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# Muddling through the muddles of nature developments in peatlands

Supporting decision-making in the complex world of nature development in peatlands in the Netherlands.

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# Colophon



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# Pre-face

Dear reader,

In front of you lies my thesis for the master's program Environmental and Infrastructure Planning at the Faculty of Spatial Sciences, University of Groningen. The completion of this thesis also means the end of my student life. In five years of studying, I obtained a Bachelor of Science degree in Spatial Planning, in which my interests in spatial planning were deepened. With this master's program I have further expanded my knowledge and expertise, and have especially strengthened my interests in environmental planning. Writing this thesis has been quite the process and proved to be challenging at times. The achievement of completing this thesis would not have been possible without the support of several individuals, whom I wish to express my gratitude to.

First of all, I would like to express my gratitude to Geny van Horssen and Gooitzen Greebe, working at Staatsbosbeheer. Especially for allocating time in their schedules to provided me with valuable consultation, support, and uncountable insights into nature developments in peatlands in the Netherlands. This collaboration allowed me to have access to their network and recruit participants who were willing to contribute to this research. Who I would like to thank as well for providing me with rich empirical data. Additionally, this collaboration gave me the opportunity to experience firsthand the nature development of peatlands in the Netherlands through a fieldwork visit.

Secondly, I would like to thank my supervisor dr. Ferry van Kann for his guidance throughout this thesis, accompanied by numerous cups of coffee. His extensive efforts to keep me afloat in assessing the complex world of nature development in peatlands, and writing a thesis on this subject, are highly appreciated.

Finally, I would like to thank my loved ones for their support throughout the process of writing this thesis. Their encouragement and motivation, both during this project and throughout my master's studies, have been crucial in helping me complete the program and bring my student journey to a successful end.

I hope this work proves to be an insightful and enjoyable piece to read!

Maarten Heikens, August 2024

Abstract
Through the rising attention to climate change, the critical role of peatlands can play in this phenomenon, and their vital ecosystem services, an increased need for the careful consideration on how to act upon these landscapes, is recognized. In the context of the Netherlands this is of further importance as the peat layers in the soil present more challenges, to the already existing list of challenges related to land-uses in areas with limited space. One of the strategies receiving increased attention to battle the challenges related to the peat layers in the soil, is nature development. However, conventional assessment methods are limited in assessing the true potential of the creation and preservation of nature in peatlands in the Netherlands. This thesis, therefore explores to what extent an assessment of the positive and negative effects of nature development in peatlands can support decision-making. By conducting two case studies, with data gathered from interviews, a project documentation review, and fieldwork, an assessment of the two projects was conducted. This to explore to what extent the assessment methods, created on the basis of a literature review, could be used to support decision-making. A comprehensive assessment of the cases is only partially possible, due to difficulties labelling the direction of effects. These difficulties can be explained by the influence the factors scale (level of detail), time, perspective, and the weighting of the individual elements, have on the assessment. Nonetheless, the overview of pros and cons, along with a complete or partial conclusion, can inform decision-makers and thereby support the decision-making process. Future research could be conducted to further investigate the influence of these factors, ultimately improving the outcome of the assessment.

*Keywords*

Peatlands, peat, nature development, decision-making, assessment methods, climate mitigation

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## List of abbreviations

MCA = Multi-Criteria Analysis

CBA = Cost-Benefit Analysis

EIA = Environmental Impact Assessment

$CO_2$ = Carbon dioxide

$CH_4$ = Methane

$N_2O$ = Nitrous oxide

# 1 Introduction

## 1.1 Background

Peatlands are a form of wetland ecosystems that can be found in various forms across the world. The soil of peatlands consists of peat, which is a unique soil type built out of partially composed organic matter (plants, mosses, etc.) (Keddy, 2010). The original, pure form of peatlands provide various important ecosystem services (see box 2), such as carbon sequestration, flood mitigation, flora and fauna habitats, and recreation (Monteverde et al., 2022; Overbeek et al., 2020). Peatlands house various complex processes related to these ecosystem services. One of the most important ones, in the face of global climate change, is the carbon sequestration abilities, the function as a carbon sink. The estimations on the amounts of carbon stored in peatlands vary based on definitions and research methods (Rydin & Jeglum, 2013; Yu, 2012). However, widely adopted estimates range from a quarter to a third of all soil organic carbon being stored in peatlands, which cover four to nine per cent of the global land area (Overbeek et al., 2020). The process consists of sequestering, emitting, and exchanging large amounts of carbon, and therefore playing a large role in Earth's carbon cycle (Bansal et al., 2023). However, this process is susceptible to rapid change, both influenced by climate change and human interventions (Temmink et al., 2022).

The formation of large peatlands in Northern Europe, began after the last deglaciation during the Holocene (Yu, 2012). In large parts of the continent peatlands could be found. In the Netherlands, peatlands once also covered a significant portion of the land surface, playing a crucial role in the landscape's hydrology and ecology. However, since the 11$^{th}$ century, the peatlands were extensively modified (Brouns et al., 2015). First, to create productive, arable land out of the wet peatlands, later, for the harvesting of the peat as a fuel (Ruimtelijk Planbureau, 2005). These widespread interventions led to significant biodiversity loss and alterations in hydrological functions. In many places the peat layer was not completely removed, however, by applying a layer of more fertile soil, the lands were often converted into agricultural fields (Ruimtelijk Planbureau, 2005). For this reason, the current landscape consists of a top layer with a layer of peat underneath. Today, many land-uses can be found on top of these peat layers, for instance cities, industrial developments, agricultural uses, and nature reserves.

Today, many land-uses have found their place on top of the peat and the original ecosystems do (almost) not exist anymore in the Netherlands, many of the original processes are still relevant. Next to the already existing challenges related to land-use, many different interests on limited amounts of land, these processes can present another layer of challenges when developing on top of peat.

***Box 1: Clarification of peat in the Netherlands***

We can distinguish two main forms of peat in the Netherlands, 'Hoogveen' and 'laagveen'. Hoogveen can be seen as bog peat, created above the groundwater level, where laagveen can be classified as fen peat, created below the water level (Stouthamer et al., 2020). This distinction is important as there are still some areas with ombrotrophic raised bogs, which are relatively untouched, and therefore highly valued and protected. The fen peat is still present in the Netherlands, however, as described previously, in the ground layers. As further discussed in section 2.3, the focus in this research is on the semi-natural grass meadows with fen peat, which will be called peatlands, even though not being a pure ecosystem form anymore.

One of the land-use types receiving increased attention is nature, as the Netherlands is creating nature networks to restore ecosystems. To be able to establish and preserve the desired nature, the extraction of (part of) the ground layer of peat is sometimes used as intervention. The extraction of peat causes emissions which, in light of sustainability, is unwanted. However, when developing nature positive effects can also be expected in the form of enhanced biodiversity, increased recreational functions, and as mentioned, the mitigation of some of the other challenges related to land-use in the Netherlands for instance (Rydin & Jeglum, 2013).

One of the key-actors in the creation, preservation and usage of nature in the Netherlands is Staatsbosbeheer. This organisation is a Dutch governmental organisation that protects and develops the green heritage, while at the same time managing, and bringing the assigned areas to sustainable use (Staatsbosbeheer, n.d. a). Staatsbosbeheer manages and creates nature, throughout the Netherlands, also in peatlands (and areas where peat is present in the soil). This brings challenges for Staatsbosbeheer because of the goal to act sustainable against the emissions following the development of nature in peatlands, with as secondary layer the fragility of these landscapes, and the inability to undo interventions on a small-time scale. A clear, integral assessment of this problem is a challenge due to the large number of elements at play, the complexity of the processes, as well as the combination of various professions.

Added to that, conventional assessment methods are limited in assessing the true potential of the creation and preservation of nature in peatlands in the Netherlands. Looking at for instance a calculation of the cost efficiency of converting agricultural lands into nature, it presents a distorted outcome as the value of recreation and enriched biodiversity are not taken into account (Bromet & De Groot, 2019). In general, valuing for instance the enrichment of biodiversity in comparable numbers is a difficult task. Furthermore, when a value is connected, comparing this to other elements presents another layer of challenges. In other words, some of the ecosystem services (see box 2) peatlands provide are left out of the assessment methods, distorting the view on the effects of interventions. Still, a kind of overall assessment of nature development in peatlands is wanted, to show the true potential of these planned interventions.

*Box 2: Ecosystem services definition*

Ecosystems, in all different forms, provide benefits to humans. These benefits could be defined as ecosystem services (Bennett et al., 2009). The provision of food, flood mitigation, and climate regulation are examples of ecosystem services. Ecosystem services in this definition include benefits provided by “wild” ecosystems, such as carbon sequestration, as well as benefits provided through management of ecosystems, such as recreation (Bennett et al., 2009, p. 1401).

## 1.2 Societal relevance & scientific relevance

Peatlands, as discussed in the previous section, provide various ecosystem services (Monteverde et al., 2022; Overbeek et al., 2020). For instance, as carbon-storing ecosystems, they play a crucial role in the global carbon cycle. Additionally, they provide habitats for a wide range of flora and fauna species, greatly contributing to biodiversity. Furthermore, recreational values can also be recognized. However, interventions in these ecosystems can bring negative effects, such as increased emissions. Moreover, these interventions are practically irreversible on a small-time scale. Therefore, it is essential to carefully consider how to act to ensure the well-being of citizens who depend on the ecosystem services peatlands provide, even when aiming to increase spatial quality through the creation or preservation of nature. This carefully considering a spatial intervention closely resonates with systematically assessing planned interventions, therefore this study can contribute to spatial planning.

Existing literature often emphasizes the negative consequences of intervening in peatlands, or the challenges associated with restoring these ecosystems (Yu et al., 2017; Moomaw et al., 2018). However, there is a gap in research that considers the potential benefits of small-scale, purpose-driven interventions, such as those aimed at nature development within peatlands. By focusing on both the positive and negative effects of nature development interventions in peatlands, this study seeks to provide a more balanced perspective that can support decision-making regarding the future of peatlands in the Netherlands. Especially when also considering the various challenges related to the peat in the soil, which are relevant in the context of the Netherlands. By enhancing our understanding of the impacts of these interventions, this study will support decision-making to not only protect the crucial ecosystems but also contribute to broader spatial planning efforts, ultimately enhancing the quality of life for citizens and maintaining the ecological integrity of the landscape.

## 1.3 Problem statement

When developing nature in peatlands in the Netherlands, through initiatives led by Staatsbosbeheer, the extraction of peat for creating or preserving the intended natural environment leads to the emission of greenhouse gasses, which are undesirable from a sustainability perspective. The complexity of the subjects involved, along with their nearly endless properties, and the difficulties comparing the elements and effects, muddles the assessment of the intervention. A more balanced assessment on nature development in peatlands in the Netherlands determining if it can be deemed a valuable intervention could therefore support decision-making.

## 1.4 Research objectives

Drawing from my academic background in Environmental and Infrastructure Planning, adopting the perspective of spatial planning, this study aims to assess the positive and negative effects of nature development in peatlands to ultimately support decision-making. This master's programme educates (besides other learning objectives) the analysis of complex planning situations with environmental related challenges (Rijksuniversiteit Groningen, 2023), and provides the foundation for this research.

This research is structured around multiple research objectives. Firstly, it seeks to enhance understanding of the processes, elements, and relationships involved in peatlands, peat, and nature development in the Netherlands. Secondly, this study aims to establish a comprehensive schematic overview, and a comprehensive overview of the relationships and effects by using the previously gained understanding. Finally, the research aims to apply these created overviews to assess the positive and negative effects of nature development in peatlands in the Netherlands in two cases, showing if the intervention can be assessed in a balanced manner. With the ultimate research objective being supporting decision-making regarding the future of peatlands in the Netherlands.

## 1.5 Research questions

Based on the problem statement and the research objectives, the main research question is:

***Box 3: Main research question***

> To what extent can an assessment of both theoretically and empirically identified elements and interconnected effects be used to support decision-making regarding nature development in peatlands?

To provide structure and address the main research question, seven sub-questions have been formulated (box 4). The first two sub-questions address the first research objective, enhancing the understanding of nature development in peatlands in the Netherlands. The third and fourth sub-questions are linked to the second research aim, establishing a schematic overview and an overview of relationships. The fifth, sixth and seventh research question address the case study and the empirical observations. The following sub-questions have been formulated:

*Box 4: Sub-questions*

What are theoretically relevant elements when developing nature in peatlands?

What are the relationships and effects of the identified elements?

How can we theoretically assess the elements and their relationships to each other?

What are empirical possibilities to assess identified elements and effects?

What are the observations from Case Study 1: Nature Creation in Weimeren?

What are the observations from Case Study 2: Nature Preservation in De Weerribben?

To what extent can an assessment be done to support decision-making?

## 1.6 Reading guide

Chapter 1 introduced the background of nature development in peatlands in the Netherlands, highlighted its relevance, and presented a problem statement, research objectives, and research questions. Chapter 2 presents a literature review outlining definitions and concepts relevant to this research. Chapter 3 discusses the methodology applied in this research, discussing research design, methods and considerations. Chapter 4 presents the empirical findings of this research. Chapter 5 focusses on discussing the findings and their implications. Thereafter, Chapter 6 answers the main research question and presents a reflection on this research.

# 2 Literature Review

This chapter outlines the theoretical background of the research. The first section illustrates how spatial planning can contribute to this research. Followed by setting definitions and identifying the relevant physical elements, relationships, and effects of peat. The next section, zooms in on the context of the Netherlands, further identifying relevant elements, relationships, and effects. The fourth section discusses nature development in the Netherlands, followed by the section identifying methods to evaluate projects. The sixth section discusses the overviews that are created. In the final section the conceptual model is presented.

## 2.1 Spatial Planning

By exploring spatial planning in general, drawing insight and concepts from this discipline, and converting these concepts to fit in with the research objectives, this section of the literature review illustrates how spatial planning can significantly contribute to addressing and assessing the challenges of nature development in peatlands.

### *2.1.1 Spatial Planning*

Since the earliest days of mankind people tend to adapt their landscapes to their certain needs. More recent (around the 1900's) this has evolved into a coordinated, planned development of our living environment. As noted by Van Dijk et al. (2019), the different land uses, and accompanying activities, we give our lands, ranging from living and working, to nature and agriculture, all require space, but this same space is limited. While these diverse functions of the land (land-uses) can coexist, they can conflict with each other as well. Therefore, it is important to carefully consider what to do with the land. There are many terms trying to encompass this process; urban and regional planning, physical planning, and land-use management for instance, which are often used as synonyms (Voogd et al., 2011). In Dutch there is a unique term for this plan making; planologie. Dissecting this word, as discussed by Voogd et al. (2011), gives some insight into this process and its core structures and origins. The word can be dissected in two ways, the first perception is the division of the Latin words Planus (=area) and Logia (=knowledge) stressing the gathering of knowledge on physical aspects (Voogd et al., 2011). The second perception is the division of the Dutch words plan (=plan) and logica (=logic) focussing on the planning and scientific parts (Voogd et al., 2011). Looking back into the English terminology shows that spatial planning has been adopted as a similar term (Voogd et al., 2011). Geography and spatial planning are closely related, both focussing on geographical structures and processes, however the differences outline another important aspect of spatial planning. The difference according to Voogd et al. (2011) lays in that spatial planning does not only try to understand this geographical domain, but also tries to understand influencing this.

*Box 5: Quote on spatial planning*

"…. de planologie gaat het evenwel niet primair om het begrijpen van, het kennis verzamelen over, deze ruimtelijke orde, maar om het begrijpen van de (optie voor) beïnvloeding hiervan." (Voogd et al., 2011, p.16)

Voogd et al. (2011, p. 16) highlight several important elements: "The systematic preparation … aimed at consciously intervening in the spatial domain ... in order to maintain spatial qualities and improve them where possible." The systematic preparation, assessing the problem through structure and a system, will be used in this study, as further explained in sub-section 2.1.1. Consciously intervening, maintaining and/or improving spatial qualities, closely resonates with the societal relevance and the aim of this research, as this study aims to supports decision-making in physical interventions.

*Box 6: Quote goals of spatial planning*

"De systematische voorbereiding … gericht op het bewust interveniëren in de ruimtelijke orde … ten einde ruimtelijke kwaliteiten te behouden en waar mogelijk te verbeteren." (Voogd et al., 2011, p.16)

As said, in the field of spatial planning interests' conflict with each other. For example, plans for a neighbourhood with improved living conditions can have negative effects on the environmental quality in the area. To tackle these conflicts planners try to make the problem at hand transparent and open for discussion (Van Dijk et al., 2019). Summarized in five ideal characteristics: *integrative*, *pluriform*, *normative*, *action-oriented*, *sustainability-oriented* (Van Dijk et al., 2019). *Integrative* (= keeping an integrated perspective, focussed on spatial and societal cohesion), *action-oriented* (= making conscious changes to land use with value for users) *and sustainability-oriented* (= being aware of the short and long term perspective of the issue) (Van Dijk et al., 2019, p.13) are relevant in this matter, which will be examined further in sub-section 2.1.3.

### *2.1.2 Complex problems*

De Roo et al. (2020) argue that when we want to understand our geographical environment by creating a complete list, naming all entities and elements, that form our physical environment, this list would rather quickly become incomprehensible long. This to conclude that a major characteristic of our geographical environment is that it is complicated. This is explained by De Roo et al. (2020, p. 279) through the following explanation: "Environments combine various elements at different levels of detail and scale, and human activities… and are affected by a wide range of variables". This complexity has been increasingly propelled by technological advances over the recent decades, turning global problems into local ones, as noted by Van Dijk et al. (2019). Complexity theory is the collective term for various theories about complex systems, existing at a threshold between order and chaos, too complex to treat as machines and too organised to be assumed random and averaged (Pourmohammadi, 2022). These theories can be grouped into three types: algorithmic, deterministic and aggregative complexity (De Roo et al., 2020). As explained by De Roo et al. (2020), algorithmic complexity includes mathematical complexity, deterministic complexity consists of chaos theory, and aggregative complexity shows how interaction between many individual elements creates systems with complex behaviour, precisely describing why geographical environments are complicated, and therefore being the most suitable for this study. This form of complexity theory characterises through a holistic view, focussing on a larger system with elements.

To manage this complexity and to understand complex environments, planners use various techniques, such as *simplification* and *systems thinking*, which can be regarded as conceptual approaches. Simplification describes the method of simplifying reality. One way of simplifying is by grouping elements, as counting every single entity or element in the real world would be not feasible, or similarly, selecting a subset that is deemed most relevant (De Roo et al., 2020). Another way is by taking a subset of elements and make assumptions about variables to simplify the complexity of the real world (De Roo et al., 2020). System thinking is an approach which considers environments as interconnected systems with dynamic interactions between various elements (Batty, 2013). Identifying different elements and studying their interactions in systems can aid in making more sustainable decisions (Batty, 2013). Important aspects of system thinking in spatial planning are threefold: (1) a holistic perspective, considering a larger system, and with that (2) recognizing that changes in one part can impact other parts, and (3) considering a dynamic system, for instance by accounting for new patterns or delays in effects (Batty, 2013). Using system thinking a system model can be created. This model maps the key elements and how these are connected (Bennett et al., 2005).

### *2.1.3 Creating a perspective*

In sub-section 2.1.1 three ideal characteristics for spatial planners were identified, namely, (1) integrative, (2) action-oriented, and (3) sustainability-oriented. After that, in sub-section 2.1.2, diving deeper into system thinking, another three aspects are identified: (1) a holistic perspective, (2) effects between parts, and (3) a dynamic system. These six aspects are relevant in this study as they can support the analysis and interpretation of complex data and systems. These six aspects can be combined into a perspective, or lens, which can guide the identification of the relevant elements, and form a basis for the operationalisation. The integrative characteristics for spatial planners and the holistic perspective from system thinking have overlap and could be combined in a holistic lens, as both recognize the importance of a larger system. The recognition of effects between parts, as well as the dynamic system can also be combined with action-oriented and sustainability-oriented characteristics and will be used as two perspectives. The recognition of effects between parts is essential in action-oriented characteristics, as conscious interventions should also consider the larger implications, thus effects between parts. In sustainability-oriented characteristics, considering short and long term, thus dynamics, is of the essence.

These combination results in three lenses; (1) a holistic lens, (2) an interconnectedness lens, and (3) a dynamic lens (figure 1). These three lenses resonate closely with the research subject and research objectives, as the holistic lens emphasizes the integral perspective, the interconnectedness lens stresses the different processes and their relationships within peatlands, and the dynamic lens allows for identifying and explanation of unexpected results. These lenses will be used in the remainder of this literature review, as well as in the operationalisation of the research (chapter 4).

*Figure 1: Three lenses*

## 2.2 Peat

This section in the literature review unravels the complexity of peatlands and peat by systematically examining the relevant elements identified in the literature. This structure and the elements are based on the seminal works of Rydin and Jeglum (2013) and Keddy (2010), both considered handbooks on wetlands and peat describing processes and relationships, as further discussed in sub-section 3.3.1. First, definitions are set, followed by a classification of various peatlands. After that the three key physical aspects of peat and peatlands are discussed, hydrology, climate, and nature.

### *2.2.1 Ecosystems*

To better understand the context, this research requires another step in the system of peatlands by examining the main peat ecosystems. However, classifications are not uniform as they are depending on definitions and locations, similar as the definitions on peatlands, expanded upon in the previous section. Additionally, ecosystems often lack clear boundaries, making natural classification more difficult (Rydin & Jeglum, 2013). For instance, Keddy (2010) classifies marsh as open water instead of as a peatland, due to the limited amount of peat and the water rich characteristics, where Rydin and Jeglum (2013) classify marsh as part of peatlands, as they can be seen as essential parts of larger peatlands. However, sticking to one classification is essential for clarity.

The classification by Rydin and Jeglum (2013) is based on two variables, the *moisture-aeration* and *pH-base* richness. The concept of moisture-aeration scratches the surface of the complex process of the formation of peat. One of the requirements for peat to form is wet conditions. A high-water table will result in a saturated soil, which creates anaerobic (low oxygen) conditions. However, fluctuations in the water table result in some surfaces being below, some at, or some slightly above the water level permanently or temporarily (Rydin & Jeglum, 2013). This allows for a variable balance between moisture-aeration, and thus variable amounts of oxygen present within the pores of the peat. Anaerobic conditions slow down decomposition of organic matter, which then leads to the accumulation of peat (Rydin & Jeglum, 2013). Based on this variable, the ratio between moisture and air, or simpler, the amount of water present, helps determine the peatland ecosystem.

The pH-base richness describes another complex process within peatlands. The accumulation of peat creates increasingly more acid and nutrient-poor conditions (Keddy, 2010). The main ecosystems differentiate in these conditions. Simplified, the pH value combined with the availability of plant nutrients makes for a certain peat ecosystem. Key in this process is again the relation with water, as the water source (more specifically the nutrients in this water) within the ecosystem plays a key role (Rydin & Jeglum, 2013).

In this research the distinction between four main ecosystems is used: marsh, swamp, fen, and bog, following Rydin and Jeglum (2013), complemented by the work of Keddy (2010). This basic distinction between ecosystems is of the essence to be able to differentiate between different peatlands, as these are often subject of different levels of vulnerability, as well as a difference between flora and fauna species.

- **Marshes** characterizes by floating or emergent plants in slow-moving or standing water. The “land” is between permanently flooded and intermittently exposed and are often located alongside open water. There is often only a limited layer of peat present, allowing the plants to root in the nutrient rich grounds underneath (Keddy, 2010; Rydin & Jeglum, 2013). Marsh lands are characterized by flora species as reed and sedges, interspersed by open water, which can cause disturbance through wave or currents (Rydin & Jeglum, 2013).
- **Swamps** characterizes by forested or thicketed lands with standing or slow-moving pools or channels of water (Rydin & Jeglum, 2013). The water table is often below the surface, allowing trees, or tree like bushes to grow. The ground is built up out of a mix of organic matter with

shallow to deep peat underneath. Swamps, in this definition, often form a part of larger peatlands as a transition zone between the peatland and land forests (Rydin & Jeglum, 2013).

- **Fens** characterizes by bushes, shrubs, sedges, reed, and in some cases small trees with the water table slightly below, at or just above the surface (Rydin & Jeglum, 2013). The peat layer is substantial, often exceeding 30 centimetres, and is located just below the surface (Rydin & Jeglum, 2013). The distinction between a fen and a swamp is blurred, as both can feature trees and spongy, wet soils.
- **Bogs** are fundamentally different than marshes, swamps, and fens, as they form a layer on top of the surface, thus being separated from the soil water, and being nourished only by nutrient poor precipitation (Rydin & Jeglum, 2013). The peat layer is almost always larger than 30 centimetres deep, with at the surface mainly mosses, some sedges, as well as deep rooting trees.

Finer classifications in peatlands can be made based on environmental factors causing vegetational variation (Rydin & Jeglum, 2013), however for this research this is not necessary as the focus area (the Netherlands) has limited untouched peatlands left (Ruimtelijk Planbureau, 2005). The ecological values in these areas are now closely linked to their land use. Influenced by factors such as business operations, peatlands have become "semi-natural" (Ruimtelijk Planbureau, 2005, p. 37), as will be elaborated upon in peatlands in the Netherlands (section 2.3).

### *2.2.2 Definitions*

Setting the definitions for peatlands is important as many terms are used inconsistently, even in the same language (Rydin & Jeglum, 2013). Keddy (2010) explores the many different terms and identifies common misunderstandings and their origin. “The proliferation of terms can be confusing to even the experts…” (Keddy, 2010, p. 37). This immediately highlights the first layer of complexity in peatlands. The most used terms found in current literature are *wetlands*, *peatlands* and *mires* (Rydin & Jeglum, 2013). Wetlands represent the broadest concept among these three and can be defined as terrain that does not entirely consist of land nor open water, occupying a transitional position between land and water environments (Keddy, 2010; Rydin & Jeglum, 2013). In order to define peatlands, it is necessary to define peat. Peat is the result of partially composed organic matter accumulated over an extended period under saturated water conditions (Keddy, 2010). It comprises diverse plant materials such as leaves, roots, mosses, and wood. Peatlands are wetlands characterized by a combination of peat-consisting terrain and water bodies (Keddy, 2010; Rydin & Jeglum, 2013). Mires can be defined as wet landscapes dominated by the presence living plants that form peat (Rydin & Jeglum, 2013). However, this form of definition can be criticized, as noted by Keddy (2010), as most plants can be used in the process of peat formation. Both peatlands and mires are narrower concepts than wetlands, but the difference between peatlands and mires, according to Rydin and Jeglum (2013), comes from set requirements combined with the terminology. For instance, Rydin and Jeglum (2013) conclude that most literature set the minimum peat depth for peatlands at 30 centimetres, but also note that this is inconsistent throughout the world. Keddy (2010) advocates to avoid the word mire completely.

For the sake of clarity, in this study, the term ‘peatland’ in this chapter to refer to the pure ecosystem form and the related processes within. Later, in section 2.3, this term will be placed into context, and receive an alternative definition.

### *2.2.3 Hydrology*

As illustrated in the previous sub-section, water is at the basis of peatlands, because they are wetlands, and water makes wetlands. The relationship between peat and water is foundational to the existence and functions of peatlands (Keddy, 2010). Or even stronger, “… it is probably the single most important condition influencing peatland ecology, development, functions, and processes (Rydin & Jeglum, 2013, p. 148). Hydrology is the science of water, examining its physical and chemical properties, as well as its relationships with the environment (Rydin & Jeglum, 2013). This research uses the two main categories, closely related to the basis of the categorization of peatland ecosystems: water source (related to pH-base richness) and water quantity (related to the concept of moisture-aeration).

Water source has a large impact on the form of peatlands that arises, and consequently on many processes that occur. The influence of groundwater, or the lack of influence, is crucial. Minerogenous (minerotrophic) peatlands are influenced by groundwater that has passed through mineral rich ground materials, therefore the peatlands consist of more nutrients (Rydin & Jeglum, 2013). Ombrogenous (ombrotrophic) peatlands, on the other hand, are isolated from groundwater sources and receive water from precipitation and are therefore non-nutrient rich (Rydin & Jeglum, 2013). The terms minerogenous and ombrogenous relate to the hydrological regime in the peatlands, whereas the terms minerotrophic an ombrotrophic relate the connected availability of nutrients and therefor the plant growth in the peatlands (Rydin & Jeglum, 2013). Many ecologists follow the convention of using the terms fen for minerotrophic peatland and bog for ombrotrophic ones (Rydin & Jeglum, 2013).

Water quantity can be seen as the physical presence of water, influenced by the water table, how high or low the water is. An even stronger concept is water balance in peatlands, as this accounts for the input, output, and storage of water within peatlands (Rydin & Jeglum, 2013). The water balance in peatlands largely dictates processes within peatlands, for example vegetation structure, plant occurrence and peat growth (Rydin & Jeglum, 2013). However, this research will not go into too much detail about the results of fluctuations in the water balance as a simplified understanding (general effects of rising and lowering of the water table) can suffice in understanding the relevant relationships between water and other elements. Secondly, as shown by for instance Howie et al. (2009), the precise results of a rise or lowering of the water table are hard to predict, showing unexpected results between studies, and cause debate among scholars.

In general, simplifying the processes, a lower water table (artificially or naturally) will result in an increase in the depth of the aerated peat layer, increased decomposition of peat, followed by subsidence, emissions of greenhouse gasses and often poorer surface water quality (Brouns et al., 2015; Strack et al., 2008). Peat has the ability to increase the water quality when functioning properly, however, with a lower water table, it can reduce the water quality by the outflow of various particles, called leaching (Rydin & Jeglum, 2013). A lower water table can be achieved by intensive water management and can be used to drain peatlands to allow for forestry, agriculture, or peat extraction (Strack et al., 2008). The other way around, rising the water table to higher levels, will allow for anaerobic conditions and the accumulation of peat. With the accumulation of peat, the sequestration of carbon can be achieved. This shows the interconnectedness between sub-elements (lens 2) as illustrated in figure 1.

Water retention is a critical hydrological function of peatlands, especially in fen peat (Keddy, 2010). Their high porosity allows peat to act like a sponge, absorbing significant amounts of water during rainfall events and slowly releasing it during dry periods. This function helps to regulate water flow in the landscape, reducing flood risks and maintaining stream flow during dry periods (Holden, 2005).

***Box 7: Identified elements of Hydrology***

The identified elements in this section are:
Main element: Hydrology
Sub-elements: Water balance, water quality, water storage

### *2.2.4 Climate*

Peatlands are of major importance for our planet, as they are critical components of the global carbon cycle and play a significant role in climate regulation (Yu, 2012). The interplay between peatlands and climate is complex, involving both greenhouse gas sequestration, as emissions (Bansal et al., 2023).

The precise amount of storage is debated among scholars, due to differences in definitions and estimations of the peat depth (Rydin & Jeglum, 2013; Yu, 2012). For instance, Joosten and Clarke (2002) estimated peatlands to store approximately one-third of global soil carbon, amounting to around 500-700 gigatons of carbon dioxide ($CO_2$), while covering about 3% of the Earth's lands surface. Whereas a more recent source, Overbeek et al. (2020), estimated a similar amount ranging from a quarter to a third of all soil organic $CO_2$ being stored, while covering a bit more ground, four to nine per cent of the global land area. However, it can be concluded that peatlands play a significant role in storing carbon.

As highlighted in sub-section *2.2.3*, the hydrology of peatlands plays a key role in the accumulation of peat, and as described in sub-section *2.2.1*, peat accumulation occurs through the decomposition of plants in anaerobic conditions, which traps $CO_2$ within. This process of sequestration is therefore at the basis of peatlands, and closely related to the hydrology. However, when the peat is not under anaerobic conditions, so the peat is above the water level, it emits $CO_2$. This also happens when extracting the peat from the ground, when taken out of the wet conditions, the peat will decay, releasing the $CO_2$ stored inside. The balance between the sequestration and the emission of $CO_2$ is therefore fragile.

While peatlands can sequester and emit $CO_2$, other greenhouse gasses, such as methane ($CH_4$) and nitrous oxide ($N_2O$) can also be released into the climate (Rydin & Jeglum, 2013). The processes within are complex, however it can be stated that both $CH_4$ and $N_2O$ are more potent greenhouse gasses than $CO_2$, and emission of these gasses happen under anaerobic conditions in peatlands, so when in wet conditions. So, a higher water table would lead to the accumulation of peat and the connected sequestration of $CO_2$, however this would also cause an increase in the emissions of $CH_4$ and $N_2O$ (Rydin & Jeglum, 2013). For this research, however, only $CO_2$ emissions are considered, as both $CH_4$ and $N_2O$ emissions are subject to high uncertainties related to micro conditions in the environment (Rydin & Jeglum, 2013), and therefore these gasses are not taken into account.

Additionally, according to Rydin and Jeglum (2013), climate change itself poses a significant threat to peatlands and their ability to function as $CO_2$ sinks. Increased temperatures, increased periods of drought and altered precipitation patterns can lead to the drying out of peatlands, which in turn accelerates peat decomposition and $CO_2$ release (Rydin & Jeglum, 2013). This process can transform peatlands from $CO_2$ sinks to $CO_2$ sources and worsen climate change (Bansal et al., 2023). However, the other way around, the restoration of peatlands can contribute to mitigating climate change by storing $CO_2$ inside (Bansal et al., 2023). Restoring peatlands, and with that, promote the accumulation of peat, can be deployed as a climate change mitigating intervention.

***Box 8: Identified elements of Climate***

The identified elements in this section are:
Main element: Climate
Sub-elements: Sequestration, emissions, mitigation

### *2.2.5 Nature*

The third physical element that plays a key role in peatlands is nature. Flora and fauna species, adapted to the unique characteristics of this ecosystem, find their place here. Flora species differ between the ecosystems, based on for instance the availability of nutrients, and the water balance, as previously discussed in sub-section 2.2.3. However, common plants in most of the ecosystems include sedges, cotton grasses and various shrubs (Rydin & Jeglum, 2013), as well as grasses, and broad-leaved herbs (Verhoeven et al. 2006). The unique conditions in bogs, makes the exemption, where the flora is dominated by Sphagnum mosses, instead of a wider variety of plants (Rydin & Jeglum, 2013). Due to the variation between wet and dry areas, and the accompanied vegetation thriving in these conditions, many different animal species also find a habitat in these ecosystems. The conditions can provide critical habitats for a range of birds, with water rich areas housing various species of ducks and geese, and dryer areas with shrubs providing shelter for smaller birds (Rydin & Jeglum, 2013). Other animals are attracted to the availability of certain plant species, or the presence of water. This includes larger animals as deer, but also smaller mammals as otters or beavers (Keddy, 2010). Small animals are also supported by the vegetation in peatlands, providing habitat for numerous invertebrates, including dragonflies, damselflies, and a variety of beetles and spiders (Joosten & Clarke, 2002).

The unique characteristics of peatlands and the variation between wet and dry areas create the basis for a large biodiversity, providing habitats for all kinds of flora and fauna (Rydin & Jeglum, 2013). This makes peatlands of high ecological value. Another value can be recognized in the recreation coming from nature, serving a recreational purpose for the population. This will be further discussed in the context of nature in the Netherlands in section 2.4.

***Box 9: Identified elements of Nature***

The identified elements in this section are:
Main element: Nature
Sub-elements: Flora and Fauna, biodiversity

## 2.3 Peatlands in the Netherlands

In the previous section, the key characteristics and processes of peat and peatlands have been discussed, to identify the relevant elements. More specifically, this research focuses on the context of the Netherlands. Therefore, in this section, the relevant elements in this context are identified by examining the historical development, the current landscape, and its challenges.

### *2.3.1 History*

In the Netherlands, peatlands once covered a significant portion of the land surface, playing a crucial role in the landscape's hydrology and ecology (Ruimtelijk Planbureau, 2005). However, since the 11th century, extensive drainage and peat cutting have drastically reduced their extent (Brouns et al., 2015; TNO, 2007). The initial reason for draining peatlands in the Netherlands was to create arable land for agriculture. However, by the 17th century, the demand for fuel led to widespread peat harvesting on an industrial scale, even below water levels (Keddy, 2010). As a result, the original peatland ecosystems were extensively modified, leading to significant biodiversity loss and alterations in hydrological functions (Ruimtelijk Planbureau, 2005). The remaining lands were made productive by being converted into agricultural fields. Technological innovations over the centuries, starting with windmills, followed by steam pumping stations, and later enhanced versions of water pumping stations, allowed for continuous lowering of water tables (Ruimtelijk Planbureau, 2005). Simultaneously, the reinforcement of dikes enabled better control of water levels, ensuring that the land remained dry and functional.

Peatlands can be connected to history in another way. The characteristics of peatlands, like the anaerobic conditions and the coupled partial decomposition, allow for the careful preservation of potential archaeological artifacts (Gearey et al., 2014). When intervening in this landscape, these potential archaeological artifacts could be lost. Gearey et al. (2014) even argues that these potential archaeological qualities should be considered as an ecosystem service, to ensure for the valuing of this heritage as natural capital. The early inhabitation in the peatlands in the Netherlands, and the extensive human-made alterations in this landscape over the centuries, makes considering the potential archaeological artifacts in peatlands in the Netherlands of importance.

### *2.3.2 Current state*

The current state of most of the "peatlands" in the Netherlands can be seen as "semi-natural" (Ruimtelijk Planbureau, 2005, p. 37), almost no natural peatlands remain. As mentioned earlier in the introduction, an important distinction has to be made for the remaining peat in the Netherlands. Various types can be distinguished, but the main distinction (box 1) has to be made between 'hoogveen' (=ombrotrophic raised bogs) and 'laagveen' (minerotrophic fen peat). This distinction is made based on the groundwater level, closely related to the categorization made in sub-section 2.2.2. Hoogveen is peat created above the groundwater level, thus dependent on precipitation (Stouthamer et al., 2020). Laagveen is peat created below the water level, which in the Netherlands is often buried below sediment (Stouthamer et al., 2020). Due to landscape alterations and the historical role of peat over the last centuries, little remains of both pure ecosystem forms, as highlighted in the previous sub-section. However, this distinction is important to make as there are still some areas with ombrotrophic raised bogs, which are relatively untouched, and therefore highly valued and protected (Makaske and Maas, 2023).

Another important aspect of placing peatlands in the Dutch context, is using the term peatlands accurately. Although thick layers of the minerotrophic fen peat are still buried in the ground in large parts of the Netherlands (Makaske and Maas, 2023), we can hardly speak of peatlands anymore. As on top of this layer of peat a wide variety of land-uses can be found, ranging from agricultural uses to cities. As previously discussed in the introduction, the focus of this research is on nature development in peatlands in the Netherlands. With these peatlands is meant the semi-natural form of peatlands that is present in the Netherlands, where fen peat can be found in the ground-layers, but the pure ecosystem is replaced with various land-uses. However, the processes discussed in section 2.2 are still relevant, even in this semi-natural landscape. Therefore, this research will continue to refer to peatlands in the context of the Netherlands.

The predominant form of land-use is agricultural lands (54%) (CBS, 2021). In these agricultural field, nature is largely influenced by the function, therefore the landscape can be deemed semi-natural (Ruimtelijk Planbureau, 2005). The biodiversity in these landscapes is relatively low, often caused by high fertilization, and a single crop (monoculture) harvest. However, the agricultural function can provide habitats and feeding grounds for several animal species, for instance mice or migratory birds (Bromet and De Groot, 2019). These landscapes are productive and have large value to the farmers. Next to that, the landscape is valued for the distinctive pattern. Throughout the grasslands a network of ditches and canals can be found to allow for the extensive water management, needed to keep the water table low enough and the lands functional. This landscape reflects the agricultural heritage and is valued for its openness and view lines (Ruimtelijk Planbureau, 2005). Other cultural heritage aspects include for instance historical windmills and bridges spanning across the characteristic ditches and canals, which accentuate the value of this landscape, and the history is depicts. Altering these landscapes could interfere with the cultural identity, as many people appreciate the human-made farmland, and its qualities (van der Windt et al., 2007).

### *2.3.3 Challenges*

The peatlands in the Netherlands also face challenges that are linked to the characteristics and processes of the underlying peat. Subsidence, as briefly mentioned in sub-section 2.2.3, forms a serious problem in the Netherlands (Bromet and De Groot, 2019). To maintain the productivity of the surface for agricultural land uses, the water table must be lowered (box 7). This leads to the decomposition and compression of the peat in the ground. The resulting subsidence necessitates further lowering of the water table, creating a vicious circle. The decomposition of the peat, caused by an aerated layer of peat, also contributes to the emission of $CO_2$. The extensive water management keeps the surface productive and workable, and therefore also profitable for farmers. However, through these challenges the current landscape is under pressure.

***Box 10: Identified elements of Landscape***

The identified elements in this section are:
Main element: Landscape
Sub-elements: Qualities, archaeology

## 2.4 Nature development in the Netherlands

The previous sections created an understanding of peat and peatlands, both in general and in the context of the Netherlands. Nature development in the Netherlands is the next layer that is relevant in this study. This section in the literature review creates an understanding of the key principles of nature development in the Netherlands, this to identify the relevant elements. First, the section elaborates on the background of nature development, followed by a brief discussion of the institutional domain, as this has a large influence on the real-life practice. As this research focuses on interventions by key-actor Staatsbosbeheer, their goals are elaborated upon in the final sub-section.

### *2.4.1 Interventions in nature*

Defining nature is a difficult task. Outlined by Omernik (2004), the perception and understanding of nature depends mostly on one's background and education. Geographers, biologists, planners, and all other kinds of professionals bring their biased views to the meaning of nature (Omernik, 2004). The focus could lay with the observation of flora and fauna, or with larger non-human processes. The focus could also be on a more human oriented perspective, seeing nature as essential for the wellbeing of humankind, or just as a form of recreation. All these different views on nature can potentially dictate, how nature is shaped, what to do with nature, or the requirements that are set for nature within a country.

This understanding of nature is also relevant in the context of the Netherlands. In the past decades there have been extensive efforts to establish nature networks, to limit human impact and restore natural ecosystems (van der Windt et al., 2007). However, the value of nature for humans, for instance, through recreation, education (relevant as sub-elements, box 11), but also through the physical ecosystem services as carbon sequestration, is recognized (Bennett et al., 2009). A mix of the previously mentioned perspectives, serving ecological values, as well as the human oriented values, and the interventions to realize this, can be observed in the Netherlands. Especially these interventions hint towards the kind of nature the Netherlands has, and how it is managed. Similar to all other land-uses in the Netherlands, nature, is purposefully created and preserved. This does not mean nature only serves human benefit, it can (and does) also very well serve non-human processes, through for instance creating peace areas where human intervention and disruption is limited.

Nature development is the term used in this study to describe interventions in the physical domain to either create, preserve, or restore nature. In this study the focus is on nature development in peatlands. In this landscape a wide range of interventions can be undertaken, but a critical intervention in peatlands is the extraction of the peat. Sometimes the extraction of peat is necessary to create the intended nature, however, this brings negative effects such as $CO_2$ emissions, as discussed in sub-section 2.2.4.

***Box 11: Identified elements of Function***

The identified elements in this sub-section are:
Main element: Function
Sub-elements: Recreation, education

### *2.4.2 Rules of the games*

Nature development in the Netherlands is bound to rules, laws, and informal constraints. The overarching name for these boundaries are institutions. Institutions are humanly set constraints (both formally and informally) to structure political, economic, and social interactions (North, 1990). One of the definitions for institutions can metaphorically be seen as 'the rules of the game', structuring and shaping what is done and how this is done (North, 1990). These institutions can be seen on various scales, from small scale in the form of organisational customs and local legislation, to large scale in the form of national, or even global, legislation or treaties.

In the context of nature development in the Netherlands a wide variety of institutions can be identified. Starting from a large scale, supranational treaties and legislation play a role, for example through lists of protected animals, or through policies related to the management of targeted areas (Natura 2000 for instance). National scale institutions add another layer to 'the rules of the game'. An example of legislation on national scale are laws that dictate how to initiate nature development interventions, encompassing for instance research into water management, the targeted species, and environmental impacts of the intervention. Multi-level governance can be observed, as provinces and municipalities also have influence on the interventions. This can be seen as institutions on a more local scale.

A prime example of the legislation in the Netherlands is in the form of 'natuurbeheerplan' (= nature management plan). This approach from the provincial government defines and maps the nature in a highly detailed fashion (BIJ12, 2024). By defining 17 nature types, and 52 management types, 'natuurbeheerplannen' can be used as a management tool to influence nature managing organisation. By connecting subsidies to the management of a particular nature types, the 'natuurbeheerplannen' can coordinate agreements on nature, ultimately ensuring that the desired quality of nature can be achieved (BIJ12, 2024). This also brings an economic aspect to the legislation related to nature development. The 'natuurbeheerplannen' can be seen as the starting point for nature development, as they dictate where and what kind of nature is created or should be preserved.

***Box 12: Identified elements of Implementation***

The identified elements in this section are:
Main element: Implementation
Sub-elements: Legislation, economics

### *2.4.3 Nature and Staatsbosbeheer*

One of the key-actors for managing nature in the Netherlands, is Staatsbosbeheer. Staatsbosbeheer is a governmental organisation that protects and develops the green heritage of the Netherlands, while managing, and bringing the assigned areas to sustainable use (Staasbosbeheer, n.d. a). However, Staatsbosbeheer does more than only those tasks. They also play a key role in the realisation of national and international nature ambitions, provide recreational facilities, and the preservation of landscape monuments (Staatsbosbeheer, n.d. a).

***Box 13: Priorities and goals Staatsbosbeheer***

These core tasks of Staatsbosbeheer closely resonate with the five priorities and goals of the organization. 1) strengthening and enhancing *biodiversity*, 2) mitigate *climate* change, and limiting effects, 3) bring nature to *recreational* use, 4) bring *natural resources* obtained through management of nature areas to sustainable use, and 5) allow for *participation* of various audiences, through for instance education (Staatsbosbeheer, n.d. b)

Bringing these priorities and goals to the numerous nature areas require tailor-made plans, based on context and specifics. With the focus of this research on nature development in peatlands, the nature areas that are developed, or managed by Staatsbosbeheer in peatlands are of particular interest. Together with other nature organisations, Staatsbosbeheer contributed to the discussion on climate challenges related to peatlands in the Netherlands, by developing a vision, to ultimately facilitate a transition in the management of these peatlands (Staatsbosbeheer, 2022). The main lines in this vision entail the realisation of natural solutions, increased retention of water, tailor-made plans (resonating with the cases in chapter 4), and careful but clear considerations are needed (Staatsbosbeheer, 2022). Both in section 1.2, and in section 2.1, the call for careful consideration in relation to spatial developments was identified. Not only does it prove to be essential in spatial developments, but also when connected to the more specific goal of nature development. The clear consideration can be aided through the evaluation of previous, or upcoming projects, which will be discussed in the next section.

## 2.5 Evaluation of projects

The aim of this section in the literature review is to discuss commonly used evaluation methods and briefly outline the use of a framework. This to create an understanding of how to assess, evaluate, and weigh interventions. Ultimately to employ components of identified methods to assess nature develop in peatlands.

As discussed in sub-section *2.1.1*, one of the key goals of spatial planning is "… maintaining spatial qualities, and where possible, improving them" (Voogd et al., 2011, p.16). Furthermore, the discipline of spatial planning itself is also under development, with ongoing efforts to enhance its practices. The literature on evaluating spatial planning, in all its forms, is practically unending. Literature on improvements related to the process, the end-result, as well as methods to objectively assess these elements, can be identified. Added to that, techniques and methods are developed to support decision-making, choosing the most sustainable, most cost-effective, most practical, or (set by predetermined criteria) the best alternative. Often used methods include multi-criteria analyses (MCA) in various forms, for instance the often-used cost-benefit analysis (CBA), the Environmental Impact Assessment (EIA), as well as the creation of frameworks.

### *2.5.1 Evaluation methods*

The MCA serves as a valuable tool for decision-makers, enabling the comparison of alternatives, by exploring the balance between the pros and cons of alternatives, and with that facilitating the selection of the best fitting decision (Geneletti, 2019). Through a process with various steps including problem structuring, criteria formulation, the scoring of alternatives against these criteria, and summarizing the information, this tool assists in decision-making (Adem Esmail & Geneletti, 2018). MCA allows for the assessment of both quantitative and qualitative data in various units of measurements, as well as the inclusion of stakeholders in the process (Adem Esmail & Geneletti, 2018). It is especially relevant when assessing complex decision-making with many stakeholders (Linkov et al., 2006). However, MCA only allows for the comparison of predetermined alternatives with set criteria to be compared. In this form it does not allow for the assessment of the relationships between the different elements, as required in this research.

The CBA is widely applied in spatial planning, also in the field of environmental decision-making, and refers to the use of economic values to weigh alternative actions, and support decision-making processes (Atkinson & Mourato, 2008). The CBA can be seen as some form of MCA, however, a significant challenge with this technique is the difficulty in assigning monetary values to elements that are not easily quantifiable, such as environmental changes (Atkinson & Mourato, 2008). Although not completely impossible, connecting monetary values to some of the relevant elements identified in this literature review, for instance enhancing biodiversity, providing habitats to endangered fauna species, or emitting greenhouse gasses, presents problems.

Environmental Impact Assessment (EIA) is another form of assessing interventions. It can be defined as a study to predict the impacts of a proposed intervention on the environment (Rosales, 2020). The EIA studies several positive and negative consequences of the proposed intervention on the environment and makes sure these are considered during the design phase (Rosales, 2020). Next to the mapping of the impacts, it proposes mitigating solutions for the negative effects. Therefore, it can greatly improve the design of an intervention. In the context of the Netherlands the use of EIA's is regulated through legislation. The milieueffectenrapportage (MER) is the Dutch form of an EIA and is required to be used in larger projects (Infomill, n.d.). The EIA, or MER in Dutch context, allows for the assessment of impacts and the mitigation of the unwanted impacts, aiding the design of the project. However, it is somewhat limited in providing an overall, balanced assessment. Despite this, it offers a strong foundation for such an assessment by listing the effects of the intervention and, where possible, indicating their direction.

A framework can assist in the organisation of complex subjects, especially as it can provide a comprehensive overview and create a shared perspective among various disciplines (Potschin & Haines-Young, 2016). As Munns et al. (2015) concluded, a large barrier to transdisciplinary projects is the misunderstandings that arise combining different disciplines. By employing a framework this barrier can potentially be removed, creating a shared understanding (Potschin & Haines-Young, 2016).

### *2.5.2 Mix of methods*

Previous listed methods all have their advantages and disadvantages, nonetheless they serve their goal for assessing interventions in different ways. In this research, with the complexity of peat and peatlands, and their processes, as well as the addition of nature development as another layer, multiple disciplines are combined. Creating an overview of relevant elements and their relationships can assist in providing a better understanding of this complex environment, this results in the creation of the schematic overview (figure 2) in the next section, and the extended schematic overview (figure 3) in the sub-section 2.6.2. However, this framework aims to provide another service, namely assisting in decision-making. Therefore, a relationships and effects overview is created (figure 4), with inspiration taken from the CBA, MCA, and EIA, weighing the pros and cons of the different elements, allowing for an assessment of how effective nature development in peatlands in the Netherlands can be.

## 2.6 Overviews

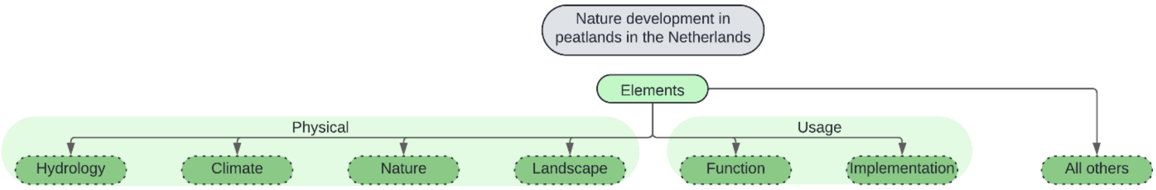
### *2.6.1 Schematic overview*

Figure 2 presents the schematic overview, which is based on the literature review identified elements, and therefore illustrates the answer to sub-question 1. The schematic overview first divides the elements by a physical and usage category. Followed by the main elements, as summarized in the boxes underneath the previous sections; hydrology (box 7), climate (box 8), nature (box 9), landscape (box 10), function (box 11), and implementation (box 12).

***Box 14: All others***

Additionally, the element of "all others" could be added allowing for the possibility of elements that were not identified as relevant in literature or cannot be categorized under the main categories. This comes from the idea that context can play a significant role in the relevant elements, or even in valuation studies in general, as noted by Vogdrup-Schmidt et al. (2017).

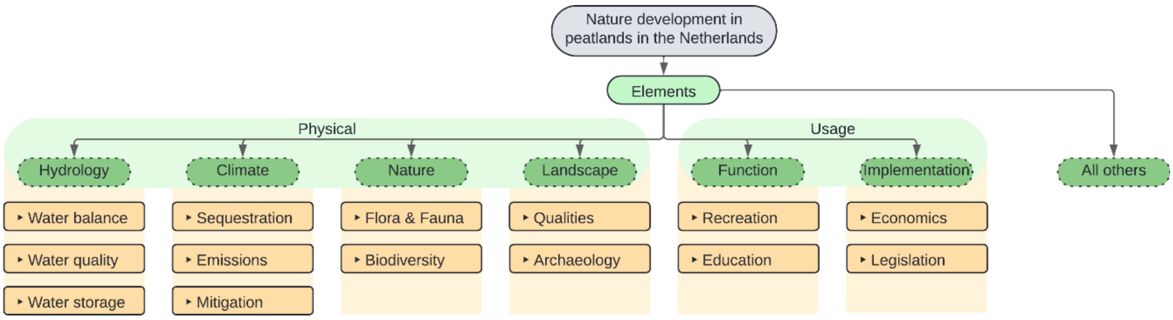
***Figure 2: Schematic overview showing elements***




### *2.6.2 Extended schematic overview*

Figure 3 presents an extended overview with as basic the schematic overview, with the addition of the sub-categories, as also identified in the literature review and summarized in the boxes. The yellow boxes showing the identified sub-categories.

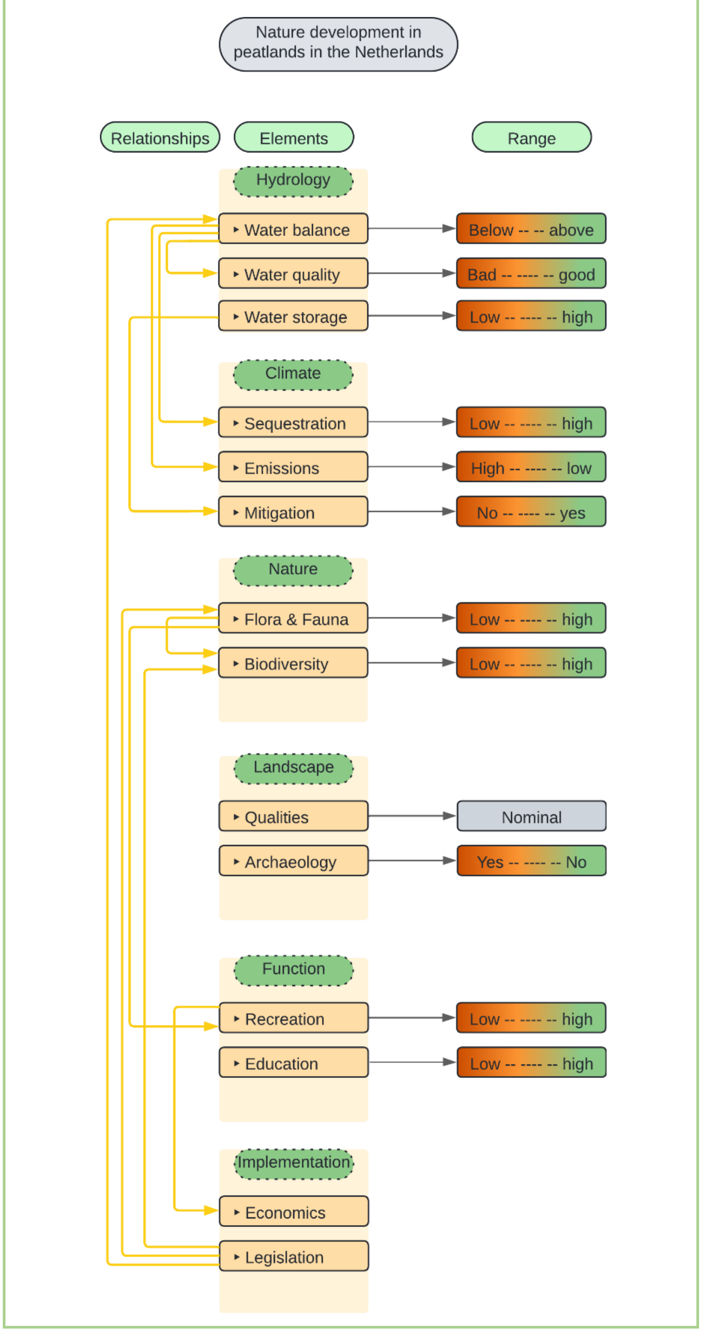
***Figure 3: Extended schematic overview showing elements and sub-elements***



### *2.6.3 Relationship and effects overview*

Based upon the literature review, the identifiable relationships and effects, and the extended schematic overview (figure 3), a relationship overview (figure 4) can be created. This figure illustrates the expected relationships between the elements, as well as the expected range of effects of the elements, therefore this figure is an illustration of the answer to sub-question 2. The effects shown in figure 4 are indicative, as the precise effects are dependent on the context, therefore these are shown in an illustrative range. Red indicating a negative effect, green a positive effect, and grey a non-identifiable effect. This model forms the basis for the operationalisation of the research, as the assessment of the elements and their effects could be aided by this overview. This will be further discussed in section 3.4.

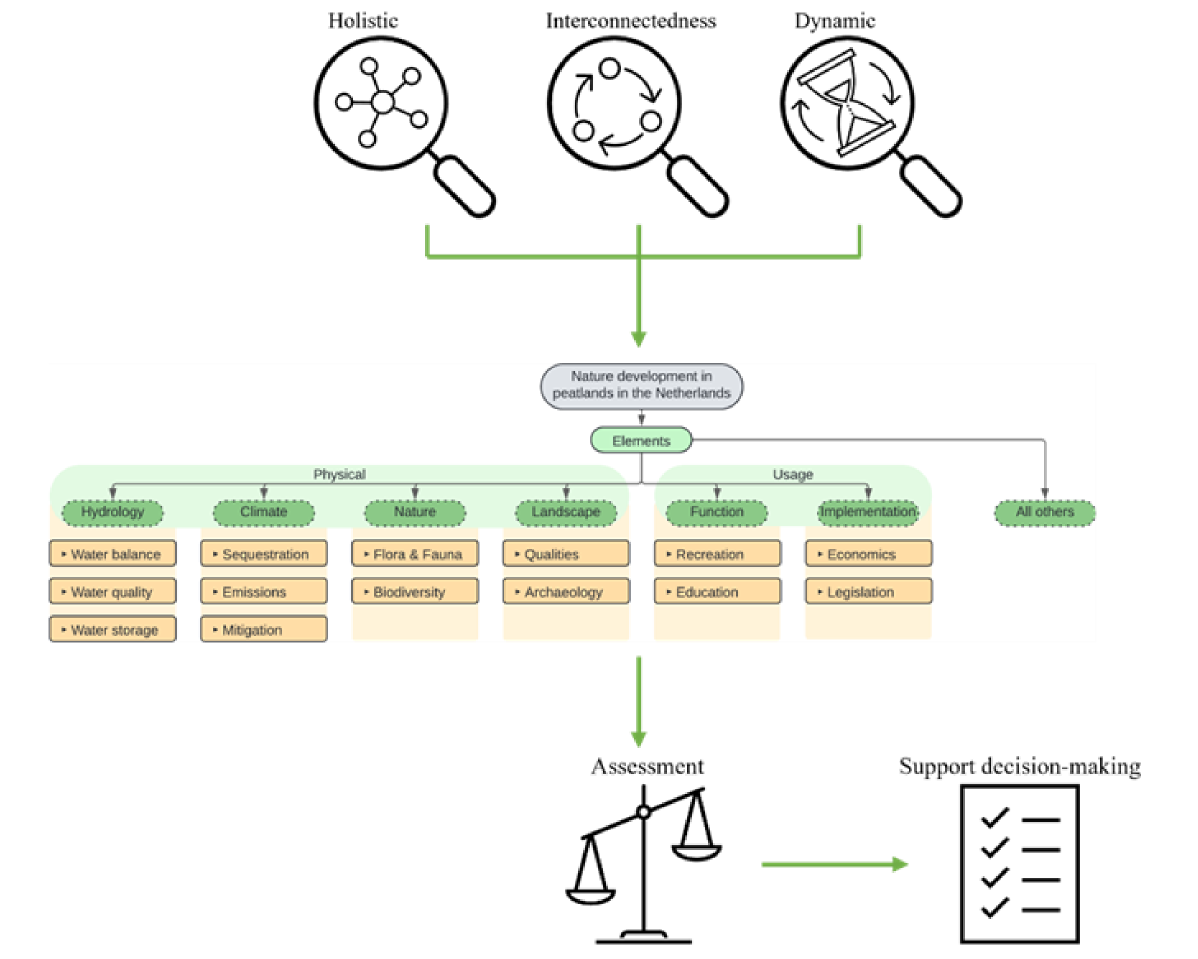
*Figure 4: Relationship and effects overview*



## 2.7 Conceptual model

This section presents the conceptual model (figure 5). The conceptual model illustrates how the lenses are used to analyse the identified elements, followed by an assessment, and subsequent supported decision-making.

*Figure 5: Conceptual model*




# 3 Methodology

In academic research deliberate choices in research design have to be made to ensure the transparency, validity, and reliability so that the research can be replicated. Therefore, this chapter explains the methodology applied in this research. Firstly, the research design is outlined. Secondly, the case study, its selection and overview are discussed. Then, the data collection methods that have been used are elaborated upon, followed by the data analysis, and lastly, the ethical considerations of this research are mentioned.

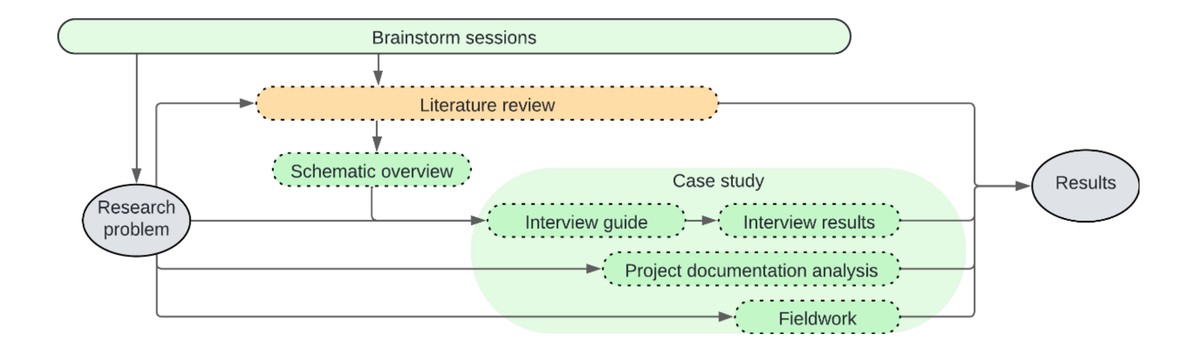
## 3.1 Research design

A qualitative exploratory research design, together with a case study, has been utilized to conduct this research. To gather data that addresses the main research question: *To what extent can an assessment of both theoretically and empirically identified elements and interconnected effects be used to support decision-making regarding nature development in peatlands?,* a combination of four data collection methods has been employed. These are: a literature review, expert interviews, analysis of project documents, and fieldwork.

The research, conducted in the Netherlands from December 2023 to August 2024, focused on nature development in peatlands in the Netherlands, and was designed to adhere to the following steps. First, brainstorming sessions with two experts from Staatsbosbeheer were conducted to establish a concrete problem statement and a first understanding of concepts and practice. Secondly, a literature review was implemented to create a deeper understanding of the relevant concepts and elements. Due to the complex nature of these concepts and elements, and their profound relationships, a brief analysis of project documents was simultaneously executed. This to be able to find a workable balance between the profound complexity and the employability of the elements and their relationships in practice. The concepts of simplification and system thinking, discussed in sub-section 2.1.2, were employed to aid in this process. Furthermore, the combination of the literature review, brainstorming sessions, and the analysis of project documents allowed for the creation of a schematic overview.

Through a case study on two separate nature developments in the Netherlands by Staatsbosbeheer, the schematic overview was applied in practice to further explore and validate the insights derived from literature. In this case study expert interviews were conducted, as well as the analysis of further project documentation. Additionally, fieldwork was undertaken to gain a deeper understanding of the subject, establish a connection with the projects, observe ongoing activities, and understand their execution. Combining these data sources contributed to addressing the research questions and formed the research results. Figure 6 shows a schematic overview of the research design.

*Figure 6: Overview of the research steps*




### *3.1.1 Qualitative exploratory research*

This research aims to assess the positive and negative effects of nature development in peatlands to ultimately support decision-making in nature development in peatlands in the Netherlands. The integral perspective on nature development in peatlands is an underresearched topic, therefore a qualitative exploratory research method can be considered most fitting (Creswell & Creswell, 2017; Leavy, 2023). *Qualitative research* characterizes through various research methods such as: different forms of interviews, field research, and unobtrusive methods (document analysis) (Leavy, 2023). The major advantage of this research approach is the collection of "rich data with descriptions and examples … with the participants concerns at the forefront" (Leavy, 2023, p.19). An *exploratory research* method can be used to develop initial insights into underresearched topics, or approach the topic from another perspective, ultimately to created new insights (Leavy, 2023). This method is characterized by a flexible and open-ended structure, allowing for new insights and adaptations during various steps of the research (Leavy, 2023).

### *3.1.2 Muddling through*

Also relevant in this research, is the term "art of muddling through", introduced by Lindblom (1959), presenting a critique on the rational planning model. Lindblom (1959) argued that the rational-comprehensive approach, which involves thorough analysis and planning through unravelling every and all elements and relationships, is often impractical in complex real-world situations due to limitations in time, information, and resources. Instead, he suggests an approach consisting of small, pragmatic steps – "muddling through" (Lindblom, 1959). This decision-making approach focuses on flexibility and adaptive learning. This research followed a process similar to "muddling through", making small steps with the use of adaptive learning to gain a better understanding of the complex world of nature development in peatlands. Using concepts as *simplification* and *system thinking* as stepping stones to "muddle through" the complex processes in peatlands. This also indicates that in practice, the research unfolded as a non-linear process, adhering to the research design but involving revisiting steps and adapting as necessary.

## 3.2 Case study

A case study can be described as "an empirical research method that investigates a contemporary phenomenon (the "case") in depth and within its real-world context…" (Yin, 2018, p.15). In this research it is relevant to assess how the literature-based elements and relationships uphold in real-world context. Next to that, Yin (2018) recognises that how or why questions are excellent starting points for deploying case studies. Following the research question in this research, a case study can be considered an appropriate research method, as the to what extent part of the question closely resonates with a how question. When designing a case study, it is critical to define the case, or in case study terminology, the units of analysis, discussed in sub-section 3.2.1.

Additionally, the choice between a single case study or multiple case study design has to be made (Yin, 2018). This study adopts a multiple case study design, enabling the comparison of two separate cases. This approach allows for a more detailed testing of the identified elements and relations and helps to eliminate the possibility of coincidental confirmation or refutation of the expected outcomes (Yin, 2018). In this research the multiple case study design consists of two separate cases, selected deliberately. Yin (2018) recognizes that no two cases are identical, allowing for the comparison between cases, however essential is a discussion on how the identical cases are sufficiently comparable (see sub-section 3.2.2). Another important aspect of the multiple case study design is the use of replication logic, being able to individually study the cases, however replicating the process (Yin, 2018). In this research this is secured by testing the elements and relationships identified from literature. Relevant for a case study design, as well as for the afore mentioned qualitative exploratory research design, is the creation of a literature review, as well as a subset of different data sources (see section 3.3).

### *3.2.1 Units of analysis*

In order to avoid overloading due to too broad research- questions or aims, careful consideration is needed when selecting the unit of analysis in a case study research design (Yin, 2018). This can be done by setting spatial, temporal and other explicit boundaries as advocated by Yin (2018). In this study the unit of analysis has several boundaries. The first is the phenomenon being studied: nature development in peatlands in the Netherlands. Nature development in peatlands in this research entails interventions to create, preserve or restore nature, with the critical intervention being the extraction of peat. The second boundary in this research is the specific locations of this nature development. Both projects are in the Netherlands. Specifically, a project in the Dutch province Brabant, Weimeren, and a project in the Dutch Province Overijssel, national park De Weerribben, which are discussed in sub-section 3.2.3 and 3.2.4.

### 3.2.2 Case selection

Figure 7: Locations

The case selection in this research was carefully considered with the aid of Staatsbosbeheer. The availability of projects within the scope of the research is limited. However, two separate instances of nature development in peatlands in the Netherlands by Staatsbosbeheer could be identified (figure 7). This forms the basis for the similarities between the two different projects. Another similarity between the projects, is the way in which this nature is developed, one of the methods used requires the extraction of peat from the ground, causing negative effects, also highlighted in sub-section 2.2.4, and in section 2.4. Another important similarity is the type of peat found in these locations, categorized as *laagveen* (=fen peat), as also discussed in the background (section 1.1) and sub-section 2.3.2. These two cases differentiate from each other in the sense that one concerns the creation of new nature, the second case concerns the preservation of the existing nature. This allows for a broader testing of the identified elements and relationships, thus also accounting for the potential differences between two different forms of nature development.

### 3.2.3 Case study Weimeren

Weimeren is a nature development project, creating new nature, in a location in the province Brabant, Netherlands (figure 8). Zooming out, this initiative is part of a larger nature development project called "Noordrand Midden," which itself is a component of the province-wide nature network in Brabant. Noordrand Midden is a collaborative initiative that brings together multiple organizations: the province of Brabant, Staatsbosbeheer, and the local water board "Brabantse Delta," collaborating to develop water-rich nature (Staatsbosbeheer, n.d.). The ambitions focus on transforming the current agricultural lands (grass meadows) into resilient natural areas, creating habitats for unique flora and fauna, thereby enriching biodiversity. At the same time, these areas will provide value to humans through water retention and recreational use.

Figure 8: Nature development Weimeren


Google Maps, 2024a, edited by author.

Figure 7: Nature development Weerribben


Google Maps, 2024b, edited by author.

### *3.2.4 Case study Weerribben*

De Weerribben is a national park in the North of the province Overijssel, Netherlands (figure 9). This fen peat, swamp together with the neighbouring national park De Wieden, is considered the largest interconnected area of its kind in Northwest Europe (Nationaal Park Weerribben-Wieden, n.d.). Characterized by canals and reed beds, this nature looks untouched, but this is all the result of human intervention in the past. Through peat excavation used for fuel, in the 20th century, the landscape transformed into valuable wetland nature, serving as habitat for unique flora and fauna species. In the current landscape the harvest of reeds is still ongoing, there is a combination of nature and agriculture. In addition to the area's rich biodiversity, it also serves as an important recreational destination. To preserve this unique landscape, its nature, and biodiversity, periodic interventions are crucial. The focus in this case lies on the preservation of the existing nature, by extracting peat, and creating open water. This intervention is undertaken in the area “Kooi van Pen” (part of De Weerribben). This preservation of nature in “Kooi van Pen" is part of a larger nature development, where new nature is created in two additional, separate areas. However, the creation of the new nature is not considered, as this is already the focus of the Weimeren case. As mentioned in sub-section 3.2.2, focussing on another form of nature development is deliberate.

## 3.3 Data collection methods

### *3.3.1 Literature review*

A literature review involves "the process of searching for, reading, summarizing, and synthesizing existing work on a topic, or the resulting written summary of the search" (Adler & Clark, 2011, p. 89). This research started with a concise literature review on peat and peatlands, which uncovered the complexity of the studied subject. Given the spatial planning perspective in this research, theories and concepts from this field were explored in literature to providing tools assisting setting boundaries for the subsequent extensive literature review. The concepts of simplification and system thinking (as explained in sub-section 2.1.2) were used to achieve this goal.

Next to that, the structure and definitions used in two seminal works were utilized to guide in the extensive (in times conflicting) literature on peat and peatlands. The handbook by Rydin and Jeglum (2013) was used to give insight into processes within peatlands, and the book by Keddy (2010) was used to uncover the larger picture of wetlands and their effects on our surroundings. Subsequently, an extensive literature review was conducted to explore relevant concepts, elements, definitions, debates, and relationships. This review first focused on peat and peatlands, followed by nature development in the Netherlands, and finally integrated these perspectives. Further, a brief inventory of commonly used evaluation methods was undertaken, to identify potential methods to assist in assessing the identified elements and their relationships. The structure of these steps is based on answering the sub-research questions 1, 2, 3 and 4. The different results following this literature review are discussed in the literature review (chapter 2), and provide the foundation for the creation of the overviews (section 2.6) and the interview guide (appendix A).

The literature used in this research was found through a structured search for academic literature based on a list of key terms, starting with general terms such as: *peat, peatlands, wetlands,* and *bogs and fens.* Later expanded by adding more specific terms, based on further identification of relevant elements and relationships, for example: *hydrology, water table, climate effects, carbon sequestration, nature, flora and fauna,* and *nature restoration* (see table 1). Sources were selected based on their relevance to the research problem, their contribution to understanding the elements, processes, and relationships, and the insights they provided to support the research objectives. SmartCat and Google Scholar, two databases for academic literature, have mainly been used to collect sources. However, some insights have been gathered through the use of hardcopies, often recommended by experts. An amount of grey literature has been analysed as well to create an understanding of the legislative context in the Netherlands, this was sourced through the use of search machines as Google.

*Table 1: Overview of key terms literature*

| Definitions of main concepts | Peat | Nature development |
|---|---|---|
| Spatial planning- practice | Hydrology, water table, quality | Legislation, nature networks |
| Peat, peatlands, wetlands | Climate, sequestration, emissions | Economy, funding |
| Nature development | Nature, flora and fauna | Restoration, creation, preservation |
| | Landscape, archaeology, features | Recreation, purpose, goals |

### *3.3.2 Project documents*

Documentary data is increasingly available through internet searches and can be considered useful to almost every case study topic (Yin, 2009). These documents come in a wide variety of forms, ranging from formal studies, progress reports, to news clippings and public announcements, and provide valuable source of secondary data (Yin, 2009). The advantages of using these documents include the ability to review them repeatedly, the precise details of the data, and their broad coverage (Yin, 2009). However, bias by author and selectivity bias, as well as difficulties in the retrievability of documents should be carefully considered (Yin, 2009). To answer research sub-questions 5, 6 and 7, and to get a better insight into the projects studied in the case study, project documents were analysed. These documents comprised of, project updates, news articles, and internet pages, as well as formal documents such as project plan designs and reports. These documents were retrieved through internet searches, as well as through recommendation by experts. Especially the project plan designs and reports provided valuable information into the project design and its considerations, consecutive steps in the project, and the context. Table 2 shows an overview of the most important project documents used in this study, as well as the number which is used to reference the document in chapter 4 and chapter 7.

*Table 2: Overview project documents*

| Nr. | Name | Location |
|---|---|---|
| Doc. 1 | MER Noordrand-Midden fase 1 | Weimeren |
| Doc. 2 | MER Noordrand-Midden fase 2 | Weimeren |
| Doc. 3 | Inrichtingsplan Natuurontwikkeling Weimeren fase 1 | Weimeren |
| Doc. 4 | Natuurontwikkeling Weimeren fase 2 | Weimeren |
| Doc. 5 | MER Weerribben | Weerribben |
| Doc. 6 | Planuitwerking interne natuurherstelmaatregelen | Weerribben |
| Doc. 7 | Werk in uitvoering: De Weerribben | Weerribben |

### *3.3.3 Expert interviews*

Through interviews another form of data can be collected, primary data. Through verbal exchange the interviewer attempts to obtain respondents views on the studied subject (Dunn, 2000). In this study two forms of interviews were conducted, unstructured brainstorming sessions with two experts, and semi-structured interviews. The brainstorming sessions were employed to set a clear problem statement, gain a first understanding of relevant elements, help with the identification of relevant project documents, as well as the identification and organisational aspects for the expert interviews and fieldwork.

Semi-structured interviews are a form of interviewing that allows for a flexibility through the use of open-ended questions, allowing for an in-depth exploration of the subject (Seidman, 2006). The semi-structured interviews were used as an additional source of data, and for validation of the elements and relationships identified in the literature review.

Brainstorming sessions were conducted online via Google Meets and were arranged 10 times during the research period from December 2023 to August 2024. The conversations with two experts were an extensive source of background information. The semi-structured interviews were conducted on the project locations and consisted of focus groups. The experts were recruited with the help of Staatsbosbeheer. Through the brainstorm sessions the correct experts were identified. The first interview consisted of three experts, the second interview of two experts, as illustrated in table 3. In these interviews the focus was on the verification and validation of the identified elements and their effects, as well as on the collection of new data. The semi-structured interviews were supported by the interview guide (appendix A), and the early iterations of the schematic overview and extended schematic overview (figure 2 and 3). In chapter 4 the experts are referenced by the identification given in table 3.

*Table 3: Overview of the interviewed experts*

| Interview | Function | Identification |
|---|---|---|
| 1 | Ecologist | Expert 1 (E1) |
| | Project manager | Expert 2 (E2) |
| | Project developer | Expert 3 (E3) |
| 2 | Area manager | Expert 4 (E4) |
| | Project developer | Expert 5 (E5) |

#### *3.3.4 Fieldwork*

Both in Weimeren as in De Weerribben fieldwork was undertaken to create a better understanding of the locations, the interventions, and to observe the effects. Literally smelling, hearing, and seeing the subject of research with the boots in the mud, right on top of the peat, helped to create a deeper understanding of the interventions.

## 3.4 Data analysis

The same way as the identified relationships and effects were illustrated in the relationship and effects overview (figure 4) in sub-section 2.6.3, the data from the case studies was used to give direction to the range of effects. By analysing the cases and applying the data to the relationships and effects overview, an assessment of the cases was done. This resulted in various insights. Subsequently, enabling the assessment of the nature development in peatlands in the Netherlands, as depicted in the conceptual model, section 2.7 (figure 5).

## 3.5 Ethical considerations

Ethical considerations are fundamental in scientific research to ensure validity, reliability, and the protection of participants' rights and well-being (Clifford et al., 2010; Bryman et al., 2016). To protect experts, informed consent was obtained before interviews started. The consent was given to the following aspects: participating in interviews, recordings of the interview, and that all information will be processed anonymously. Further, the information was handled carefully. Next to that, transparency and integrity were upheld throughout the research process, with disclosure of any potential biases or conflicts of interest that could influence findings.

# 4 Empirical findings

This chapter presents the analysis of the identified elements and sub-elements in the extended schematic overview (figure 3), plus their direction following the relationships and effects overview (figure 4), with the use of the collected data on the case studies. First by analysing the project of Weimeren, followed by the analysis of the project De Weerribben. This chapter finishes with an overview of the similarities and differences based on the comparison of the two cases.

## 4.1 Weimeren

Within the Weimeren project, the creation of new nature is achieved through a range of interventions and measures. These include, among others, the extraction of peat, the planting of specific flora species, and the implementation of water table adjustments. This intervention can be seen as a large-scale project where nature is created following a precise plan. In the following sub-sections, the effects of the elements and sub-elements deranged from project documentation, fieldwork, and the interview are listed.

### *4.1.1 Hydrology*

In Weimeren a natural water table is used within the area, which allows for higher levels in winter with gradual lowering throughout the dryer summer months. In addition to that, the water table can be artificially influenced, allowing for extra water to compensate for dry conditions. This to ensure the intended nature stays healthy (doc. 3). The *water balance* follows the nature function of the project area. This has several positive effects, for example on the nature and the peat. In document 4, another effect of the water table is identified: higher water levels in adjacent areas. While this impact is limited and only affects small regions, it could potentially have negative consequences on those areas. The interconnectedness (one of the lenses from figure 1) between elements can be identified in this sub-element, for instance between the water table and nature.

The *water quality* in Weimeren is an interesting element because of the various expected results through time, as well as the influence this sub-element has on the success of the project (noted in doc.3). First, during and shortly after the interventions leaching of particles from the peat can be expected, as the peat is disturbed due to the extraction of the layers on top. However, later on, the water quality improving characteristics of peat can be reestablished. Furthermore, the water quality has a large influence on the achievement of the set nature goals in this project (doc.3). Nutrient levels in the water largely dictate the flora species that will form in the area, and thus will steer the kind of nature that forms. For the success of the nature development and the realization of the intended nature water quality plays a critical role.

Further diving into water quality on a project level shows another interesting layer for this sub-element. Through research the potential water quality is modelled, on which 'boundary conditions' (randvoorwaarden) are set. These boundary conditions are listed and then integrated into the design of the project by setting conditions for the ways of execution. These conditions can be seen as mitigating measures. Both the MER documents (doc. 1 and 2), as well as the project design documents (doc. 3 and 4) show these boundary conditions and the subsequent design choices. The reason for the use of the mitigating measures is to assure that the interventions have the foresighted outcome. Additionally, the need for these design choices suggests that the initial effects can potentially be negative, or that the standalone initiative allows for a chance to add additional qualities. An example of the boundary conditions and the subsequent mitigating measures from document 3 is shown in figure 10. Figure 10 shows three of the in total seven boundary conditions and design choices for water quality in Weimeren.

*Figure 8: Boundary conditions and design choices on water quality in Weimeren*

| Randvoorwaarden waterkwaliteit | Inpassing in ontwerp |
|---|---|
| Minimaal 20 % van het oppervlaktewater moet ondiepe zones hebben < 1 meter. Dit is van invloed op de waterkwaliteit, maar ook op het voorkomen van structuur voor macrofauna en vis. | Rietmoeras met ondiep water beslaat meer dan 50 % van het open water, de zoete plas heeft flauwe taluds 1:10 tot 1 meter waterdiepte, daarna talud 1:3. Waterplanten, macrofauna, vissen kunnen deze zone optimaal gebruiken. |
| Bestaande bovengrond niet toepassen in de plas vanwege ongewenste voedselrijkdom | Bovengrond fase 1 wordt afgevoerd/ en of verwerkt in het terrein. Bovengrond wordt niet verwerkt in de plas. |
| Het talud dat voornamelijk uit veen bestaat zo vroeg mogelijk 'vastleggen' m.b.v. waterplanten of riet, en eventueel krabbenscheer | Na aanleg wordt deel van de oevers voorzien van rietaanplant |

*Inrichtingsplan Natuurontwikkeling Weimeren fase 1, 2019, edited by author.*

The boundary conditions and design choices shown in figure 10 are now briefly discussed to illustrate how this influence the assessment of the sub-element water quality. The first section of the table describes the boundary conditions, and the second section of the table shows the design choices to realize the boundary conditions. The first boundary condition concerns the depth of certain zones to influence both the water quality and fauna species. The subsequent design choices show how this is ensured in the design through dictating the depth and the slope of the embankments. This combination of boundary condition and design choices shows the interconnectedness between elements as well as a holistic approach to the design. The second boundary condition entails the usage of the top layer of ground which is excavated. The design choice ensures that this ground is not used in the lake to realize the foresighted water quality, which is also related to the set nature goals. Again, showing an interconnected and holistic approach to the design. The third boundary condition describes the capture of the peat layer within the embankments through the use of water plants and reeds. The design choice logically consists of reeds being planted on parts of the banks (see figure 11).

The three combinations of boundary conditions and design choices used as example (figure 10), together with the other seven measures (doc. 1, 2, 3 and 4), illustrate the efforts to ensure a fitting (good) water quality. These mitigating measures are an illustrative example of the milieueffectenrapportage (MER = EIA) implementing mitigation to battle aversive impacts in the design phase of the project. This also holds value for the other elements, as this is done throughout the project. For the assessment of the elements and sub-elements the project level mitigation measures add another layer, as negative effects are (partially) influenced, (potentially) undone, or accounted for. An overall assessment of the water quality is therefore difficult. However, similar to document 2 and 4, that conclude that a light positive effect could be expected within the area after the realisation, a light positive effect is given.

The *water storage,* as a characteristic of peat itself, gradually releasing water into the environment and therefore serving a water regulating purpose, as discussed in the literature review (chapter 2.2.3) will be greatly reduced due to the extraction of peat in the area. However, over a longer period of time, with peat regrowing, this effect will slowly return. Water storage could have another definition, which is not discussed in the literature review, namely the storage of excess water coming from a river. This will be further discussed in chapter 4.1.7.

### *4.1.2 Climate*

The *sequestration* effect of the landscape is a difficult to assess sub-element, both to assess on itself, as well as, to give direction. This is because of the difficulties with getting hard data on the actual sequestration abilities of the landscape. However, extracting peat is likely to result in a lower sequestration of $CO_2$. Nevertheless, since the current landscape is semi-natural, it has little to no sequestration capabilities of its own. The future landscape, after the nature development, is expected to show sequestration abilities as peat is accumulated over time (doc. 4). However, this is subject to various small scale, complex processes, influenced by many other effects. So, an unambiguous assessment cannot be made.

The *emissions* of the intervention will be high when assessed in the short term. As large amounts of peat are extracted from the ground, $CO_2$ emissions will be significant. However, as noted by expert 1, over the long term the emissions can potentially be lower than the old landscape. This can be expected because of the creation of a robust nature area, where a natural water level is managed (doc. 3). In comparison to the old landscape, where a lower, agricultural water level was maintained, the emissions from the peat can be expected to be lower. Again, this shows the interconnectedness of the sub-elements as the water table influences the sequestration and emissions. In the short term the emission of $CO_2$ as a result of the creation of nature can be deemed as a significant negative effect. Over a longer period, the nature development and subsequent landscape abilities can provide positive effects.

The nature development can greatly improve the climate *mitigation* abilities of the landscape. The robust nature landscape with a natural water table allows for the accumulation of peat (and thus sequestration of $CO_2$) over time, as described before. Additionally, the effects of increased biodiversity and a robust nature network itself on the climate should not be underestimated (E1). The increased biodiversity in the nature area can potentially have positive effects on the environment in the form of for instance increased pollination (E1).

### *4.1.3 Nature*

*Flora and fauna* species play a critical role in the nature development, it basically forms the nature. On a project level, during the realisation the existing flora and fauna species can be expected to be disrupted. The old situation was researched, with a special focus on the presence of endangered or listed species (doc.3 and 4). Subsequently, as also illustrated in figure 10, deliberate design choices (mitigating measures) are undertaken. This ensures for instance that the ecologically valuable forests are preserved. Another notable example is the mitigating measures for the protected frog species: 'poelkikker'. This frog needs small ponds to breed. During the realisation of the nature the existing ponds will disappear, however, new ponds are created to serve the frogs (doc.4). In addition, special screens are placed to protect the frog from machines carrying out the realisation of the project (figure 11). This, again, illustrates the mitigation measures on a project level to limit or compensate negative effects. In general,

***Figure 9: Mitigation measures in Weimeren***

On the foreground of the picture frog screens, on the right side of the picture planted reeds with protection nets, picture by author, 2024, Weimeren.

with reduced human influence in the area, the ecosystem can develop relatively undisturbed. It is therefore expected that various special (potentially endangered) flora and fauna species will establish themselves in the newly created nature. This relatively quiet area also provides opportunities for more common animal species to thrive.

On a broader scale, the project is part of a nature network within the province, which enhances the ecosystem by creating a larger, interconnected natural area. Through the combination of various forms of nature, for instance open water, swamp areas and grasslands with a wide variety of species, great chances for an increased biodiversity are created (E1 and doc. 2). This nature with waterbodies and a large variety of flora species offers habitats for swamp and water birds, as well as fish and dragonflies. Both for lora and fauna, the *biodiversity* will be greatly enhanced compared to the old situation.

This gain in biodiversity is partly subject to the ability of the nature to fully establish in this area. Even though designed, and as illustrated before, partially controlled through mitigating measures, nature has its own will. *"Nature always surprises"* (E1). Showing a dynamic process, nature does not always follow the rules, sometimes attracting unexpected species for instance (E1). Time is another factor that has an influence on nature, or more precisely, on the effects to present themselves. As nature is growing, results only show after time has passed (E1).

### *4.1.4 Landscape*

As a consequence of the nature development and its physical interventions the *landscape* will be greatly altered. From a grass meadow dominated landscape, with a historical arrangement formed by straight roads and ditches, it will be turned into a water rich nature area. As described in sub-section 2.3.2, this landscape is valued for representing cultural heritage, and its open characteristics (doc. 2). Through deliberate design choices parts of the sight lines in the landscape are preserved (E3, doc. 3, doc.4). Similarly, through design choices, a historically present quay will be reestablished (doc. 2). Nonetheless, the landscape will lose its current state, and be turned into a completely different form of landscape. Assessing the new landscape *qualities* compared to the old landscape, and labelling this as positive or negative, is subjective.

In the early stages of the project, before the realisation started, extensive research was done into the potential *archaeological* value of the project area (doc. 2). This research is required by law when significant soil-disturbing interventions are planned. The largest parts of the project area were marked as low archaeological expectancy value (doc. 2). This means that, even though not completely ruled out, the chances of finding or disturbing archaeological findings are minimal. This also means that the assessment of this sub-element is neutral.

### *4.1.5 Function*

The *recreational* values of the landscape are, similarly as the landscape element, subjective, as every user can value the landscape and recreational function differently. Nonetheless, recreation is of the essence in the project (doc. 4). Staatsbosbeheer values experiencing the landscape (box 13), which can also be seen in the efforts to realise a nature area that provides value to both nature and humans (doc. 4). The inner part of the nature area will be closed to the public, however, on the borders hiking paths and observation platforms will be implemented to allow for recreational use of the nature area (E. 2 and doc. 4). To identify and realise valuable recreational elements for users, participation from stakeholders was used (doc. 4). This resulted in deliberate design choices in the form of for instance cycle paths, adventurous hiking paths and an observation hill (doc. 4). Through the various measures, as a consequence of integrating recreation into the scope of the project, the recreational value of the landscape will be positively influenced by the nature development.

*Education* as function of a landscape can be closely linked to the recreational values of the landscape, as both can occur when “using” a landscape. Even though the project documentation used in this research does not explicitly mention educational benefits, positive effects on this sub-element can be expected. The biodiversity rich nature area, together with the measures that allow for the use of the landscape, provide an improved chance for education on nature for users.

### *4.1.6 Implementation*

The *economic* element to the nature development in Weimeren is a multi-faceted story which is closely intertwined with legislation, the design and the realisation of the project. Without going into a high level of detail or through the complete timeline of the project design, some aspects can be highlighted. The finances for the nature development project come from a set of sources. The first is subsidies available for nature development (doc. 4). The second source is a collaboration between Staatsbosbeheer, the province of Brabant, and the waterboard Brabantse Delta, which will be discussed in more detail in sub-section 4.1.7. The third source of financing comes from the nature development itself. With the realisation of the nature soil has been extracted, a topsoil layer, and a lower layer consisting of peat (E2).

This soil was extracted to create the intended nature, including a larger pond for open water, and specific designed banks to create peat forming nature as described in sub-section 4.1.1. Selling the extracted materials forms the third source of financing, but also means that materials are re-used and thus not wasted. The destination of the topsoil layer will be discussed in sub-section 4.1.7., the extracted peat finds an useful application at a mushroom grower (E3 and doc. 2). Using the peat for this application not only benefits the financial part of the project, but it also offsets a part of the emissions related to extracting the soil (E3). This is due to the significant shorter distance the peat, used in the process of mushroom growing, is transported compared to the regular business operation of the grower (E3). Especially as parts of the quantity of peat are transported by boat, further reducing emissions (doc. 1). This action, combined with bringing the materials to use, even though linked to the economic sub-element, illustrate a new sub-element which will be elaborated upon in section 5.1.

An ambition and a perspective form the basis for the nature development in Weimeren. However, as with all other spatial interventions in the Netherlands, *legislation* is an important sub-element, guiding a development, through laws and regulations. The legislation is of an even more important role on a project level, influencing all other sub-elements, again, showing the interconnectedness and a holistic perspective (figure 1).

#### *4.1.7 All others*

As mentioned before (sub-section 4.4.1), the sub-element water storage could have another definition than identified in the literature review. The Weimeren project area (also before the nature development) full fills a water storage function for the river 'De Mark' which borders on the North side of the nature area (doc. 1 and 2). When this river experiences high water levels, the area can serve as an overflow zone. By allowing water to flow into this area and retaining it, other areas downstream can be kept dry. This water storage function can be closely related to climate mitigation, as in the future these kinds of water retention areas can prove to be vital to keep important areas dry.

Similar to the re-using of the peat discussed in the previous sub-section another element, which does not completely fit the extended schematic overview (figure 3), can be identified, which is best captured by the Dutch word 'koppelkans' (= coupling opportunity). Through the collaboration between several organisations including Staatsbosbeheer, the province Brabant, and the waterboard Brabantse Delta, a coupling opportunity could be found between the nature development and the reinforcement of the dike bordering the nature area. The aforementioned topsoil layer coming from the nature development will be used for this reinforcement (E2, doc. 1). The collaboration between the projects brings benefits in the form of for instance cost-effectiveness and sustainability advantages.

***Box 15: definition of 'koppelkans'***

'Koppelkans' (= coupling opportunity) is a Dutch term for the benefits coming from combining projects or initiatives.

### 4.2 Weerribben

The national park De Weerribben is an unique area in Europe, which is highly valued for its biodiversity, unique landscape, and cultural heritage. To preserve the biodiversity and nature, maintenance has to be undertaken periodically. Due to natural growth the areas of open water shrink significantly, which reduces the variety of the landscape. Especially this variety of the landscape attracts rare flora and fauna species. Through the creation of long narrow ditches (in Dutch = petgaten), by extracting the soil, the variety of the landscape is reestablished, by adding open water. Other interventions, such as the removal of specific trees, as well as species specific measures, are simultaneously undertaken. This preservation is part of a larger nature development in De Weerribben, consisting of two additional, separate areas.

The focus in this part of the research is on the preservation interventions in the area "Kooi van Pen", as also further explained in sub-section 3.2.4. In the following sub-sections, the effects of the elements and sub-elements deranged from project documentation, and the interview are listed.

### *4.2.1 Hydrology*

The *water balance* in De Weerribben variates throughout the different areas (doc. 5). In the target area "Kooi van Pen", the water table fluctuates, but is generally high, just below the surface layer (doc. 5). The nature development has an effect on the water balance in the sense that there will be more open water than in the current situation, however this does not directly result in a standalone effect. In relation to for instance the sub-elements flora and fauna, and biodiversity, this will have a positive effect, this will be further elaborated upon in the corresponding sub-elements.

The *water quality* in De Weerribben is important on a large scale, as the nature area functions as a natural water filter (E4). On a smaller scale, as a direct result of the nature preservation intervention, with the extraction of peat. In this specific area the water quality will be negatively affected for a short period of time (doc. 5). Due to the extraction of the ground layers in contact with the water, clouding of the water can be expected. Through deliberate design choices in the execution of the intervention, the negative effects are limited (doc. 5).

The ability of the peat to store water is similar as to the process described in the Weimeren case, and thus locally reduced by the extraction of peat. However, this ability is reestablished overtime by the regrowing of peat. Furthermore, as also observed in the Weimeren case, the alternative definition of *storing water*, as a retention area, is recognized (E4). However, in De Weerribben this retention function is linked to the ability of the peat to store water, as the area functions as a large sponge, slowly releasing water to the environment (E4).

### *4.2.2 Climate*

The *sequestration* capacity of the landscape will be reset in the areas where peat is extracted. These areas will start to form new peat growing vegetation and thus capture $CO_2$ all over again. The precise sequestration abilities, and thus the amounts of $CO_2$ captured, before and after the intervention, are unclear. Therefore, no effect can be connected.

E*missions* related to the nature preservation can be expected, and will be significant, as peat is extracted from the ground. $CO_2$ emissions will be high due to the decomposition of the peat, which is stored within the nature area itself. This will result in a significant negative effect for emissions.

De Weerribben as a whole play a large role in *mitigating* climate effects in various ways. As mentioned before, the area function as a sponge, slowly releasing water to the environment, thus evening out peaks in water quantities, relevant in the light of climate change mitigation. Furthermore, the peat rich nature functions as a $CO_2$ sink. Even with the nature preservation interventions slightly reducing this function, this reduction can almost be rendered insignificant due to the size of the total area, and its subsequent amount of $CO_2$ stored. However, as mentioned by expert 4 this crucial function of this nature area does not receive the attention it deserves.

### *4.2.3 Nature*

The *flora and fauna* species in De Weerribben are labelled as exceptional (doc. 7). Several rare fauna species find habitat in the nature area (doc. 6 and 7). Especially the "grote vuurvlinder" (= large fire butterfly), living in De Weerribben, is special, since this is the only place on earth where it is found (E4, doc. 6 and 7). Enlarging its habitat, but also creating suitable conditions for the butterfly to live, in existing nature, through for instance the removal of young trees from the banks of ditches, are part of the nature preservation (doc. 6). Another striking example of the species-specific interventions is the accommodation for the Black Tern (in Dutch = Zwarte Stern), a small bird thriving in peatlands. Through the deployment of 80 small rafts, the perfect location for a nest is provided, helping this bird in its activities (doc. 6). Several rare flora species can also be found in De Weerribben. The extraction of the peat will reset the growth of the nature in this landscape. This allows for the growth of for instance rare forms of peat (in Dutch = trilveen) (doc. 6). However, the full effects of this intervention will take decades to show, as the vegetation has to accumulate for peat to grow. The flora and fauna species currently living in the area where the interventions are taken place, are marked, on which design choices can be made, to limit negative effects. The attention for the specific, rare, flora and fauna species results in a positive effect. Additionally, less rare, 'normal' nature will also benefit from the interventions, resulting in significant positive effects.

The *biodiversity* of De Weerribben is one of its core qualities (E4 and doc. 7). By resetting the landscape, as described before, the variety of nature in the landscape is reestablished. This variety is characterized between wet and dry nature (doc. 7). This strengthens and enhances the biodiversity, as the large number of species thrive in this mix of special nature. Especially the realisation of new open water, through the extraction of peat in long narrow ditches (in Dutch = petgaten), will contribute to providing habitat for several fauna species.

### *4.2.4 Landscape*

The landscape of De Weerribben is, as described in sub-section 3.2.4, largely human-made. The cultural heritage is visible in almost all aspects of the landscape. To name two aspects: several small windmills can be discovered hinting at the water management efforts in the past, and straight sightlines through a labyrinth of ditches and channels can be observed, showing the peat extraction of the past. The extraction of peat will be the best visible intervention and will alter the landscape significantly. To compliment the cultural heritage *qualities,* and to contribute to the 'story' of De Weerribben*,* the long narrow ditches are created in locations where historically similar ditches could be found (doc. 5). Additionally, the historically open character of the landscape will be reestablished in certain areas by removing trees, this will then add *qualities* in a more diverse alternating landscape (doc. 6). However, during and shortly after the intervention, the landscape will temporarily lose its natural look.

The *archaeology* expectations in De Weerribben are low, as large parts of the area were not accessible for centuries due to extensive swamps (E4, E5, and doc. 6). On the few historically higher located grounds the archaeological expectations are higher, therefore the extraction of peat will not be implemented in these locations. The other, smaller scale interventions do not have an effect on archaeology. This means that through design choices no effects can be expected on the archaeology sub-element.

### *4.2.5 Function*

The *recreation* function of De Weerribben is high. Many people enjoy the landscape for its diverse nature, cultural and historical background, and overall appearance (E4 and doc. 7). During the extraction of peat, as stated before, the nature in specific areas will be reset. This means that afterwards the nature needs time to regrow, the non-natural look of the landscape could have a small, temporary negative effect on the recreation in these specific areas (doc. 5). Over a longer period of time, the increased biodiversity, and the potential of new or expanded groups of rare species, could improve the recreational function. No clear direction can be given to this sub-element.

The *education* function of the landscape is not addressed in the project documentation in the sense that users will learn by using the newly created landscape. Unmistakenly, this can be the case in De

Weerribben as tours through the nature area are organised, and numerous information points are present on several locations. Let alone, the educational value of perceiving the cultural and natural aspects of this unique landscape. However, education can be found in the close monitoring of the success of the interventions. The results of the resetting of the landscape through the extraction of the peat are relatively unknown (doc. 5 and 6). By closely monitoring the results of the intervention on nature, insights into the use of these interventions are gained.

#### *4.2.6 Implementation*

The *economics* of the interventions in De Weerribben is, similar to the Weimeren case, a multifaceted story. However, it is substantially different due to the project being nature preservation instead of nature creation. However, it does not provide a clear negative or positive effect. The economic aspect is, again, closely linked to the legislation sub-element, as subsidies and funding are based on regulations and laws.

The interventions in De Weerribben are a direct result of *legislation*. The regulations and guidelines applicable to De Weerribben (Natura2000) dictate the management of the nature, and thus also (partially) how the nature is developed. The creation of open water is an intervention resulting directly from regulations aimed at preserving the nature and its qualities. However, this does not give an effect to this sub-element, it, again, steers the nature development.

## 4.3 Similarities and differences

The most striking similarities and differences between the two cases are now briefly discussed. First, the significant influence of scale, time and perspective on the effects, and the direction of the effects, is recognized in both cases. This is further discussed in section 5.2. Another similarity can be recognized in the influence of the mitigating measures in both cases. Through deliberate design choices and precise mitigating measures negative effects are reduced or even completely eliminated. This, however, adds another layer to the scale, or level of detail, of the assessment.

The most striking differences between the two cases can for a large part be related to the differences coming from the creation of new nature opposed to the preservation of existing nature. Relevant examples of this can be observed in the coupling opportunities, which are very influential in the case of Weimeren. Due to carrying out a large-scale project, both in size, as in the list of interventions, developed from scratch, coupling opportunities are possible. When working with existing nature, and the smaller scale of the project, in the sense of a shorter list of interventions, coupling opportunities are limited. Another relevant example is the positive effect realized in the Weimeren case by re-using the peat, thus limiting (although not completely undoing) the effects of the emissions as a consequence of the nature development. In De Weerribben project, the re-using of the extracted peat was also inventoried, however due to practical implications and the connected financial aspect, could not be realized (E4). The practical implications relate to the transportation of the peat from the extraction site to a location outside of the nature area. Not only does the transportation of the peat through the existing nature present financial challenges, it also potentially harms the existing nature (E4). When developing new nature, on a large scale, when designed correctly these challenges are not so apparent.

# 5 Evaluation

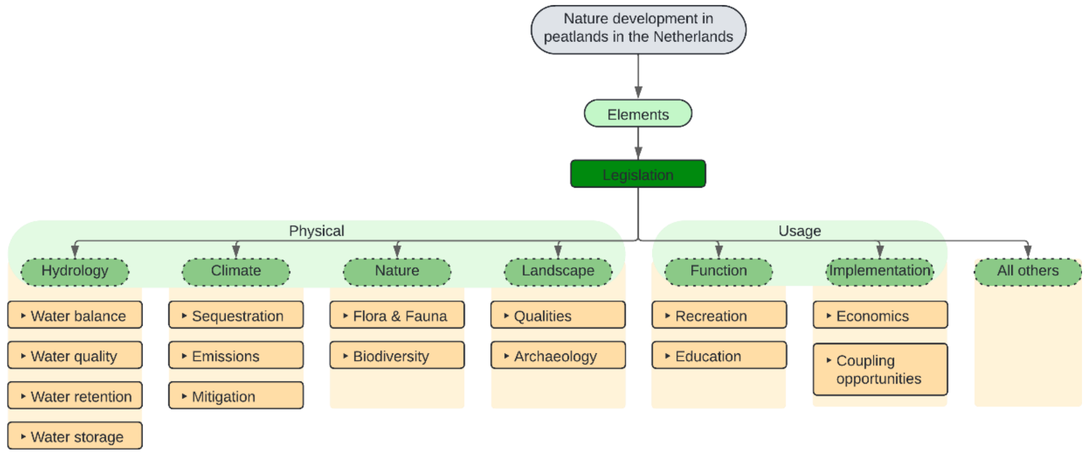
This chapter presents the evaluation and discussion of the empirical data analysis of the cases. First, by debating the implications of the data from the cases for the extended schematic overview. Secondly, by looking at the implications of the data for the relationships and interconnected effects, needed to assess the project. Subsequently, factors that are of influence on the assessment are discussed. Furthermore, the assessment of the cases is briefly discussed. Finally, further observations are elaborated upon, including the extent to which the assessment can be used to support decision-making.

## 5.1 Schematic overviews

### *5.1.1 More advanced schematic overview*

The extended schematic overview provided in sub-section 2.6.2 (figure 3) forms the basis, or structure, for the assessment of the projects. This overview can be adapted to align with the findings from both cases. The main elements: hydrology, climate, nature, landscape, function, and implementation, proved to be relevant both in Weimeren, and in De Weerribben. The sub-elements were also subject to similarities, however, more importantly, also provided new insights. The new insights resulted in the re-organizing of the extended schematic overview, and the addition of two new sub-elements, creating a more advanced schematic overview (figure 12). The following paragraph discuss the new insights from the empirical analysis of the cases for the extended schematic overview.

*Figure 10: More advanced schematic overview*



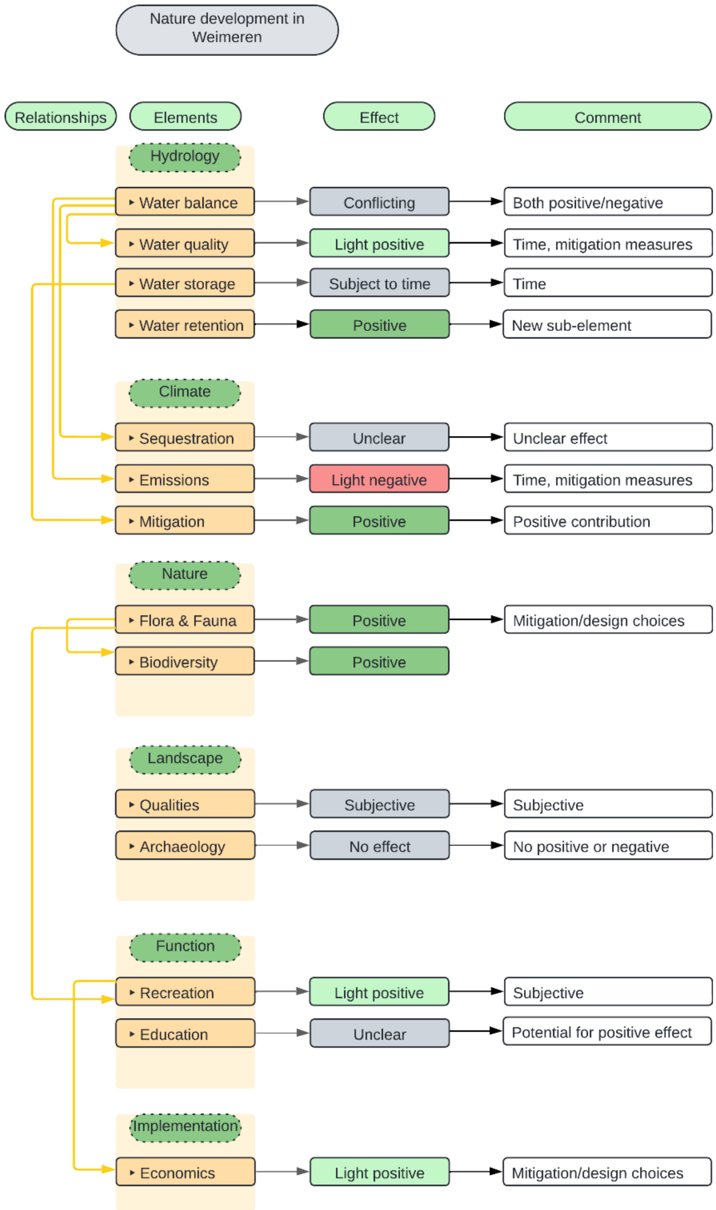

The first new insight, results in relocating the sub-element 'legislation' above the overview instead of forming a single sub-element, as legislation is part of all sub-elements. As discussed in sub-section 4.1.6, and 4.2.6, legislation proved to be of a more important role when looking at the cases. Therefore, a different place in the schematic overview, overarching instead of as a sub-element, is more fitting. The second new insight, results in the new sub-element: water retention. In both cases, it became clear that the water storing abilities of peat as a material are relevant, as identified in section 2.2.3. However, another definition; water storage in an area serving the purpose of water retention, related to water safety, proved to be relevant as well. The third insight is the use of coupling opportunities in projects during the implementation. Even though discovered, but not completely implemented in the case De Weerribben, in Weimeren this has had a relevant influence on the project.

### *5.1.2 Relationships and effects*

To make an assessment, the relationship between elements and sub-elements, and the interconnected effects should be identified. In sub-section 2.6.3 the relationships and effects overview was created, illustrating elements, sub-elements, relationships, and the expected range of effects. This to support the operationalisation of this research. This figure is adapted following the more advanced schematic overview (figure 12).

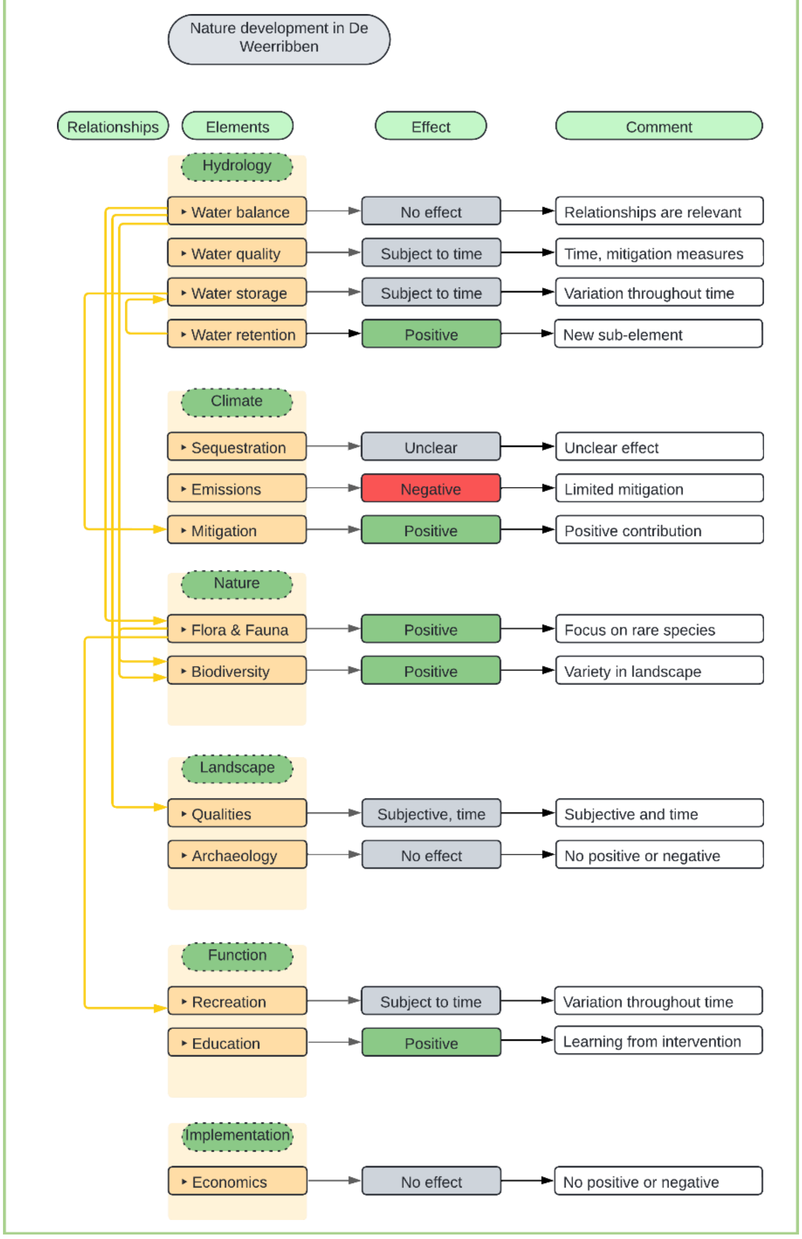
Applying the analysed empirical data to the relationships and effects overview was challenging, as it was difficult to draw clear, unambiguous conclusions about the directions of these effects for the elements and sub-elements used. Figure 13 illustrates one of the possible outcomes, when applying the data from the case Weimeren. Six of the fourteen elements have not been assigned a direction of effect due to various reasons, commented on in the figure, which will be explained in detail in section 5.2. These factors are scale, time, and perspective. The remaining eight elements were assigned a direction, but they are also influenced by the same factors discussed in section 5.2. To clarify, an example derived from the case Weimeren can be used. Taking the sub-element flora and fauna, a positive effect was given (figure 13). Following the description of this sub-element in sub-section 4.1.3, this direction to the effect was given based on various small scale elements and mitigation measures undertaken to limit negative effects.

*Figure 11: Applied data Weimeren*



In similar fashion the project of De Weerribben can be assessed, resulting in figure 14. This figure illustrates a possible outcome of when the empirical data is applied in the relationships and effects overview, illustrated in sub-section 2.6.3.

*Figure 12: Applied data Weerribben*




Again, similar to applying the empirical data from the Weimeren case, it was difficult to draw clear conclusions about the directions of the effects for the elements and sub-elements used. Eight of the fourteen elements have not been assigned a direction of effect due to similar reasons as in the Weimeren case, commented on in the figure, and will be further discussed in section 5.2. The remain six elements were assigned a direction, but they are also influenced by the same factors discussed in section 5.2. To highlight another example, the sub-element recreation is labelled subject to time (figure 14). This is because, as described in section 4.2, because of the various effect directions over a longer time frame. First, it could be assessed as a negative effect because the recreational value is reduced as consequence of the intervention. Later on, a positive effect could be observed, as the nature restores itself, with added cultural heritage aspects.

## 5.2 Beyond the schematic overview and effects

In this section the factors that influence the assessment of the elements are discussed. This because the analysis of the empirical data and applying the data to the overviews has resulted in several more general insights. Of which, aforementioned, is that it is challenging to assess a single element and effect. The factors, discussed in the following sub-sections, contribute to this significantly.

### *5.2.1 Scale*

One of the most important factors that influences the assessment, and especially the direction to the effects, is scale. Scale in the sense of how detailed the elements, or sub-elements, which are assessed are taken into account. A constant balance has to be sought between going into detail and being able to make an unambiguous, general assessment. Derived from the case study Weimeren, again, taking the element of nature as an example, several levels of scale can be identified. First a broad scale, assessing nature in relation to the network. Then, a smaller scale, the general effects of the project in the form of enhanced biodiversity. Furthermore, an even smaller scale, looking into the mitigation measures on specific animal species, can also be observed. The potential effects of the nature development on this animal are listed, which are then mitigated, to reduce the potential negative effects. All these levels of scale present their own direction to the effect this element has. This does not only make a conclusive, overarching direction to the nature effects borderline impossible, it also clouds the assessment as small scale, higher detail, effects can almost infinitely be identified.

### *5.2.2 Time*

The second important factor that has an influence on the assessment through the schematic overview is the factor of time. Several of the effects of the elements are drastically different after time has passed. Taking the example of the element: emissions, in the Weimeren case, this can be observed in the following way. During the realisation of the project, the emissions of $CO_2$ are high, which can be labelled as very negative. However, after several years the established nature can support peat growth which will start the sequestration of $CO_2$, this means a positive effect on emissions. When the nature area is compared to the old landscape, this difference is even larger, as the semi-natural landscape emitted instead of sequestrating $CO_2$. This marks another way of looking at the factor time. Before and after the intervention. The effects of the realized nature, also in the case of De Weerribben, can be completely different when compared to the old situation, opposed to the standalone effect.

### *5.2.3 Perspective*

The third important factor is the perspective that is taken. This is related to the label 'subjective' the sub-elements landscape quality and recreation function, have received. The labelling of a landscape quality as positive or negative is subjective to the user's perspective and interpretation. This is similar with recreation, a person's perspective on recreation value of a nature kind ultimately decides if it is labelled positive or negative. However, the deliberate design choices made in the case Weimeren, to incorporate the existing sightlines into the future nature design, can contribute to the positive perception of the landscape (E2). An even stronger example can be observed in the case De Weerribben, since the design choice to recreate the historically present long narrow ditches (in Dutch = petgaten), helps tell the 'story' of the cultural and natural heritage (doc. 5). Thus, contributing to the positive perception and function of the landscape. Perspective also closely resonates with the following factor that is of influence on the assessment, the weighing of the elements compared to each other.

### *5.2.4 Weighting*

The weight of the elements ultimately decides the outcome of the assessment. When one effect of an element is considered to be more important than another effect of an element, a heavier weight is connected. The outcome of the assessment will be more heavily influenced by the latter element. The weight given to an element is subject to the perspective taken by the person or organisation that executes the assessment. As a hypothetical example, an organisation related to climate mitigation will potentially value positive effects of this element as more important than the other elements. Therefore, influence the outcome of the assessment. The weighting of elements, and following assessment outcome should therefore be carefully considered.

## 5.3 Assessment of the cases

Following the empirical data analysis, applying this to the relationships and effects overview, and the discussion of influencing factors, the cases Weimeren and De Weerribben are now briefly discussed. Adopting the priorities and goals of Staatsbosbeheer (highlighted in box 13) as a perspective, explicitly valuing biodiversity, mitigating climate change, recreational use of nature, bringing natural resources to sustainable use, and participation of various audiences, both the nature development Weimeren and De Weerribben can be seen as positive interventions.

The project Weimeren scores (light) positive on several sub-elements, including climate mitigation, flora and fauna, biodiversity, recreation, and economics (bringing natural resources to sustainable use). Through mitigation the negative effects of the emissions, as a consequence of the intervention, are limited. Considering all elements, keeping in mind the various conflicting smaller scaled effects, and including the observations from the fieldwork, from this assessment it can be concluded that Weimeren is a positive intervention, especially when considered over a longer timeframe.

The project Weerribben scores positive on five sub-elements, including climate mitigation, flora and fauna, and biodiversity. Even though the negative effects of emissions are not mitigated, due to mainly practical boundaries, this assessment concludes that the nature preservation intervention in De Weerribben has a positive outcome. Especially, when held against the background of the necessity of the intervention for the many rare, or even unique, species.

## 5.4 Support decision-making

Although a comprehensive assessment of all elements is in theory possible, in practice this would result in a costly affair, both in terms of time and means. The presented assessment therefore balances between detail and feasibility, without drowning in infinite analysis. Despite the needed simplification, the assessment can still support decision-making, however, can only limitedly provide solid and lasting support. In other words, decision-making remains a human effort. Even then, this assessment still delivers an overview of pro’s and con’s and can therefore be used to make a balanced conclusion on the outcome of the intervention. The overview of pro's and con’s, together with the balanced conclusion, can support decision-making on nature development in peatlands by providing decision-makers with information.

# 6 Conclusion

This chapter presents the conclusions of the research, by answering the sub-questions and the main research question. It also critically reflects upon the process of the research.

## 6.1 Conclusion

In this section, the sub-questions are systematically addressed to build a foundation to effectively answer the main research question. This offers a cohesive overview of the study’s findings. The first, second, and third sub-questions were addressed in the literature review (chapter 2). The fourth sub-question was addressed in both the literature review (chapter 2) and the methodology (chapter 3). The fifth and sixth sub-questions were addressed in the empirical findings (chapter 4) and the evaluation (chapter 5). The seventh sub-question was addressed in the evaluation (chapter 5) as well. This section presents an overview of the most important answers to the sub-questions.

*Sub-question 1*

What are theoretically relevant elements when developing nature in peatlands?

In the literature review the relevant elements and sub-elements for developing nature in peatlands were identified. This resulted in the creation of a schematic overview (figure 2), illustrating the relevant elements, and an extended schematic overview (figure 3), illustrating the relevant sub-elements. The relevant elements are hydrology, climate, nature, landscape, function, implementation, and all others. The relevant sub-elements are water balance, water quality, water storage, sequestration, emissions, mitigation, flora and fauna, biodiversity, landscape qualities, archaeology, recreation, education, economics, and legislation.

*Sub-question 2*

What are the relationships and effects of the identified elements?

In the literature review the relationship between elements and sub-elements were identified and illustrated in the relationships and effects overview (figure 4). The relationships between sub-elements are extensive, and ten were identified (for an overview of the relationships, see figure 4). The interconnected effects were presented in a range, showing potential expected positive or negative results.

*Sub-question 3*

How can we theoretically assess the elements and their relationships to each other?

Through the evaluation of often used assessment methods, namely the Multi-Criteria Analysis, Cost-Benefit Analysis, Environmental Impact Assessment, and frameworks, pro's and con's of said methods were identified. Combining elements of the methods the relationships and effects overview was created (figure 4).

*Sub-question 4*

What are empirical possibilities to assess identified elements and effects?

Through interviews with experts, the analysis of project documents, and fieldwork the identified elements and effects were assessed in two case studies. The first case study focusses on the creation of new nature in Weimeren. The second case study focusses on the preservation of existing nature in De Weerribben. Both therefore focus on the development of nature in peatlands in the Netherlands by Staatsbosbeheer.

*Sub-question 5*

What are the observations from case study 1: Nature Creation in Weimeren?

The observations from case study 1, with as structure the sub-elements from the extended schematic overview (figure 3), are systematically discussed in section 4.1. These observations are further discussed, and applied in section 5, resulting in the assessment of the case. The case assessment, as illustrated in figure 13, not only reached a positive conclusion but also highlighted four general influences on the evaluation: scale, time, perspective, and the weighting of effects.

***Sub-question 7***

What are the observations from Case Study 2: Nature Preservation in De Weerribben?

The observations from case study 2, organized according to the sub-elements from the extended schematic overview (figure 3), are systematically reviewed in section 4.2. These observations are further discussed, and applied into section 5, resulting in the assessment of the case. As illustrated in figure 4, the assessment not only reached a positive conclusion but also identified, similarly to case study 1, the four general influences on the evaluation: scale, time, perspective, and the weighting of effects.

***Sub-question 6***

To what extent can an assessment be done to support decision-making?

The presented assessment balances the level of detail with the feasibility of making an assessment, as discussed in section 5.3. Despite the need for simplification, the assessment can still support decision-making. Through an overview of the pro's and con's a balanced conclusion can be made. However, this does limitedly provide solid evidence, therefore decision-making remains a human effort.

***Main research question***

To what extent can an assessment of both theoretically and empirically identified elements and interconnected effects be used to support decision-making regarding nature development in peatlands?

The combination of theoretically and empirically identified elements and their interconnected effects can limitedly be used to support decision-making regarding nature development in peatlands. Due to the challenges related to giving an unambiguous direction to the effects of the identified elements, the assessment can only partially present a comprehensive overview. This is, amongst other reasons, the consequence of the influence the factors scale (level of detail), time, perspective, and the weighting of the individual elements, have on the assessment. Nonetheless, the overview of pros and cons, along with a complete or partial conclusion, can inform decision-makers and thereby support the decision-making process.

## 6.2 Reflection

The process of this research presented many similarities with the art of muddling through, as discussed in sub-section 3.1.2. An approach consisting of small, pragmatic steps, often dictated the way of research. Through an iterative process, repeating steps, and trying to find the correct or fitting approaches, the previous chapters illustrate the end-result. Similarly as the lenses identified in sub-section 2.1.3, used in the literature review, the research was holistic, influenced by various effects and aspects (highlighting interconnectedness), and characterized as a dynamic process. The holistic approach to the research could be seen as both a strength as well as a limiting factor. By trying to be holistic, considering every and all aspect, an assessment becomes practically close to impossible. As discussed, with unlimited time and funds, a complete list of elements, their relationships, and interconnected effects can be created. The interconnectedness in the process could be observed through the various different approaches to making the assessment, that were tried as part of this research. This was then influenced, again, by several elements, for instance conversations with a supervisor or the discovery of new implications. The research most definitely showed a dynamic aspect. By the passing of time throughout the research process, and the iterative steps, the development of the research was not linear in any way. Future research could consider a method to better label a direction to effects, for instance by examining the relationships between smaller scaled effects, the factor of time, and perspectives. Furthermore, the weighing of the elements could be further studied, as this research does not go in to much detail on this part of the assessment. Nonetheless, this research contributes to spatial planning by offering a method to support decision-making on nature development in peatlands in the Netherlands.

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# Appendices

## A. Appendix A: interview guide

## Interview-guide Staatsbosbeheer

### Introduction

Hello, my name is Maarten Heikens, and I am in the final phase of my master's degree: Environmental and Infrastructure planning, at the University of Groningen. One of the learning objectives is writing a thesis. This interview is conducted to gather data for my thesis.

First of all, thank you for participating.

To give a bit of background, my thesis focusses on nature development in peatlands in the Netherlands. Balancing the positive and negative effects of the intervention, to assess whether the intervention is valuable. Ultimately trying to support decision-making.

- Ask permission for recording the interview -

1. Do you have any questions before we start?
2. Could you introduce yourself?
3. What is your function?

### Phase 1 (open interview, gather information)

4. What elements are relevant in nature development in peatlands?
5. What other aspects are relevant in nature development in peatlands?
6. What are work areas relevant in nature development in peatlands, in short, what are important aspects by making an integral decision?

### Phase 2 (validation of information)

Based on literature a schematic overview of relevant elements was created (show schematic overview).

7. Could you provide feedback on the elements that are presented in the overview?
8. Are there relevant elements missing?

### Phase 3 (gathering information)

There are several methods to assess interventions, Multi criteria analyses (MCA), Environmental impact assessments (EIA), and in the context of the Netherlands, the milieueffectenrapportage (MER).

9. How does a project team assess these interventions?