unwanted species

Maintenance	Description	Specie richness	Rare species-%	Red list species-%	Protected species-%	Unwanted species-%
2xM+a	Two times mowing per year	35.1	2.59	2.57	0.18	2.15
1xM+a-lt	One-time mowing per year	53.6	15.73	7.68	2.80	0.38
2xWs	Switch grazing with sheep	31.2	1.53	2.64	0.07	2.74
Ws-int	Short, intensive grazing with sheep	32.6	1.45	0.78	0.00	3.40
Ws-ext	Continuous, extensive grazing with sheep	27.0	1.86	5.13	0.14	2.20
2xWj	Switch grazing with youngstock	37.0	1.73	3.31	0.26	1.60
Wk-ext	Extensive grazing with youngstock and manure	20.5	0.81	1.23	0.00	3.06

Table 7, problem species on a dike (Source: Handreiking grasbekleding)

Plant	Latin Name	Problem	Mentioned
Giant Hogweed	Heracleum mantegazzianum	Displacing native plants	Digigids, onkruid groot
Big Butterbur	Petasites hybridus	Shadow effect	
Japanese Knotweed	Fallopia japonica	Displacing native plants, damage to dike	
Field thistle	Cirsium arvense	Indication of nitrogen in the soil, competition with native species	Digigids, onkruid klein
Stinging nettle	Urtica dioica	Indication of nitrogen in the soil, decrease of visibility, shadow effect	
Knight sorrel	Rumex obtusifolius	Shadow effect, decrease in visibility	
Moss			
Rapeseed	Brassica Napus	Domination of grass species, decrease in visibility	Not mentioned in Digigids, but still considered a problem
Ragwort	Jacobaea vulgaris	Risk for animals	
Horsetail	Equisetum arvense	Risk for animals	
Giant balsam	Impatiens glandulifera	Displacing native plants	

Table 8, the dry matter production at various N-outputs

N-output (kg/ha)	150	80	0
Dry matter production (kg)	8000	6000	4000

	1a	**2a**	**3a**	**1b**	**2b**	**3b**
(sea)dike	5.4	7.1	10.0	5.4	7.1	10.0
Permanent grassland						
Grazing (ha)	6.5	5.8	8.3	1.5	1.5	1.5
Forage production (ha)	2.4	3.1	3.4	1.5	1.5	1.5
Temporary grassland						
Gras seed land	-	-	-	10.3	9.1	10.4
Autumn grass	-	-	-	10.4	15.9	26.3

Table 9, needed area on a dike for 100 ewes in ha