CATTAIL CULTIVATION - NETWORK OF PRACTICES

Understanding the characteristics of the network of practices in the paludiculture pilot with cattail cultivation in Helmond, the Netherlands

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Cattail Cultivation – Network of Practices

Understanding the characteristics of the network of practices in the paludiculture pilot with cattail cultivation in Helmond, the Netherlands

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Abstract

Due to the 'pilot paradox' the conditions which give pilot projects room to experiment and to learn (and, thus, arrive at innovative results), also appear to constitute the main barriers to their broader uptake in policy goals, content, or instruments. Therefore, despite best intentions, the majority of pilots, also in land and water management innovations, fail to scale up. Yet, in the face of climate change, finding ways to upscale practices which can make the landscape climate-adaptive is more relevant than ever. One such practice which has the potential to contribute to an adaptive landscape is paludiculture. Paludiculture is the practice of crop production on wet soils with certain crops that can be grown in partially submerged condition predominantly on peatlands. This research offers new insights into the characteristics of paludiculture with cattail cultivation (*Typha latifolia*). It does so by using the concepts of network of practices and societal embedding to zoom-in and zoom-out on this innovative practice. The cattail pilot site in Helmond in the Netherlands is taken as the starting point of the research. Snowball sampling is used to conduct a series of (semi-structured) interviews in order to gather insights from other actors involved in paludiculture. By using network of practices, it enabled the exploration a number of linkages and incompatibilities between practices related to cattail cultivation and its surroundings. Both are important to consider as linkages can potentially provide synergies, while incompatibilities can cause barriers in wider implementation. Overall, the research found that paludiculture is currently dominated by research institutions and organisations, therefore lacking societal embedding. Furthermore, it is not suitable for independent implementation and currently has too many thresholds in the cultivation and production stages. Consequently, the research questions whether the main purpose of paludiculture should be framed as an agricultural product or as a climate adaptive practice, in which more synergies exist. Finally, the research stresses the need for more integration of paludiculture in the policy environment in order to make it a viable cultivation in future.

Key words: *Paludiculture, wet cultivation, cattails, Typha, network of practices, societal embedding.*

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I hope whoever reads this will becomes a little wiser of the characteristics of cattail cultivation and its potential for societal embedding. Please feel free to contact me with any questions via LinkedIn.

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Glossary

The glossary gives a short definition of terms that are used in this research.

Term	Definition
Interrationalities	Interrationalities can be understood as linkages between practices and constellations but can also show possible incompatibilities between practices. Therefore, interrationalities could possibly show synergies and barriers for wider implementation.
Network of practices	The combination of all interacting and connecting constellations of practices by different actors. These networks are influenced by the nexus of practices surrounding them. (Hui, Schatzki, & Shove, 2016)
Paludiculture	The practice of crop production on wet soils with certain crops that can be grown in partially submerged condition predominantly on peatlands (Geurts et al., 2019).
Pilot paradox	When ''the conditions that are necessary to give a pilot room to experiment and to learn (and, thus, arrive at innovative results), also seem to constitute the main barriers to the broader uptake and translation of its results into changes in policy goals, content, or instruments'' (Buuren et al., 2018 pp.146).
Practice-based approach	The approach adopts ''real-time practice as the starting point of social and organizational inquiry'' (Nicolini, 2009 pp.1392). As a result, the focus is on what is *said* and *done* and are less bound to theoretical boundaries.
Societal embedding	The process of business environment embedding, regulatory embedding, cultural appropriation, and embedding in user's environment (Geels & Johnson, 2018).
Upscaling	For the purpose of this research, upscaling is conceptualised as the process of societal embedding.

Abbreviations

CAP	Common Agricultural Policy
CConnect	The Interreg Carbon Connects project
CO2	Carbon dioxide
ENG	English (translation)
EU	European Union
GHG	Greenhouse gases
Ha	Hectare
Int.	Interview
KLIMAP	Climate Adaptation in Practice project
LANDMARC	Land Use Based Mitigation for Resilient Climate Pathways project
LNV	Landbouw, Natuur, en Voedselkwaliteit (ENG: Ministry of Agriculture, Nature, and Food Quality)
NDL	Nederlands (Dutch translation of a term)
SNA	Social Network Analysis
SOM	Soil Organic Matter
SPT	Social Practice Theory

For abbreviations of the SNA maps, please refer to Annex F.

Contents

1. Introduction 1
1.1. Pilot paradox 1
1.2. Climate change 1
1.3. KLIMAP 1
1.4. Living lab Helmond 2
1.5. Reading guide 2
2. Theoretical framework 3
2.1. Societal embedding 3
2.2. Approaches to upscaling and transitions 4
2.2.1. Multi-level perspective 5
2.2.2. Network of practices 6
3. Knowledge gap 10
3.1. Problem statement 10
3.2. Research objective 10
3.3. Research questions 11
4. Methodology 12
4.1. Case study background 12
4.1.1. Peatlands in the Netherlands 12
4.1.2. Pilot site context 13
4.2. Research steps and methods used 13
4.2.1. Integration of the concepts into the research steps 13
4.2.2. Research methods 14
4.2.3. Research steps 16
5. Results 18
5.1. Full network overview 18
5.1.1. Key actors and institutions in the network 18
5.1.2. Societal division of the network 20
5.2. Elements 22
5.2.1. Meanings 22
5.2.2. Materials 25
5.2.3. Competencies 29
5.3. Dimensions 33
5.3.1. Temporal dimension 33
5.3.2. Spatial dimension 36

5.3.3. Social dimension 39
5.4. Nexus 43
5.4.1. Policy environment 43
5.4.2. Business environment 46
5.5. Synthesis 50
6. Discussion of findings 52
6.1. Discussion of results 52
6.2. Use of the network of practices approach 53
6.2.1. Integration with societal embedding 53
6.2.2. Comparison with the multi-level perspective 54
6.3. Limitations 55
6.3.1. Limitations of the business environment definition 55
6.3.2. Decisions made in interviews 55
6.3.3. SNA decisions and results 56
6.4. Recommendations 57
6.4.1. Recommendations for the research community 57
6.4.2. Recommendations for policy makers 58
7. Conclusion 60
8. Bibliography 62
Annex 66
Annex A: Social network analysis exercise 66
Annex B: Decisions made to create SNA maps 68
Annex C: Interview guide 69
Annex D: Interviewees & organisations 72
Annex E: Explanation of research steps 75
Annex F: Abbreviations and translations of SNA maps 78
Annex G: Purposes of paludiculture explained 80
Annex H: Values analysis of pilot users 85
Annex I: Materials of cattail cultivation explained 86
Annex J: Temporal dimensions results elaborated 94
Annex K: Spatial dimension results elaborated 98
Annex L: Social dimension SNA maps 103
Annex M: Policy influencers SNA map 106
Annex N: Full results overview 107

1. Introduction

1.1. Pilot paradox

Despite best intentions, the majority of pilot projects testing new innovations fail to scale up (Broek et al., 2020; Buuren et al., 2018; Meijerink, 2020). Pilots allow for new challenging and potentially ground-breaking practices to be tested at small scale. Buuren et al. (2018) explains that this is possible due to the fact pilots take place in boundary spaces where alternatives to currently dominant technologies and methods of governance can be tested for their potential. However, Buuren et al. (2018) claim the existence of a 'pilot paradox'. This is when ''the conditions that are necessary to give a pilot room to experiment and to learn (and, thus, arrive at innovative results), also seem to constitute the main barriers to the broader uptake and translation of its results into changes in policy goals, content, or instruments'' (Buuren et al., 2018 pp.146). This means that pilots appear to lose their ultimate goal along the way, if one assumes the goal is to implement better alternatives on a wider scale. In other words, many pilots fail when it comes to upscaling. Upscaling is a concept which refers to the ''creation of conductive conditions and policies for scaling at higher levels'' (Schut, Leeuwis, & Thiele, 2020 pp.2). Upscaling not only refers to technical feasibility, but also to the wider societal embedding of an innovation. Thus, wider implementation of a pilot requires both technical and social embedding.

1.2. Climate change

This pilot paradox is a centuries old phenomenon, also in land and water management pilots. To test new ideas in land and water management in agricultural contexts pilots are commonly used (Langeveld & Röling, 2006). Especially in the context of climate change, there is currently an increasing need for adaptation and innovation in water management strategies worldwide (Aguiar et al., 2018; Iglesias & Garrote, 2015). The Netherlands, a country generally known for its water abundance, now not only faces the longstanding battle of potential flooding but also the increasing occurrences of droughts (Beleidstafel Droogte, 2019). KNMI'14 climate scenarios predict more extreme weather conditions (KNMI, 2015). Summers will become warmer, with a lower total precipitation while the occurrence of peak rainfall increases, and winters become wetter (KNMI, 2015).

This change in weather conditions places significant pressure on existing spatial design and infrastructure of water management of the Netherlands. Until recently the priority was flood management. This led to the design of the current national water management system being primarily geared towards discharging surface water and precipitation towards a safe outlet as fast as possible, often the outlet being the North Sea (Beleidstafel Droogte, 2019). However, the change in precipitation volume and distribution in time calls for a significant change in water management strategy. In future, the Netherlands will also need to manage potential droughts and therefore find ways to store water, instead of immediately discharging it. Avoiding droughts is essential. They can result in high costs in multiple sectors, ranging from nature to land subsidence, disturbance of shipping routes, reduced drinking water availability and agricultural damages (Brockhoff, 2021; Philip et al., 2020). In 2018, drought in the Netherlands resulted in an estimated economic loss of 450-2,080 million euros (Van Hussen et al., 2019). Consequently, it is essential to find innovative ways to adapt to these changes.

1.3. KLIMAP

Multiple players are actively working on finding innovations in order to adapt the national water management system. One such project is 'Climate Adaptation in Practice', hereafter referred to as KLIMAP. KLIMAP is a project consisting of 24 different parties ranging from regional governments to companies and knowledge institutions who together want to uncover how water and soil systems in areas of sandy soils can be made climate adaptive (KLIMAP, 2021). These sandy soils pose a particular challenge due to their permeable nature, making them more vulnerable to drought compared to other soils (Beleidstafel Droogte, 2019). The project is divided into three themes or 'work packages': (1) adaptation pathways, (2) testing grounds/living labs, and (3) exploration of the future.

In work package (2) testing grounds/living labs potential innovations are explored and tested at pilot level for their effectiveness and feasibility considering technical, economic, and social influences (KLIMAP, 2021). Broek et al. (2020) argue that the living labs of KLIMAP also face challenges when it comes to considering large scale implementation, stating that here too the pilot paradox is encountered. Through a Qualitative Comparative Analysis Dongen (2021) also confirms the existence of the pilot paradox in Dutch pilots searching for innovations on sandy soils. Broek et al. (2020), Dongen (2021) and Buuren et al. (2018) all agree that the consideration of a follow-up trajectory (post-experiment) which assesses the relevance and suitability of the innovation in other locations is essential yet often lacking in pilots. Other locations feature different societal embedding and different users, whom most likely do not have the entrepreneurial characteristics of innovators typically involved at the pilot level (Brockhoff, 2021). Therefore, Broek et al. (2020) argues that too little attention is paid to upscaling that could avoid the pilot paradox. In order to better understand the pilot paradox, this research delves into one of the living labs pilots in KLIMAP as a case study.

1.4. Living lab Helmond

The living lab that was taken as the main starting point of the research is a paludiculture pilot plot cultivating *Typha latifolia*, commonly known as cattails, in Helmond, the Netherlands. Paludiculture is the practice of crop production on wet soils with certain crops that can be grown in partially submerged condition predominantly on peatlands (Geurts et al., 2019). The practice of cattail cultivation is relatively new in the Netherlands. The first pilot site dates back only a decennium. Most paludiculture pilots are carried out in peatland polders, as submerging the soil reduces land subsidence and carbon emissions (Deelexpeditie Natte Teelten, 2020; Geurts et al., 2019). In Helmond, the pilot is carried out on a low lying peat plot in a stream valley surrounded by high sand soils (KLIMAP, 2021). In this area, there are also benefits relating to water and climate adaptation. Water is ponded on land, allowing for slow groundwater infiltration while at the same time allowing for storm run-off to be stored at peaks, reducing the risk of flooding. Furthermore, different economic and ecological benefits exist (Jong, 2020). Cattails can be sold to make insulation material and they also have positive effects on water quality (Geurts et al., 2019). More context on the pilot site is found in section 4.1. Case study background.

1.5. Reading guide

The thesis is divided into 6 main chapters. The theoretical framework in the next sections elaborates on the understanding of societal embedding, the perspective taken on upscaling, and the use of the network of practices approach. Chapter 3 on the knowledge gap presents the problem statement, the research objective, and research questions. Chapter 4 on methodology elaborates on the case background and the operationalisation of network of practices including the research methods used. The results in chapter 5 describes the findings starting with zooming in on the pilot site in Helmond, the temporal, spatial and social dimensions, as well as the policy and business environment. The discussion of findings in chapter 6 will consider the implications of the results, the use of the network of practices concept, the limitations of the research, and recommendations to the research community and policy makers. Finally, the main conclusions of the findings are covered in chapter 7.

2. Theoretical framework

The theoretical framework aims to clarify how the terms of the research are understood and from which perspective the research will be conducted. The key terms such as societal embedding, the practice-based approach, network of practices, and social practice theory (SPB) are explored. It is important to note that this theoretical framework is inspired on the PhD proposal by Giller (2021). In this way, the research could be seen to complement the PhD research by Giller.

2.1. Societal embedding

Diffusing a socio-technical system, such as a new agricultural practice (i.e. paludiculture) or discourse (i.e. water storage instead of discharge), is more complex than introducing a new product on the market (Geels & Johnson, 2018). Not only the technical feasibility is relevant, but also the social acceptability (Schut et al., 2020). According to Geels & Johnson (2018), diffusion of a socio-technical system exists in three parts: (1) the upscaling from small to large from a technological systems perspective, (2) the diffusion of innovations across space, and (3) the diffusion of societal embedding of innovations. The third part is essential as ‘’new technologies not only need integration in relevant industries and markets, but they also need broader societal embedding’’ (Geels, Pieters, & Snelders, 2011 pp. 145). Therefore, upscaling of new innovations also raises the question, how can a new innovation be fully socially embedded in society? In order to address this question, we must first understand what is understood as societal embedding.

Geels & Johnson (2018) state that societal embedding occurs when the new product considers the pre-existing environment. For simplicity, we can appraise the new innovation paludiculture as a ‘new product’ in the existing agricultural practices. Geels & Johnson (2018) distinguish between 4 environments which must be considered and must align in order for a new product to diffuse (and thereby scale up): (1) the business environment, (2) the policy environment, (3) the wider society, and (4) the user environment (Figure 1). The first, the (1) business environment, refers to the integration of new products in their relevant markets and suitability in the existing industry (Geels et al., 2011). Therefore, in order for a product to be embedded in society it needs to be economically viable (Geels et al., 2011). One could thus ask the question to what extent cattails have a viable market?

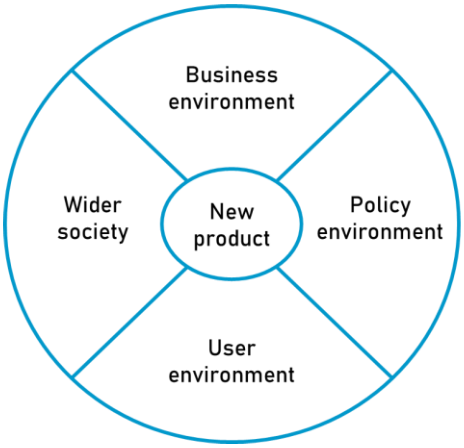


Figure 1. Environments of societal embedding (Geels & Johnson, 2018)

The three other factors refer to the socio-cultural legitimacy of the new entity. The (2) policy environment includes local to national actors (i.e., governments or other regulatory bodies) checking whether the innovation fits rules and standards. To achieve this, one must allow for regulatory embedding including the creation of new rules and standards, subsidies, or endorsement of technologies by politicians. This leads us to the question, does the cultivation of cattails receive subsidies? The (3) wider society concerns the acceptance by the wider public requiring it to fit societal and cultural norms and beliefs held by actors such as farmers, nature organisations, academics, and public leaders (Geels et al., 2011). This triggers the question, will a new agricultural practice such as paludiculture collide or compromise with dairy farmers? To support the acceptance in wider society, cultural appropriation must take place, such as creating positive narratives in order to draw political, financial, and user support.

The (4) user environment refers to routines, beliefs, skills and practices (Geels & Johnson, 2018). This introduces a further dimension at user level, which the other three factors do not fully consider. In order for a new innovation to succeed in the user environment, the innovation must consider already existing practices and requires the development of new competencies, beliefs, and daily life routines. In the original framework, this would refer to the customer of a product, such as a consumer. However, in this case we assume the user of the practice is the farmer or landowner which carries out paludiculture. In other research, a farmer might be considered as the business environment due to their entrepreneurial nature. However, for the purpose of this research and to be able to zoom-in on the practice, users are appraised as those cultivating the cattails. This raises questions such as would a dairy farmer start paludiculture if they had no previous cultivating experience? This is challenging since it requires users to become familiar with unknown practices. On top of that, routines need to be broken in order for societal embedding to occur. This is a difficult feat, as explained later in section 2.2.2. Network of practice (Castelo, Schäfer, & Silva, 2021).

Overall, societal embedding can therefore be understood as the process of business environment embedding, regulatory embedding, cultural appropriation, and embedding in user's environment. One could see the parallels with the reasons for success of pilots at local level. Pilots usually work at the local level due to their 'safe environment', including stable funding and materials (business environment), liberty and exceptions from usual rules and regulations (policy environment), experimental culture (wider society), and entrepreneurial participants (users' environment) (Buuren et al., 2018). However, for these same reasons, the pilots fail when scaled up when these environmental conditions can no longer be guaranteed. Therefore, it is relevant to not only focus on why the pilot works at its own level, but also to consider the surrounding environment, in order to assess potential societal embedding or lack thereof. Therefore, for the purpose of this research, upscaling is conceptualised as the process of societal embedding (Mylan et al., 2019).

2.2. Approaches to upscaling and transitions

Now that we understand what societal embedding entails, what processes are needed for it to occur, and that upscaling is conceptualised as societal embedding, it is relevant to specify what approach is taken to upscaling of practices within this research framework. Overall, the approach to upscaling differs widely among researchers. The general point which all definitions appear to agree on is the need for a *systems thinking* approach, where broader factors are considered including hydrology, economics, politics, cultural norms and values (Schut et al., 2020). Furthermore, the success of a pilot is not just based on the number of adoptees but rather its success in the system (Schut et al., 2020; Wigboldus et al., 2016). By taking a systems thinking approach, this allows the consideration of the complexity of world, and recognises that these systems are becoming more interconnected over time (Arnold & Wade, 2015). Geels & Johnson's (2018) approach to societal embedding recognises and incorporates this by considering a broad array of areas.

However, it must be noted that this abstract concept does not provide the operationalization needed in order to understand what is happening at the pilot level and its direct surroundings. As Arnold & Wade (2015) state ''systems thinking is, literally, a system of thinking about systems'' (pp. 670). In this research the goal is to understand how a system transitions from old practices to new practices and why it might not transition at all. If we assume societal embedding requires change, then we must assume there is a transition or a resistance to transition to something new. Rotmans, Kemp, & Asselt (2001) define a transition as ''a gradual, continuous process of change where the structural character of a society (or a complex sub-system of society) transforms'' (pp. 16). This change is not uniform and rather differs in time, space, and actors, which government policy can partially control, but never fully (Rotmans et al., 2001). In the case of socio-technical change, such as the introduction of paludiculture, it raises the question how a practice is socially embedded and thus upscaled, ultimately leading to change in the system. The following section introduces two approaches which can be used to analyse possible transitions to new practices and routines: the most commonly used approach using the multi-level perspective, and the more novel approach of network of practices approach, which will be used in this research.

2.2.1. Multi-level perspective

In general, to understand transitions and thereby upscaling of socio-technical innovations a multi-level approach is often used (Mylan et al., 2019). Geels & Kemp (2000) divided the world in three levels which have different scales and timelines, but continuously interact and influence each other to different extents. These three levels distinguish the micro level where several niches can be identified, the meso level at which one or more regimes can be observed, and the macro level in which there is a dominant landscape (Zolfagharian et al., 2019). The simplified visualisation of this structure can be seen in (Figure 2).

The landscape level can be defined as the overarching sphere or (societal) context in which both the regime and niche operate (Brockhoff, 2021). At this level national culture, economics, politics, trade, and more play out (Geels & Kemp, 2000). At the meso level multiple regimes can be present, where all regimes are dominant structures in the social system in the form of practices and actors. Therefore, every regime has dominant beliefs, rules and norms with core actors keeping these structures in place by continuous reproduction of practices (Geels & Kemp, 2000). One can think of politicians or policy makers who make policy documents that more often than not continue to support current practices.

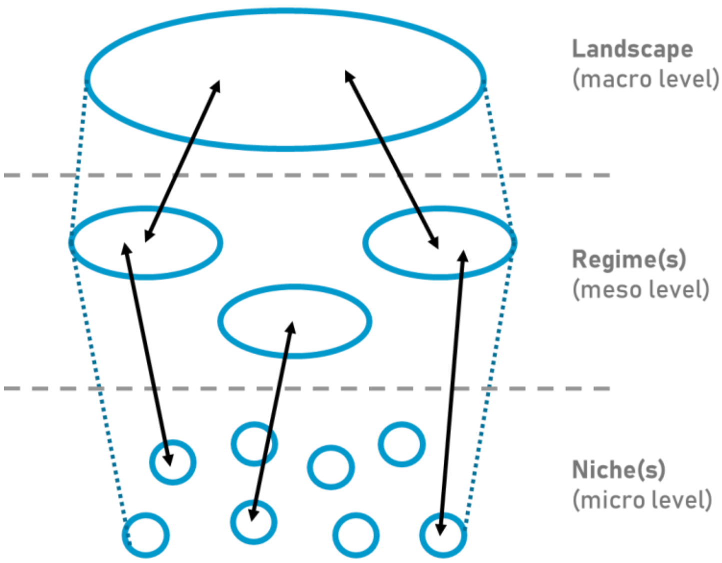


Figure 2. Three levels Brockhoff (2021)

At the micro level several niches occur. These niches are less strongly dominated by the landscape compared to the regime and operate at a much smaller scale (Mylan et al., 2019). This allows for (individual) innovative actors at this level to try out new practices and carry out pilots testing new innovations without strong inhibitions from the dominant landscape or regime (Brockhoff, 2021). Therefore, there is more flexibility and creativity in order to fully discover the potential of an innovation. However, as stated, for the same reasons a pilot can be successful, it can also be the reason it fails to scale up to the regime level (Buuren et al., 2018). Therefore, as the niche operates more independently from the regime, it also makes it difficult to influence and change the regime. Furthermore, pilots are often characterised by more resources and relatively small-scale application (Buuren et al., 2018). Again, this combination allows pilots to thrive in their small, independent and resource rich environments, but for these same reasons can result in unsuccessful implementation at the higher regime level (Buuren et al., 2018).

Despite the argument from Mylan et al. (2019) that the landscape not only influences the regime but also vice versa, this approach assumes a hierarchical structure (Giller, 2021). Research on implementing new innovations has often taken this approach and found useful and insightful results.

However, one can question whether this approach might suffer from theory bound thinking. This might cause one to overlook what is observed and happening in the field. According to Laakso et al.(2021) a practice only spreads if it manages to attract new 'carriers', which is not necessarily linked to regime changes. So, instead of a regime change, why not consider a change in practices as a good starting point?

2.2.2. Network of practices

Essentially, introducing a new innovation such as paludiculture introduces a new practice into society. In order to introduce a new practice (similar to introducing a new product), it requires one to consider the societal embedding of the practice. For instance, does it clash, combine, or mould with what is already taking place (Geels & Johnson, 2018)? Geels & Johnson (2018) state that societal embedding also includes the users' environment, which includes routines, beliefs, skills, and practices. Therefore, for societal embedding to occur (and thus upscaling), it must be understood how a new innovation influences existing routines, beliefs, skills, and practices. Furthermore, the factors of business environment, policy environment and the wider society are also relevant to understand how this impacts a new innovation, and vice versa. What if one were to observe these factors, not from the theoretical multi-level perspective, but rather simply research what the societal embedding of a practice is by observing what is said and done?

Practice-based approach

By taking this perspective, we can take a practice-based approach (Giller, 2021). A practice-based approach means ''adopting real-time practice as the starting point of social and organisational inquiry'' (Nicolini, 2009 pp.1392). Therefore, a practice is taken as the central point of the research from which social and organisational networks can be plotted. This differs from the multi-level approach as there are no pre-defined levels. Rather, the research works iteratively, zooming-out to uncover and understand connections between practices. As a result, the focus is on what is *said* and *done.* Laakso et al. (2021) similarly use the term practice-based initiatives or interventions in their research on upscaling. They state that by focusing on the practice, you focus on 'what people say and do', similar to Nicolini (2012). Therefore, the focus is not on behavioural change but rather on the directly observable actions at a moment in time. Consequently, the practice-based approach does not research cognitive patterns on what people think but rather limits itself to their words and actions.

The advantages of the practice-based approach have been extensively addressed by Nicolini (2009, 2012). The most interesting argument to use a practice-based approach is that it offers an opportunity to analyse the complex structure of socio-material activities and their effects (Nicolini, 2009). It does not require a definition of the regime or landscape prior to the research. Additionally, practice-based initiatives encompasses more than the individual(s) and rather aims to link the practice to their social foundations (Laakso et al., 2021). Thus, Nicolini (2009) describes the practice-based ontology as ''the belief that many social and organisational phenomena occur within, and are aspects or components of, the field of practices'' (pp. 1394).

Components of practices

Practices have been defined in multiple ways, but the general consensus seems to be that practices are a routinised type of behaviour (Castelo et al., 2021; Laakso et al., 2021; Nicolini, 2012; Reckwitz, 2002). According to Castelo et al. (2021), practices are made up of several (inter)connected components, of which four components are explored in depth: elements, location, timing and companions. These four components were originally based on the practice of eating (Warde, 2016). However, this research takes these same four components for the agricultural practice of paludiculture with cattail cultivation as starting point.

Elements can be considered as the building blocks of a practice (Castelo et al., 2021). Elements refers to meanings, materials, and competencies. Meanings entail that one person might value and appraise a practice differently compared to another. An example could be given for paludiculture, based on the question whether it is valued more for emissions reduction, or for income generation. Meanings are connected to socio-cultural contexts, for instance traditional practices. Materials consider seeds, (water management) equipment, machinery, and funding necessary to carry out paludiculture.

Competencies are skills or characteristics that not only enable practices to be completed, but also increase the effectiveness of the practice and improve efficiency (Oonk et al., 2020). Woodruffe (1993) refers to a competency specifically as a set of behaviour patterns that an individual must be able to perform in order to fulfil their tasks or functions. Yet, a competency in this paper is understood as more than a behaviour pattern, and rather wishes to understand a competency as a cluster of skills, knowledge, attitudes, and personal traits needed to perform the practice investigated (Oonk et al., 2020). More specifically, what skills, knowledge, attitudes, and personal traits might one need to carry out paludiculture? Because the distinction between knowledge and skill is a highly philosophical debate, this thesis will not dive into this conceptual complexity. Therefore, the research understands knowledge and skills as one bundle, understanding skills as the ability to apply the knowledge, but also knowledge as a way to acquire skills (Stanley & Williamson, 2017). It is a choice to understand these concepts as an iterative process analysed together.

The other three components (location, timing, and companions) are more self-explanatory. Usually, a practice is carried out in a certain location. In the analysis, it is interesting to understand how the practice fits into its location, why it is carried out in that location, and how the rest of the location is impacted by its presence. For instance, if the water level is raised, how does this impact the location context and does this clash with other surrounding land use. Similarly, a practice usually is carried out at a certain time of day, month, or year. For instance, the time at which the crop needs to be sown and harvested, or the time needed to maintain the field or carry out water management. The necessary time consumption can explain a lack of suitability for the user environment. Companions refer to who is needed for the practice to be carried out and if it is done is cooperation. In this case, this will most likely be the actors such as the farmer and the pilot coordinators. For clarity, these three components will be named as the spatial, temporal, and social dimension (Castelo et al., 2021). Overall, by breaking a practice down into these four parts, one can better describe and operationalise the practice investigated.

Practices as part of routines and networks

Laakso et al. (2021) takes this a step further and distinguished practices into two dimensions: as entities and performances. Practices-as-entities are ''recognisable sets of elements that can be spoken about and identified as shared practices'' (pp.2). This appraises practices as day-to-day occurrences that are usually carried out, but not necessarily a habit. Practices-as-performances when a practice is reproduced and becomes part of the routine actions. This is when a practice becomes a sustainable iteration rather than an incidental occurrence (Giller, 2021). This means that, according to Laakso et al. (2021), we should aim for an innovation to become a performance as this entails that a practice becomes normalised in the routine, and only then is a practice truly and sustainably upscaled (Sengers, Wieczorek, & Raven, 2019). Therefore, this second dimension can also be referred to as the practice of scaling, thereby becoming socially embedded (Giller, 2021).

To turn practices into performances is difficult since it requires a change in routine. Even to change a single practice into a routine is challenging as each practice is interconnected in a network of practices (Castelo et al., 2021). These routines are thus connected parts where practices are surrounded by structures which can be described as networks (Castelo et al., 2021). Castelo et al. (2021) argues that the term ‘network of practices’ best encompasses the analysis of practices. This because it enables not only the exploration of its internal structure but also gives way to exploration of ‘’how practices themselves intersect, compete and potentially clash with one another’’ (Scheurenbrand, Parsons, Cappellini, & Patterson, 2018 pp.228). This is especially useful in a case where the practice is not necessarily accepted and well-established straight away, such as pilot projects which are still experimenting in a safe environment (Buuren et al., 2018; Geels & Johnson, 2018).

To define what network of practices are, it must be understood what they are built up of and what surrounds them. In literature, use of different semantics has made this part quite confusing. However, the choice was made to follow the terminology proposed by Hui, Schatzki, & Shove (2016) as this has the clearest distinguishing terminology and was also selected by Giller (2021). As a result, network of practices can be visualised Figure 3 in which four distinct components can be recognised: bundles, constellations, network, and nexus (Hui et al., 2016).

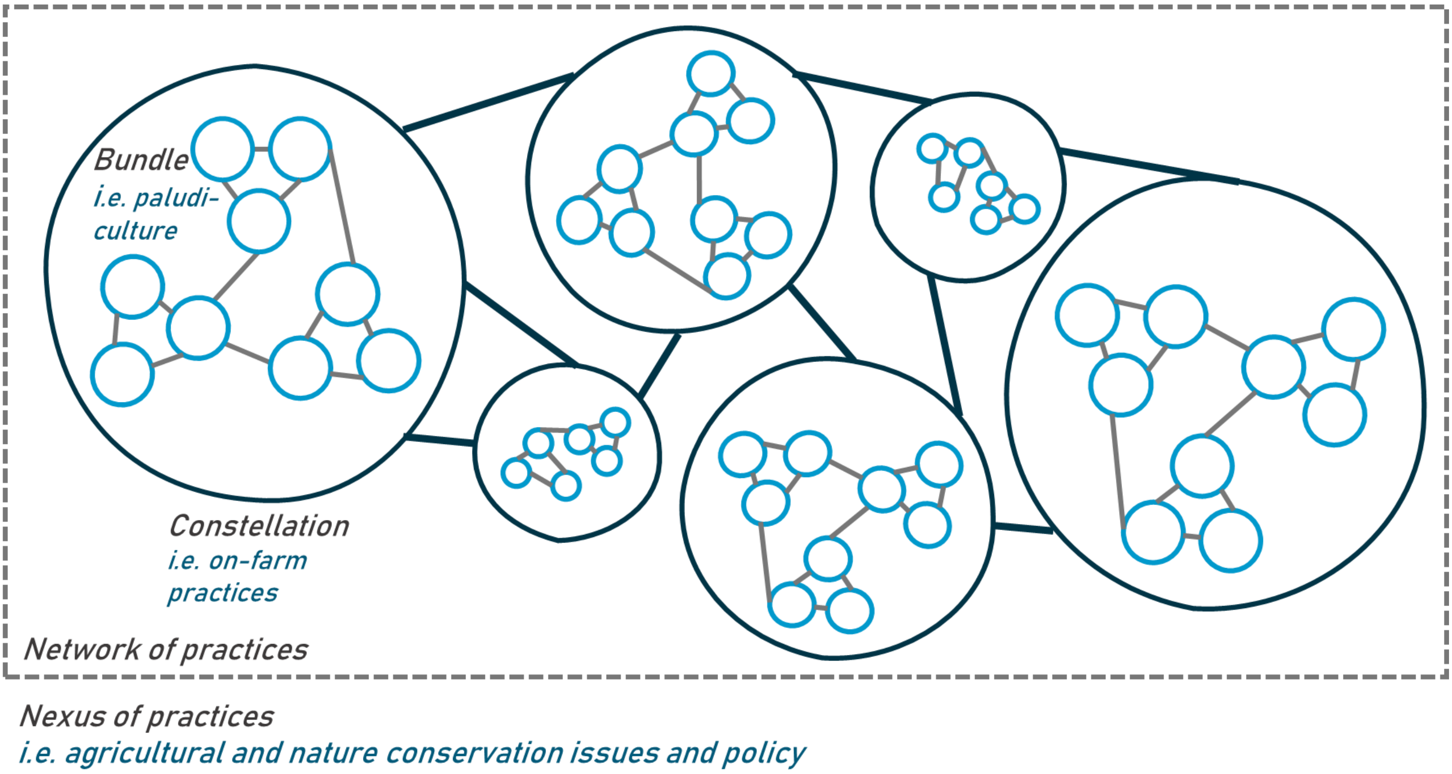


Figure 3. Visualisation of network of practices

Bundles build up constellations, while constellations build up the network. The nexus surrounds and influences this network. Bundles can be defined as practices that are closely linked to the core practice being researched. In this case, that refers to all on-farm practices that have a close link to paludiculture, for instance water management of the paludiculture field or seeding of the field. Constellations are one step up and consider all practices by one actor and link the bundles of practices together, for instance, cases in which farmers carry out both paludiculture and dairy farming on their land. The network then links up constellations of different actors together, for instance that of the farmer to their neighbours, nature conservationists, water boards, etc. Finally, the nexus is the broader context in which various networks link, such as the policy environment. All in the broader context does not have a direct impact on bundles as it is far out of the close sphere of influence. Within this network, interrationalities exist. Interrationalities can be understood as linkages between practices and constellations but can also show possible incompatibilities between practices. Therefore, interrationalities could possibly show synergies and barriers for wider implementation.

Overall, the following definition of a network of practices can be given:

A network of practice is the combination of all interacting and connecting constellations of practices by different actors. These networks are influenced by the nexus of practices surrounding them.

Based on this understanding of practices, a number of conclusions can be drawn. Firstly, the innovation paludiculture specifically focussing on cattail cultivation is understood as the practice in this research. Secondly, the practice can be appraised in four interacting and connecting components: elements, spatial, temporal, and social (Castelo et al., 2021). Thirdly, in order for practices to become part of the regime, they should become performances and not remain entities (Laakso et al., 2021). And finally, in order to investigate innovations and upscaling, one must examine the network of practices to do so, which can be visualised as aggregates of bundles and constellations of practices.

Operationalising network of practices

Now that there is a common understanding why the network of practices are taken as central point of investigation and what this entails, we must now ask the question, how do you operationalise the practice-based approach in order to analyse the network of practices? There are multiple methods, or toolboxes, in which a practice-based approach can be conducted, but the social practice theory (SPT) lends itself most to a study on the network of practices (Castelo et al., 2021; Giller, 2021; Nicolini, 2012). SPT distinguishes itself by its focus on '*relationality*' meaning the connections between practices and the complex relationships between them, where no practice can operate in insulation (Castelo et al., 2021; Nicolini, 2012). By taking this perspective, it takes a broader view than only the internal structure of a practice, but also takes into consideration interactions and clashes between practices, which Scheurenbrand et al. (2018) states is essential. Additionally, if we agree that practices are part of routines, then we also agree with the fact that practices are not isolated. Thus, a network of practices also entails a network of people and actors which keep this network of practices going. This is essential to explore as practices are unavoidably social (Reckwitz, 2002). Therefore, besides the practices themselves, differences between groups of people should also be considered, such as ethnicity and gender, as this can also impact the adaption of a practice (Warde, 2016). Therefore, when looking at the network of practices, attention must also be paid to elements within and elements surrounding it.

Nicolini (2009, 2012) uses the toolbox of 'zooming in' and 'zooming out'. By doing so, both internal and external interactions are explored. Essentially, zooming in focusses on the central practice or a defined group of practices. One could relate this to focussing on the bundles and constellations (Hui et al., 2016). Zooming out then focusses on the linkages, connections, and associations between the (group) of practices and what the effects of these connections are, thereby mapping the networks of constellations. In this way, Nicolini takes different angels for observation and interpretation without making one or the other more dominant or important. How we can operationalise zooming in and zooming out is explored and explained in section 4.2. Research steps and methods used.

3. Knowledge gap

In this chapter, the problem statement, the research objective, and the research questions are given.

3.1. Problem statement

As stated in the introduction, it is of paramount importance that the water management system in the Netherlands must adapt in order to deal with climate change (Beleidstafel Droogte, 2019). New alternatives are being tested, but such pilots often fail to scale up (Buuren et al., 2018; Dongen, 2021). Research has been conducted to prove the existence of the pilot paradox and how this in general can be explained and possibly emitted (Broek et al., 2020; Dongen, 2021). Additionally, previous research on upscaling has dominantly adopted a multi-level approach, assuming a hierarchical structure in which the niche and regime are theoretically separated (Geels & Kemp, 2000).

However, it can be questioned whether the multi-level approach allows for a thorough understanding of what happens in practice and therefore this research suggests trying out a new perspective and approach. Through observation, the practice-based theory focuses on what is said and done and by who (Nicolini, 2012). Therefore, it is interesting to uncover how the practice-based approach can be used in analysing an agricultural pilot and practice such as paludiculture. This is particularly so due to the lack of existing previous research in agriculture using the practice-based approach (Giller, 2021).

In order to tackle this knowledge gap, it was key to select a case study of a pilot project that has the potential to suffer from the pilot paradox. One such case study, a living lab in KLIMAP, is the paludiculture pilot in Helmond as presented in the introduction. The practice is very new and therefore uncommon and unknown in this region and therefore presents itself with a significant challenge to scale up. This pilot has been subject to economic and hydrological research, but none referring to the socio-cultural legitimacies of societal embedding. Therefore, a knowledge gap exists concerning these characteristics of business environment, wider society, policy environment and user environment. Without knowing the current characteristics of the network of practices, and thereby understanding the (potential) societal embedding of the paludiculture, there is little to no knowledge on how this pilot can be upscaled. Consequently, this research aims to better understand potential issues in upscaling by researching the characteristics of the network of practices of paludiculture, taking the pilot in Helmond as starting point or bundle of practices.

3.2. Research objective

The case study of paludiculture using the crop cattails on sandy soils offers an interesting opportunity to use the practice-based approach to explore the characteristics of the network of practices, thereby discovering the potential for upscaling in that particular case. Therefore, the main objective is to observe what is happening in this pilot by researching the characteristics of the existing network of practices. Ultimately, by exploring the characteristics of the network of practices, it will allow an understanding of the social embeddedness of the new practice and how it integrates, or does not, into existing practices. It is important to note that this research does assume that there is potential for upscaling the paludiculture innovation on a larger scale, thereby meaning it has the potential to contribute towards the adaptation to climate change. That being said, this research does not aim to create a detailed strategy plan describing how the paludiculture pilot should scale up, but rather provide initial advice and insights on potential ways to make use of the existing structures and practices in order to stimulate societal embedding.

Additionally, it is interesting to reflect on the use of the practice-based approach in the agricultural sector in the discussion. By doing so, it can provide new insights into current research on upscaling as well as operationalise a network of practices in an agricultural context. Overall, the research will be based on empirical evidence generated through qualitative research methods as described in the next chapter. Additionally, the research could be of added value to the PhD research by Giller (2021).

3.3. Research questions

The main research question is as follows:

What are the characteristics of the network of practices in the paludiculture pilot with cattail cultivation in Helmond, the Netherlands?

The main research question focusses on the characteristics of network of practices of cattail cultivation. In these characteristics, which can be found in a number of steps in which the factors of social embeddedness will be integrated: user environment, wider society, business environment, and policy environment. The pilot in Helmond will be taken as case study, and around this the network of people and practices will be researched.

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

1. Of what elements (materials, meanings, and competencies) does the practice of cattail cultivation consist of and why?
2. What are the temporal, spatial and social characteristics of the network of practices of cattail cultivation?
3. What are the interrationality with surrounding practices?
4. How is the network of practices of paludiculture with cattail cultivation influenced by its nexus?

4. Methodology

This methodology chapter is divided in two parts: firstly the case study background and secondly the research steps and methods used. The case study background describes the location, parties involved, and other relevant details of the pilot site. The second part the steps taken to operationalise the network of practices and social embeddedness. In each step the research methods used are explained.

4.1. Case study background

First, the context of peatlands in the Netherlands is given including a short introduction on cattails. Then, the pilot site is introduced.

4.1.1. Peatlands in the Netherlands

As stated, paludiculture is the practice of crop production on wet soils with certain crops that can be grown in partially submerged condition predominantly on peatlands (Geurts et al., 2019). Peatlands are unique soils containing a high density of organic material (Deelexpeditie Natte Teelten, 2020). These peatlands in the Netherlands have largely been converted to drained agricultural land and can be found across the country, as indicated in green in Figure 4 (de Vries, 2004). The highest concentrations of peatlands are found in the Northern provinces and in the West of the country, but smaller patches can be found in other parts of the country, including the province of Brabant. In Brabant the landscape is characterised by stream valleys, including the area around Helmond (T. de Jong, 2016). Thus, this research takes a case study in a stream valley as starting point.

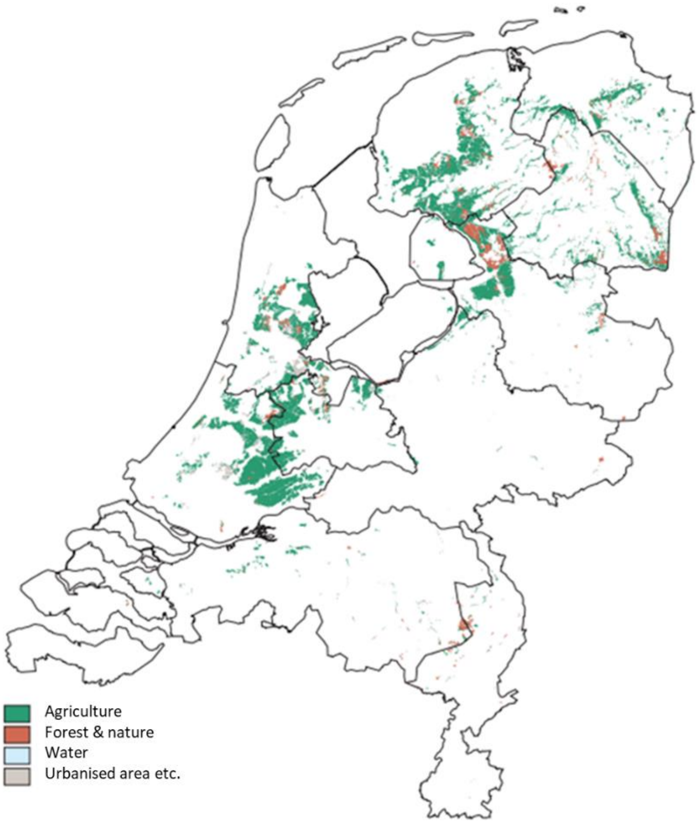


Figure 4. Peatland locations indicated in colour. Green = agriculture, Red = forest and nature, Blue= water, Grey = urbanised area.

Figure 5. Typha angustifolia and Typha latifolia, adapted from Flora van Nederland (2013).

In this thesis, the focus is on cattail cultivation, also known as bulrush or *Typha*. There are two types of cattail species which are cultivated, *Typha latifolia* (large) and *Typha angustifolia* (small). In the pilot site in Helmond, the large cattails are dominant (Int. van Duinen; Int. Geurts). To see the difference, refer to Figure 5. Typha angustifolia and Typha latifolia, adapted from Flora van Nederland (2013).

4.1.2. Pilot site context


Figure 6. Pilot site Helmond view from East side of the field. Picture taken the 18th of October 2021 by A. Ossendorp.

The pilot plot is located on Estate Groot Overbrugge just North of Helmond in the province Brabant in the Netherlands (coordinates 51.498209, 5.638015) (Koper, Peek, Steyntjes, Weert, & Wielders, 2021) (Figure 6). The pilot site is slightly under 1 ha of large cattails (re-)sowed or planted at different times since September 2019. The land is owned by the Estate Groot Overbrugge and multiple parties are involved in management and measurements. The Interreg Carbon Connects project, hereafter referred to as CConnect, is the initiator of the pilot. CConnect is funded by the European Union (EU) and has a wide group of stakeholders involved across Northwest Europe. The project, having started in 2018 and expected to be completed in 2023, aims to reduce high emissions caused by now traditional agricultural practices on agriculturally converted peatlands in Northwest Europe (De La Haye, Devereux, & van Herk, 2021). To do so, CConnect is involved in a total of 11 different pilot sites to research new bio-based business models for peatlands. Helmond is one of such projects exploring the potential of wet cultivation of crops and was set-up and largely funded by CConnect in 2019 (Int. van Duinen).

KLIMAP and LANDMARC (Land Use Based Mitigation for Resilient Climate Pathways) became involved at a later point in time, only once the pilot site was fully functional and running. LANDMARC is another EU funded project from the EU's Horizon 2020 Research and Innovation Programme between 2020 and 2024 (LANDMARC, 2022). LANDMARC's main goal is to improve knowledge on how and where land based mitigation technologies such as paludiculture can be most effectively positioned. Bioclear Earth, one of the main partners of LANDMARC, conducts emission measurements in Helmond. KLIMAP became involved due to their interest in buffer zones for the surrounding areas. Due to the people involved from CConnect and KLIMAP the site also has direct collaboration with other institutions including Waterboard Aa & Maas, the Radboud University, KWR Water Research Institute, and Foundation Bargerveen. There are other similar pilot sites in North-Brabant including Soerendonk, Scheiendsven en Biest-Houtakker (KLIMAP, 2021). However, to limit the scope of the research and because of the involvement of a landowner in Helmond unlike the other sites, this research takes only Helmond as starting point of the research.

4.2. Research steps and methods used

In the following section, the integration of the concept of societal embedding in the research steps is given, followed by the research methods used. Finally, the research steps are elaborated.

4.2.1. Integration of the concepts into the research steps

The concept of network of practices is complex and difficult to operationalise. However, Castelo et al. (2021) did so in their research on the network of practices in food consumption. The basic ideas of the operationalisation for the network of practices of consumption can also be adopted for an agricultural practice. Therefore, the 5 steps created by Castelo et al. (2021) were taken as guideline to the methodology; step 1 defining the unit of analysis, step 2 finding the elements of practice, step 3 exploring the temporal, spatial, and social dimension of the practice, step 4 the interrationality between practices, and step 5 the context of practices.

The content of each step was adapted slightly to integrate the concepts of societal embedding and to be applicable to paludiculture. Firstly, based on the understanding of the SPT by Nicolini (2012), Castelo et al. (2021) operationalises the zoom-in and zoom-out of the SPT into 5 sequential steps. In this, steps 1, 2 and 3 zoom-in, while steps 4 and 5 zoom-out. In this research, this differs as to find the spatial, temporal, and social dimension (step 3) it already requires zooming out and look at existing surrounding practices outside the farm boundaries. In this way, one can take learning experiences from other pilot plots. Therefore, step 3 is understood as already zooming out. Furthermore, for consistent terminology, the context of practices is renamed as nexus of practices in order to relate to the network of practices framework. For a simple overview of the steps refer to Figure 7.

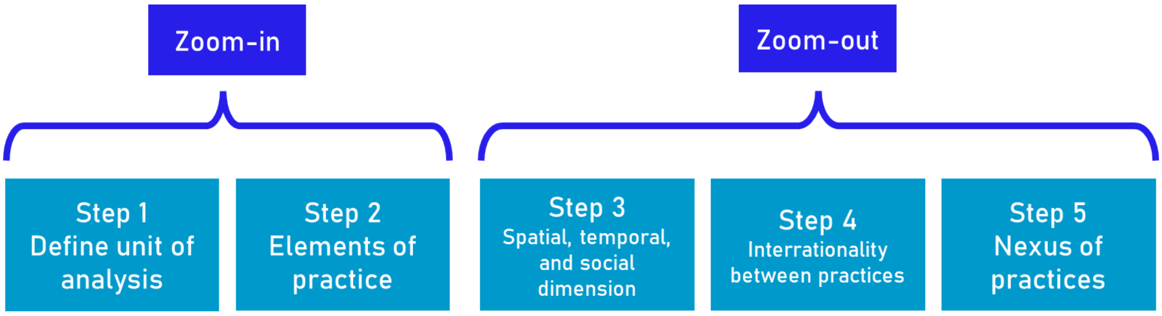


Figure 7. How to operationalise research on network of practices adapted from Castelo et al. (2021) and Nicolino (2012).

It is important to note that these steps do not necessarily need to be carried out in order, but for the sake of clarity the structurisation of the research roughly followed these steps.

An additional small change was made to the structurisation of the steps. During the research it became clear that interrationalities are discovered by finding overlaps in the dimensions of step 3. Therefore, in the explanation of the research steps and the results chapter, steps 3 and 4 are combined. This leaves us with the question, how is the conceptual framework integrated into the methodology steps? In step 2 one zooms-in on the elements of practise, thereby representing the user environment as meanings, materials, and competencies largely relate to those directly involved at field level. In steps 3 and 4 one starts zooming out, thereby considering the wider society. In step 5 one looks at the context of practices, which in this case is defined as the policy context, consequently reflecting the policy environment, and the business environment (Figure 8).

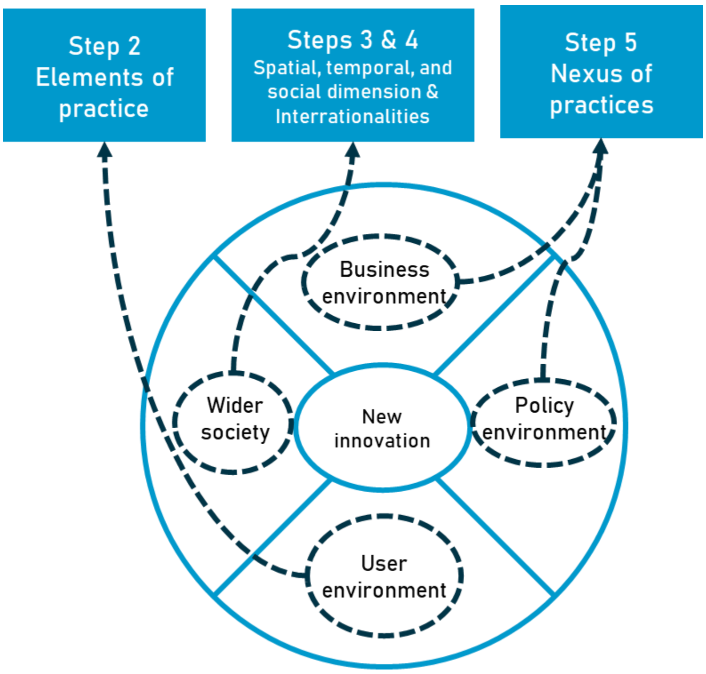


Figure 8. Integration of social embeddedness in the research steps.

4.2.2. Research methods

Before explaining each step, it is important to provide an overview and explanation of all forms of data collection used. Overall, the research adopted three methods of data collection: a social network analysis (SNA), semi-structured interviews, and an additional short grey literature study.

The SNA is a method to find and map out the complex ''web of relations on the individual, organisational and societal level'' (Ghali et al., 2012 pp.4). By doing so, one can uncover the social element of the practice, which all practices inevitably have (Reckwitz, 2002). Despite the fact that SNA it is not strictly speaking a practice-based theory, a SNA does allow for practices to be outlined as an organisational phenomenon. Bharwani et al. (2013) state that SNAs are a ''formalised method to visualise stakeholder and knowledge networks, and in doing so, to understand them in the context of future action'' (pp. 2). These networks can be graphically represented in maps through which the linkages can represent flows such as information, advice, money, policy, etc. (Bharwani et al., 2013). An example of the results of a SNA from another research is seen in Figure 9 (Criado & Villodre, 2018).

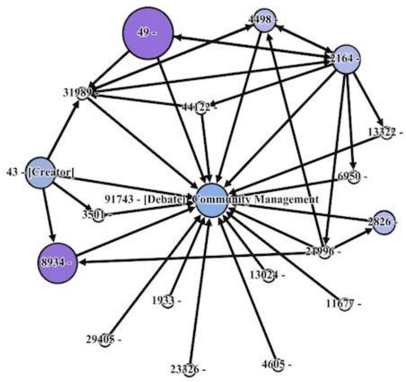


Figure 9. Example of SNA where number of interactions depending on the power of public employees for the debate of the role of the community manager (Criado & Villodre, 2018).

In this research, each interviewee was asked if they would be willing to fill out a SNA exercise (Annex A: Social network analysis exercise). For the majority of those who filled in the exercise it was done after the semi-structured interview had taken place when they had more time to consider their answers and send these back via email. In total, six maps were made of which the first two represent the full network and will be used as starting point to the results. The first map will show the full network divided into the type of organisation or individuals spoken to. For instance, a water board, project, city government, nature advocates, and so on. The second map divided those spoken to into the four components of social embeddedness to provide a starting point for the following result chapters. The other four maps will be explained further in steps 3 and 4. The software GEPHI version 0.9.2. was used. Furthermore, to create the maps a number of assumptions had to be made. These can be found in Annex B: Decisions made to create SNA maps.

The semi-structured interviews were the main method of data collection. The interview guide was divided into 3 sections of which the first focused on elements of practise, the second on the dimensions and interrationalities, and the third on the policy context (please refer to Annex C: Interview guide). Results for the business environment were reflected in all three parts and therefore did not have a separate section in the interviews. In total, 27 semi-structured interviews and a single open interview (with the HAS students in the field) was held between the period of October and December 2021 (Figure 10). The majority were held online due to COVID-19. For the connected institution per actor, please refer to Annex D: Interviewees & organisations. In the results chapter, interviews are referred to as *'Int. Surname of interviewee'*.

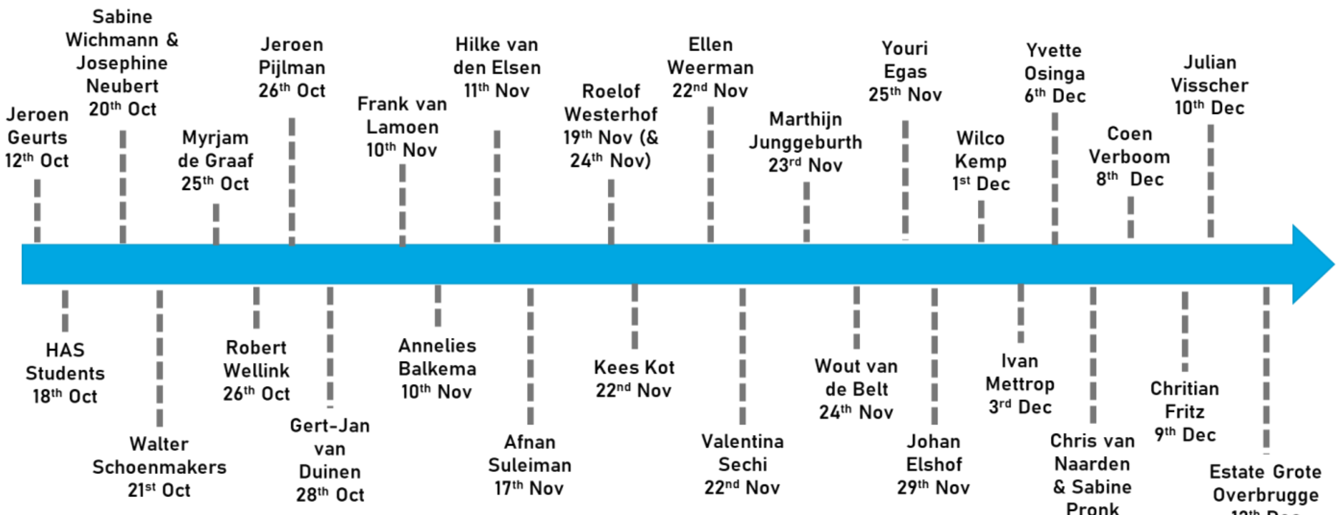


Figure 10. 28 Interviewees and date interviewed.

It is important to note that due to the wide variety of backgrounds and expertise of the interviewees, the interview guide was adapted slightly before each interview. For instance, a planter was asked more in-depth questions on the materials needed for paludiculture while less on the policy context, while a policy officer of a water board the contrary. The final form of data collection, the short grey literature study, was mostly used to support findings in step 5.

4.2.3. Research steps

This section provides a general overview of the research steps is given. For a more detailed step by step explanation, please refer to Annex E: Explanation of research steps.

Defining the unit of analysis

Step 1 concerns the definition of the unit of analysis, thereby defining what practice or what group of practices are investigated and what the boundary of this practice (group) is. In this, it must be clarified at what point the zooming-out starts. In this research, the practice investigated is paludiculture with cattail cultivation, taking the pilot in Helmond on the Estate Groot Overbrugge at starting point. The boundary condition for zooming in is defined as those directly involved in the operation and continuation of wet cultivation, even if in a different plot or pilot site. Furthermore, the social embeddedness perspective also introduced a clear boundary for the research. This means the research did not elaborate on hydraulic discussions or economic debates on the feasibility of paludiculture with cattails, but rather aimed to provide insight into the social embeddedness of the practice.

Elements of practice

Step 2 zooms in on the elements of practices, the first of the four components of practices. These elements can be appraised as the basic units of a practice-as-entities, such as the materials, meanings and competencies used. These are needed in the daily performance of the practice, thereby focussing on the social embeddedness in the user environment. Thus, this aimed to understand bundles of practices and constellations of practices with the farm as the boundary. To uncover such bundles and constellations, the semi-structured interviews were held with those directly involved in the pilot site in Helmond (6 interviewees) and other pilot sites. The questions were oriented towards understanding why those involved decided to engage in paludiculture, and what materials, competencies, and meanings they associate with paludiculture based on their own personal experiences. By understanding why paludiculture was adopted and works at the pilot level, it enabled a better understanding why paludiculture might clash with other practices in a different social context due to different elements. During these interviews, contact details for new interviewees (snowball sampling) were collected as explained in the following section.

Dimensions and interrationalities

The following steps, steps 3 and 4, started zooming-out, where the pilot site itself was still central but the focus lay on how this practice fits into its direct surroundings of practices and people. Step 3 explored the other three components of a practice, namely the temporal, spatial, and social dimension, while step 4 consisted of finding the interrationalities between and within these dimensions. This recognised that the performance of practices is context-specific and that practices are adjusted based on different context and are not self-isolated, as described in the theoretical framework (Scheurenbrand et al., 2018). Due to the goal to map networks and the limited time span of the research the choice was made to use snowball sampling. Simply put, snowball sampling is the gathering of new interview contacts based on recommendations from the previous interviewee (Noy, 2008). In this case, exponential non-discriminative snowball sampling was used, meaning each interviewee was asked for multiple refers whom were all approached.

Two main methods were used to collect data for this step: the SNA exercise and the semi-structured interviews (the second section). In total, 6 SNA maps are made, of which the first two maps show the entire network. To create this, the interviewee was asked to create a full list of individuals and organisations with which they had had contact with about paludiculture in the past two years. Besides visualising the full network, the SNA also aimed to provide insight into the social dimension. To do so, four specialised maps were formed by asking superlatives within the created long-list asking which organisations are most important for (1) knowledge-sharing, (2) promoting, (3) dependent for its implementation, and (4) the policy implementers of paludiculture. For each of these questions the interviewee was asked to fill in their top five individuals and/or organisations. In total, 12 fully filled out SNA lists were completed of which 8 had completed answers to the superlatives. However, these results did not fully encompass the total of 28 interviews. Therefore, a number of decisions and assumptions were made, as explained in Annex B: Decisions made to create SNA maps. As a result, it enabled a basic qualitative SNA which could support findings of dimensions and interrationalities.

The semi-structured interviews also served as input for the interrationalities between practices, building links between the constellations (Castelo et al., 2021). This aimed to reveal possible co-dependence between actors and practices, for instance sequences in which practices usually occur, shared elements between practices, or even the need to co-exist, or simply that practices usually interact (in time and space). Overall, steps 3 and 4 incorporate wider society of social embeddedness.

Nexus of the network of practices

Finally, step 5 aimed to identify the context of the network of practices, and thereby the nexus of practices. This explored how the network of practice is shaped and influenced by broader influences. This could consider pre-existing external arrangements, political, socio-cultural norms, economic agreements, and so on. In this research, the focus was on the policy and business environment, the first and third components of societal embeddedness. For both the policy and business environment, the semi-structured interviews and a short (grey) literature study acted as input for the results. The policy environment was distinguished by national and international funding and the business environment as the funding and market of cattail cultivation. Overall, multiple methods were used in this research including semi-structured interviews, a SNA, and a short (grey) literature study. For a summary of the methodology and steps, refer to Table 1.

Table 1. Summary of methodology

Steps	Data & collection method	Information acquired
Step 1: Defining unit of analysis	- Defined in research proposal	- Refined at what boundary zooming out begins
Step 2: Elements of practice	- Semi-structured interviews with those involved in the daily performance and requirements of paludiculture and snowball contacts section 1	- Gained understanding of meanings, competencies, and materials needed to practice paludiculture - Collectedadditional contacts for potential interviewees
Step 3: Spatial, temporal, and social dimension & **Step 4** Interrationality between practices	- Semi-structured interviews with surrounding actors (interviewees partially based on snowball sampling) section 2 - Social networks analysis (SNA) exercise	- Understanding the social, temporal and spatial component of paludiculture in context of other agricultural practices and wider society - Building an understanding of the social network surrounding paludiculture in the case study area and the companions operating in it - Finding the interrationality between practices (complexes, bundles, and nexuses) and visualising this in a networks image
Step 5: Nexus of practices	- Semi-structured interviews section 3 and part of section 1 - (Grey) literature reading of policy documents	- Understanding the context, primarily policy, which influences paludiculture - Understanding the funding and market of cattail cultivation

5. Results

In this chapter the results of the social network analysis (SNA), the semi-structured interviews and (grey) literature study are presented. Firstly, the full network is shown of those involved in paludiculture in the Netherlands and how this relates to the social embeddedness of this innovation. Secondly, the elements of practices are discussed including what meanings, materials, and competencies are necessary. Thirdly, the temporal, spatial, and social dimensions and their interrationalities are presented. Fourthly, the nexus is presented in which the policy and business environment are discussed. An overview of the chapter is shown in Figure 11.

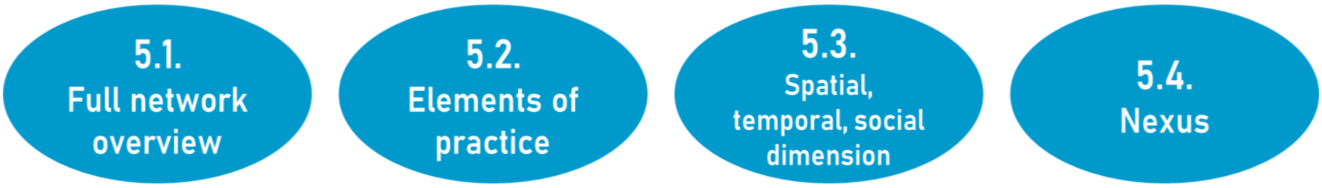


Figure 11. Overview results chapter

5.1. Full network overview

To help guide the reader through the chapter the full image of the actors' network serves as a starting point (Figure 12). Based on the compiled answers of all 28 interviews, the maps in Figure 12 and Figure 13 were created. For an explanation of all names in the network please refer to Annex F: Abbreviations and translations of SNA maps. For an understanding of the actors and institutions connections please refer to Annex D: Interviewees & organisations. To understand the decisions and assumptions made to create the maps please refer to Annex B: Decisions made to create SNA maps.

5.1.1. Key actors and institutions in the network

It is interesting to distinguish the network into types of organisations or actions, for instance by differentiating between projects, public entities, commercial enterprises, and civil society. The result is a busy image from which a number of primary conclusions can be drawn. Firstly, knowledge institutions and universities are central to the network (depicted in dark blue in Figure 12). This includes parties such as the Radboud University, KWR, Stichting Bargerveen, and University of Greifswald. This indicates that the network is currently strongly dominated by scientific research and there are not yet any cattail cultivators operating independently from a research project or institutions. This means the network is dominated by controlled practices within pilots with currently little interaction with common practices of farmers and landowners.

Secondly, projects in which these knowledge and scientific institutions are involved are also central (depicted in orange). This applies to the CConnect initiative, as previously introduced, in particular, part of which is the pilot site in Helmond. Other projects that are central to the network and are involved in cattail pilot sites are Better Wetter, LANDMARC, and KLIMAP. Deelexpeditie Natte Teelten (ENG: Partial Expedition Wet Cultivation), is a project in which many experts were involved to combine knowledge on wet cultivation, thereby acting as knowledge brokers (Deelexpeditie Natte Teelten, 2020).

Thirdly, very few companies are currently involved in paludiculture (depicted in red). Additionally, any companies that are involved will most commonly be found on the outer ring of the network. The most important ones to name are Wellink Equipment, Wetland Products, and Bouwgroep Dijkstra Draisma. Overall, this confirms the highly scientific nature of paludiculture at this point in time, being dominated by research institutions and universities.

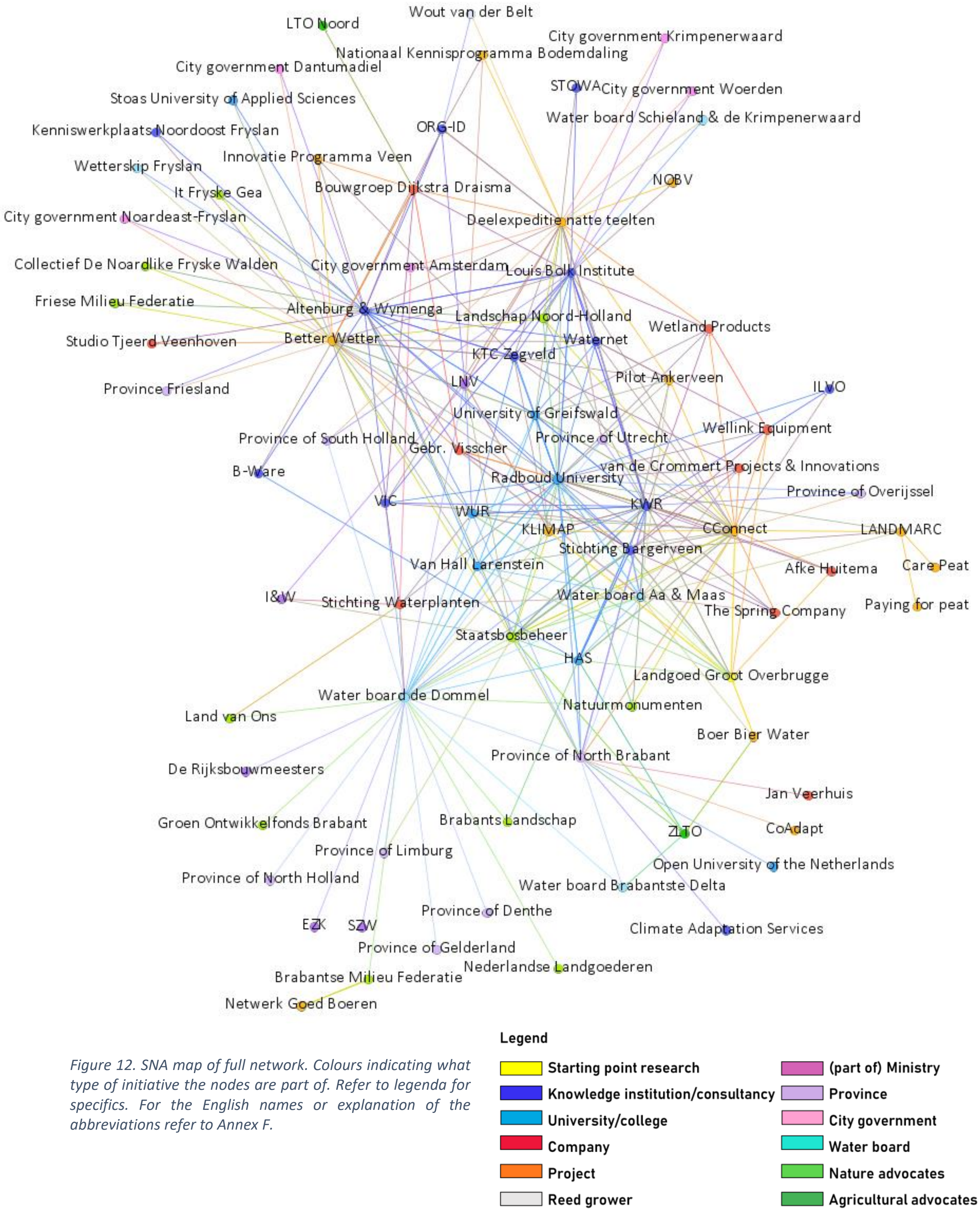


Figure 12. SNA map of full network. Colours indicating what type of initiative the nodes are part of. Refer to legenda for specifics. For the English names or explanation of the abbreviations refer to Annex F.

5.1.2. Societal division of the network

It is interesting to relate the map in Figure 12 to the conceptual framework, distinguishing the user environment, the wider society, the policy environment, and the business environment. The result is shown in Figure 13. To explain these results, it is important to recap how each actor and initiative was categorised. The user environment was defined as those that are directly involved in the operation and continuation of wet cultivation, even if in a different pilot plot than Helmond. If a pilot site was both part of a research institution and also had a pilot site, the user environment took precedent and was coloured green. The wider society consisted primarily of nature and agricultural advocates and was coloured orange. The policy environment was seen as those involved in policy making and the implementation of policy, including water boards, provinces, city governments, and ministries. These were coloured blue.

The understanding of the business environment was a more complex decision due to multiple factors. Initially it was expected that the business environment would be more present in the form of businesses as defined by Geels et al. (2011). In a traditional sense, business is appraised as an organisation or enterprising entity which is engaged in either professional, industrial, or commercial endeavours and thus, whose goal is to earn a profit (Hayes, 2021). However, due to the small amount of (independent) businesses engaged in paludiculture this would not show the current market and financing of the pilots, which is essential to understand how the network of practice currently functions. Furthermore, it is not suitable to place all the projects, research institutions, and universities under wider society. This as they themselves are now the dominating actors driving the paludiculture exploration. Therefore, the decision was made to define the business environment as the traditionally understood sense of business as well as entities paying for or funded by research institutions. This means that funded projects (for instance by government institutions), research institutions, consultancy companies, and businesses are all defined as business environment and shown in pink. In this sense, it can be understood that the business environment still need to prove and 'sell' their product to landowners and farmers, the potential users.

A number of trends can be identified in this network. Firstly, also due to the choice in definition of the business environment, we again see that research is the main driver of the user environment. Research institutions are dominant at the centre. Secondly, we see a clear relation between three user environments, Better Wetter, KTC Zegveld and the pilot in Ankerveen. This can be explained by their similar setting in the peat meadows or fenlands of the Netherlands. The pilot of the Estate Groot Overbrugge in Helmond is more removed from this due to its stream valley setting in the South of the country. This spatial distinction between the peat meadows and stream valleys will be further elaborated upon in section 5.3.2. Spatial dimension.

Thirdly, the policy environment has the most influence on the business environment, in particular to those connected to research. This can be explained by the origin of funding in the business environment, as explained in section 5.4. Nexus. Furthermore, in several examples those in the policy environment are also partners in research projects. For instance, the water boards Aa & Maas as well as de Dommel are partners in the KLIMAP project. This suggests the projects are places where the research institutions and the policy environment meet in a common 'business environment'.

Finally, wider society is in general on the outer edge of the network and therefore less involved in paludiculture. The main exception to this trend is Staatsbosbeheer, the state forest management, who was involved in a cattails pilot site in the nature area the Peel in Northeast Brabant. Overall, this apparent disconnect from wider society shows that paludiculture is still very much in an experimental phase and therefore not yet part and discussed by wider society.

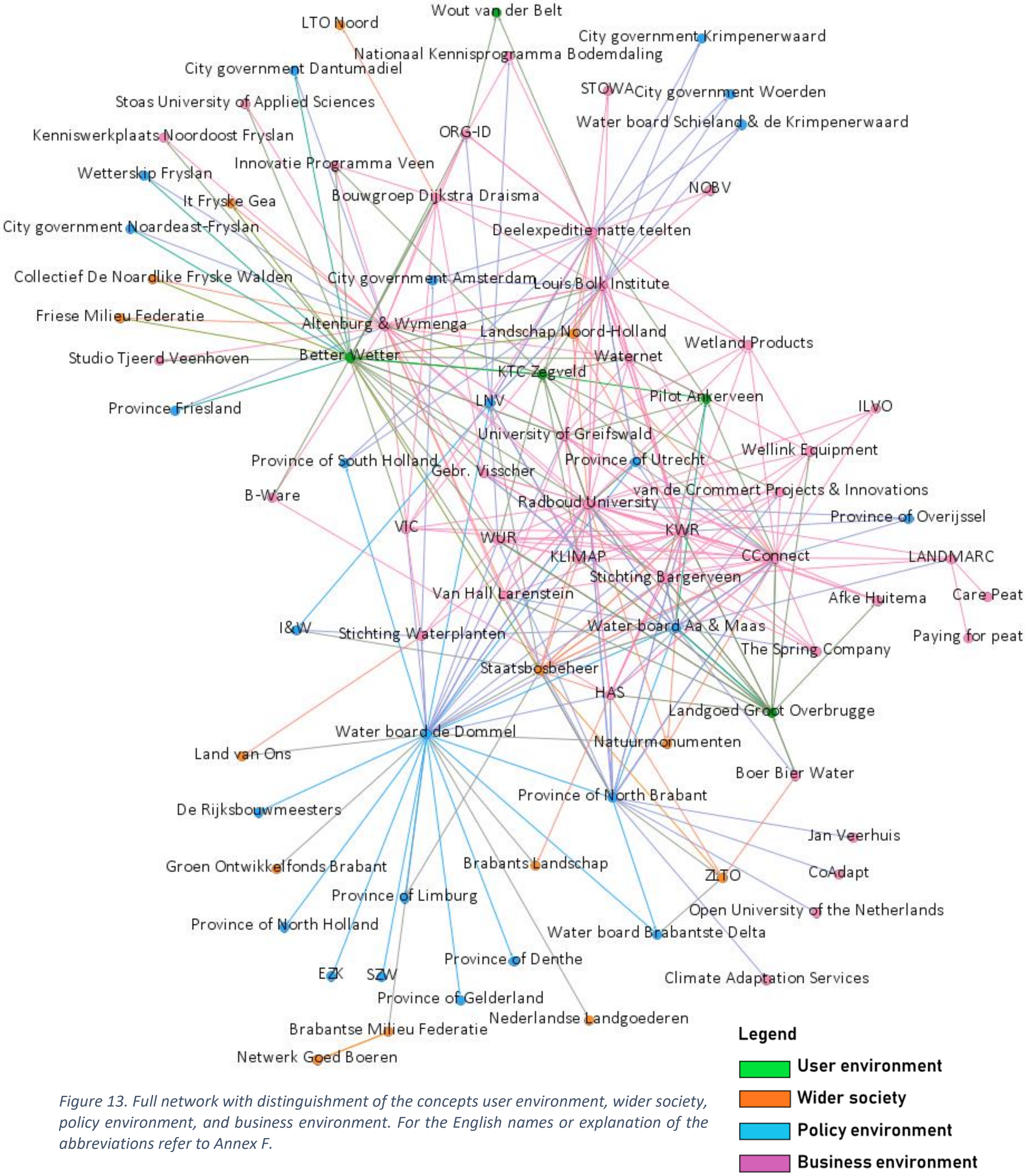


Figure 13. Full network with distinguishment of the concepts user environment, wider society, policy environment, and business environment. For the English names or explanation of the abbreviations refer to Annex F.

5.2. Elements

To build a network of practices, one must first understand what the building blocks of the central practice are. In this chapter, the different meanings, multitude of materials, and necessary competencies are presented of paludiculture with cattails as central example.

5.2.1. Meanings

One practice can hold a different meaning depending on who you ask. In this chapter, three main points are addressed; the distinction between paludiculture and wet cultivation, the diverging goals of paludiculture, and the value of pilot users including landowners and farmers.

Distinction between paludiculture and wet cultivation

In this thesis, the choice was made to use the terminology paludiculture consistently. However, during the data collection phase it became apparent that the terms 'paludiculture' and 'wet cultivation' are used interchangeably, leading to ambiguity in definitions. Paludiculture typically refers to the re-wetting of peat soils as main goal and therefore the restoration of natural peatlands.

Wet cultivation on the other hand is a broader term. This is not necessarily related to peat soils and in scientific research is often connotated to wet rice cultivation. Therefore, one could say that paludiculture is a type of wet cultivation specifically on peat soils. Yet, in 5 out of 27 interviews the interviewees used the terms wet cultivation (Dutch: *natte teelten*) and paludiculture interchangeably, meaning they made no clear distinction between them (Int. Geurts; Schoenmakers; van Duinen; Osinga; Fritz). Pijlman addresses this difference:

> *''Can you draw a line between paludiculture and wet cultivation? The definition says paludiculture aims at preserving and restoring peatlands. Then you could take it as a transition phase to near-natural conditions, something that is temporary … Wet cultivation with the aim of biomass production can be seen as more an agricultural approach. Ultimately, there must be a revenue model in it, if not it will be difficult to develop. However, aiming at high biomass productions does not necessarily match with the aim of restoring peatlands. Therefore, pursuing wet cultivation or paludiculture does not always give the same results." – Int. Jeroen Pijlman*

Therefore, the question arises, what is the end goal of paludiculture, nature restoration or agricultural production? And consequently, does this mean that the term paludiculture can only be used if the ultimate goal is to restore natural peatlands?

> *''Paludiculture is about peat conservation and wet cultivation is much broader.'' – Int. Ivan Mettrop*

As a result, interviews show there is no consensus on definitions among researchers. In the interviews with other actors (not directly involved in research on paludiculture) interviewees either used wet cultivation consistently or paludiculture, but both were used to refer to cattail cultivation. Therefore, the issue in terminology, and therefore meaning, appears to be related to the purpose of the practice. Thus, the choice of term is dependent on the end purpose of the practice, agricultural production (wet cultivation) or peatland restoration (paludiculture). At the end of the following heading, a suggestion will be made on how to understand paludiculture in this thesis research.

Diverging goals

As discussed, paludiculture and wet cultivation are frequently used as interchangeable terms, leading to confusion about the purpose of the practice. Not only is this relevant to clarify before larger scale implementation of a practice, but even at pilot level this should be defined clearly. During the interviews it became apparent that different actors had different primary goals for paludiculture.

These goals included (1) reduction of carbon emissions and reducing land subsidence, (2) agricultural production of a crop, (3) water storage for peak discharge and/or groundwater restoration, (4) ecological connection zones, (5) biodiversity, (6) improving water quality. For a broad explanation of each purpose refer to Annex G: Purposes of paludiculture explained.

The first important purpose of paludiculture is that of (1) land subsidence and reducing carbon emissions. When peatlands are drained the organic material will decompose due to oxidation resulting in land subsidence and the release of carbon dioxide (CO2). A way to prevent both is by re-wetting peatlands, thereby storing carbon and halting land subsidence (Joosten, Tapio-Biström, & Tol, 2012). Yet, many peatlands are drained or damaged, while storing CO2 has become more important following the Paris climate agreement (De La Haye et al., 2021; United Nations, 2015). Additionally, land subsidence is a mayor issue for the Netherlands, especially in peat meadow areas (NDL: veenweidegebieden) (Raad voor de leefomgeving en infrastructuur, 2020). CO2 reduction and land subsidence are often linked to each other as common goals of paludiculture which can exist side by side. However, Westerhof nuances this due to the fact methane must also be considered in the GHG balance.

> *''(Water levels) at 20 cm below ground level your CO2 emissions are the lowest and your methane emissions are not yet very high. Water levels at 20 cm below ground level also can seriously reduce subsidence but to completely stop subsidence, you have to flood it. With the risk of increasing methane emissions and you also have to talk about other land uses and another landscape.'' – Int. Roelof Westerhof*

Essentially, if we accept that cattail cultivation conditions usually consist of water levels at or above ground level, this means that the main purpose is land subsidence, not mitigation of GHG. If the main goal is to mitigate GHG, the ideal water level is at 20 cm below ground level (Wichtmann, Schröder, & Joosten, 2016). The final call has not been made whether this trade-off is worth it, but research is still being carried out on the effect of paludiculture on the overall GHG balance (NOBV, 2021). Overall, this means that the goals to halt land subsidence and GHG emissions might not go hand in hand after all. Therefore, when implementing paludiculture one should be aware of the negative effects it might have on climate mitigation. This again leads to confusion about the purpose and therefore the meaning of paludiculture.

If we relate these observations to previous section (Distinction between paludiculture and wet cultivation), both wet cultivation and paludiculture can aim to reduce land subsidence and C02 emissions. If land is flooded and then used for production then it can be appraised as wet cultivation, often as an alternative on land which can no longer be used for its original purpose. At this point, paludiculture is understood as something you can still do with the land even in submerged conditions to still produce something of material value. This entails an additional purpose of (2) agricultural production. Yet, if peatlands are kept as natural peatlands, then it should be defined as paludiculture. For cattails it is already quite clear that land subsidence and CO2 will not go hand in hand because of the need for the water level to be higher for production to be optimal, thereby making methane an issue. It is important to note that the main starting purpose of the pilot site in Helmond was carbon storage due to its connection to CConnect. However, due to its location in a stream valley the land subsidence discussion is less prominent compared to the peat meadows of the Netherlands. This difference in spatial factors will be elaborated further upon in section 5.3.2. Spatial dimension.

Another purpose mentioned, often in the stream valley context, is (3) climate adaptation of the water management system. However, this purpose is less prominent, and it is often lost in discussion on land subsidence and CO2 retention.

''There is not enough attention for it (climate adaptive properties of paludiculture), especially in high laying peat areas and stream valleys, because in low peat meadows CO2 retention is more obvious.'' – Int. Walter Schoenmakers

KLIMAP joined the pilot site in Helmond to explore the possibilities of climate adaptation for recharging groundwater levels and allowing for inundation of the plot in moments of peak discharge to prevent flooding (Int. de Graaf). There is a necessity to capture and store water locally in areas with sandy soils before it discharges to large waterways and lost to the sea. Paludiculture is a potential way to allow for slow and effective infiltration of discharge into the groundwater. Overall, this shows that the nature of paludiculture, especially cattails which are inundated almost all year round, also lends themselves as a potential basin. Yet, there is a contradiction here. If the goal is to recharge groundwater it suggests natural re-wetting and thus paludiculture. However, if the goal is to not ruin cultivation despite using it as a floodable area, then it matches wet cultivation. In reality, both purposes can be achieved, thus the real-life complexity is not reflected in the definitions of the terms. What was noticeable was that some experts involved in paludiculture were not aware of the potential purpose to contribute to the climate adaptation agenda (Int. Mettrop; Int. Elshof). This shows that the purpose of the same practice can be significantly different depending on what actor is spoken to and that this particular purpose is not as recognised by part of the wider research community.

A further purpose proposed for paludiculture is using it as (4) ecological connection zones between agricultural land and nature. This is particularly interesting as there is a movement to also increase groundwater levels in nature areas (Int. Weerman). This directly impacts the direct neighbours to these nature areas, which is often agricultural land (Int. Schoenmakers). Any agricultural land directly bordering nature might become too wet to continue current activities, thereby forcing famers to consider an alternative type of production (Int. Osinga). A particular pilot of which the main purpose was this was the Peel located in Northeast Brabant (Int. Schoenmakers). Therefore, paludiculture is also appraised as a way to protect nature areas in which water levels must be increased.

An additional benefit of paludiculture, which is sometimes recognised as a smaller additional purpose is increasing (5) biodiversity. There is ongoing research whether paludiculture increases biodiversity as it introduces a wet landscape into an otherwise dry landscape, thereby providing conditions for species with an aquatic stage (Int. HAS students; Int. Weerman). Currently, this is not the main purpose of projects and pilot sites, but it is interesting to see what the results of the current research the HAS students will be (Koper et al., 2021). Additionally, because cattails are *helophytes,* they have a natural ability to biologically filter water and remove nitrates and thereby reduce eutrophication, thereby improving (6) water quality (Int. Neubert & Wichmann). There are a few examples of pilots conducted by water board de Dommel which selected cattails specifically for this ability including Soerendonk, but most consider it an additional purpose (Int. Balkema; Int. van Duinen).

As shown throughout this chapter, multiple purposes can be combined to underpin paludiculture with cattails. This makes it an intriguing crop with a multitude of positive effects. However, all purposes do not have a direct link to either the definition of wet cultivation or paludiculture. Wet cultivation is related to production which is most likely linked to preventing land subsidence. However, production as well as restoring peatlands can still be an additional goal in the other named purposes. Does this then mean that wet cultivation and paludiculture are mutually exclusive? Mettrop believes both purposes can exist together at the same time in the short term:

''I don't think nature and production are necessarily contradictory. It's both about the same thing, you have the same end goal, re-wetting. But after 5 years we already see less tall plants. Then you have to start fertilising and fertilising in wet areas is not possible. In the short term, I think it's best to combine.'' – Int. Ivan Mettrop

Mettrop states that in the short term paludiculture and wet cultivation can co-exist therefore making this distinguishment between wet cultivation and paludiculture less relevant at first. In the long term, this becomes an issue as fertilising is illegal on wet soil due to eutrophication risks, meaning soil nutrients cannot be replenished for the crop (Int. Egas; Int. Mettrop).

However, it is difficult for research pilots to combine the purposes of production and restoration. In practice, often one trumps the other. Mettrop continued to explain that in Better Wetter, the initial goal was to focus on ecosystem services of paludiculture for the Frisian Boezem. This area is a continuous system of lakes, canals, and waterways in the Northern province Friesland. This to increases the flexibility of the area, including water and CO2 storage. However, due to a partner joining the project whose goal is production, made the research more cultivation-oriented than ecosystem service oriented (Int. Mettrop). This shows that combining purposes still has its challenges, but there is potential to do so. In this way, you can try to capture as many people as possible to increase the possibility of large-scale implementation. And perhaps Wellink summarises it best:

> *"The best thing is when it makes different people happy." – Int. Robert Wellink*

Now, after being aware of all the purposes and terminology associated with paludiculture, it is interesting to clarify what this thesis understands when speaking of paludiculture. In this case, we will define paludiculture as follows:

> The practice of re-wetting peatland, whether this is for the restoration of peatlands and/or for agricultural production, in order to halt land subsidence, store CO2, make the water management system climate adaptive, create ecological connection zones, and/or improve the water quality.

Values of pilot users

The previous sections refer primarily to the meaning of paludiculture in research and therefore by experts. Meaning can also relate to the value of paludiculture to the direct users, in this case land users of paludiculture plots. Therefore, it is interesting to uncover why land users or farmers decided to participate in the project themselves and 'sacrifice' part of their land. During data collection, the question why they joined the project was put to the Estate Groot Overbrugge and to Kemp, the dairy farmer involved in pilot Ankerveen with cattails in a peat meadow setting (Int. Estate Groot Overbrugge; Int. Kemp). Furthermore, Neubert and Wichmann were also asked about the main motivations of the farmer involved in the pilot at Greifswald (Int. Neubert & Wichmann). For the purpose of this report the answers are summarised here, but for the full analysis of values and relevant quotes refer to Annex H: Values analysis of pilot users.

Overall, the interviews referred to above identified a number of critical ingredients for the pilots, namely, (1) having a suitable plot, (2) connecting value to development of a new innovation, thereby valuing research and curiosity, (3) having a trustful working relationship with the researchers, and (4) aiming to contribute to something good in relation to carbon storage and protecting wider society. Additionally, it is important to note that in all three of the cases this is a hobby project, not their main income activity. Therefore, it is an additional interest next to their usual activities which does not take up a significant amount of time compared to their main occupation. These factors will be discussed more in depth in section 5.3. Dimensions .

5.2.2. Materials

Materials refers to the necessary tools and resources needed to carry out paludiculture with cattails. This section will elaborate on the selection and preparation of the plot, how the cattails are planted, the field management after planting including water management, and how to harvest the crop. This chapter does not elaborate on what happens beyond the field into production. This is part of section

5.4.2. Business environment. For the purpose of this research, the findings are summarised. For a detailed description of the materials refer to Annex I: Materials of cattail cultivation explained.

Preparation of the field

Before being able to start planting or sowing the seeds, the field needs to be prepared for paludiculture. This includes a number of steps which must be carried out. Firstly, a suitable plot location must be found (Int. Fritz). This is essential as water accessibility is necessary throughout the year. To access water, permission must be granted by the water board (Int. Geurts; Int. van Lamoen; Int. Neubert & Wichmann). Furthermore, it might require permission from the city government in order to comply with other rules and regulations such as spatial planning (Int. van Lamoen). Additionally, the soil must be peat in order for it to be called paludiculture in the definition of this research. In general, this means the location must be in peat meadows or close to the stream valley where peat soils can also be found (Int. Geurts).

Once the location is selected it requires adaptation in order to allow for water management suitable for paludiculture. In general, this requires levelling the field, creating a basin with small dikes, digging ditches alongside the plot, installing a (solar-powered) pump, and potentially dividing the plot into 'ploughing boxes' (Int. Kemp; Int. Neubert & Wichmann). Water levels can be checked using a gauging rod and reading it manually or by using a remote system (Int. Geurts; Int. Verboom). In Helmond, unique conditions apply due to the use of a sub-irrigation system, which was installed due to the landowner's previous knowledge of this technique (Int. Geurts; Int Van Duinen; Int. Estate Groot Overbrugge). The research found no other pilot site which uses this irrigation technique. It is important to note that van Duinen indicates that the sub-irrigation pump was too slow to bring the water up to the necessary level right after the planting. Therefore, an additional surface pump was used at the start of the process (Int. van Duinen). The design of the sub-irrigation system was carried out by the engineering bureau Promeco and Emons Group. The final point of preparation before planting is allowing for the water level to be raised just above ground level, in which the best case the soil is nutrient rich and flat (Int. Visscher). Overall, the preparation is dependent on the type of water management system selected, whether traditional surface irrigation or sub-irrigation. But both are beneficial in naturally wet areas, require a level ground to start with, and need water ponded to start planting.

Planting

There are multiple ways to start cattail cultivation of which the most common is the use of seeds or plugs. For an overview of the comparison between plugs and seeds refer to Table 2. For the details and argumentation for this table refer to Annex I: Materials of cattail cultivation explained.

Table 2. Comparison of plugs and seeds

Factors	Seeds	Plugs
Costs	low	high
Labour needed	low	high
Chance of geese feeding	medium	high
Chance of successful production	low – medium (depending on weather and water level conditions)	high
Possible to harvest in first year	no	yes

Overall, the most important point to highlight is the varying chance of success in production. Seeds are taken from the cigar of the cattails which in natural conditions are spread through the wind (Int. Egas). In natural conditions, many of these seeds never develop into plants, but because of the sheer volume of seeds still some will succeed. Egas compares this to Russian roulette as there is little clarity which will germinate, and which do not (Int. Egas). On the other hand, plugs are cultivated in greenhouses by growers on request with seeds that already have been sprouted in controlled conditions (Int. Visscher). These plugs are usually between 15 to 20 cm tall when planted directly into the soil, as done in Helmond (Int. Koot). The Estate Groot Overbrugge explained that plugs were chosen to increase the chances of success (Int. Estate Groot Overbrugge). For the Estate Groot Overbrugge one of the main conditions to agree to the pilot site on their property was to make the chance of success as high as possible, meaning that risks had to be limited at every point in the cultivation, including planting (Int. Estate Groot Overbrugge). They were discouraged to use only seeds due to examples of other pilot sites failing to sow successfully. Kemp confirmed the risk of seeds, which was the first method in Ankerveen.

> *''… but the seeds were not soaked well, and all blew to 1 corner. Well then you now know that if you want to start sowing, they must be really well soaked. Otherwise, they will not sink to the bottom. But it is also a pilot for that, it can also go wrong.'' – Int. Wilco Kemp*

Because the use of seeds introduces more unpredictable factors, including the weather and germination conditions, plugs would have to be ordered to limit the risk of failure (Int. Visscher). However, this is not an easy task since there are so far no breeders to be found with a plentiful immediate supply of cattails (Int. Koot; Int. Visscher). This highlights the current niche market of cattail cultivation. On the other hand, there are examples of successful sowing, for example by pushing the cigars of the cattails into the soggy ground or thoroughly soaked seeds (Int. Mettrop). This suggests that there is potential for sowing to work in the future if research finds ways address the difficult conditions. However, it is also important to note that if seeds are used, one cannot harvest in the first year (Int. Mettrop). On the other hand, there are clear reasons to opt for sowing instead of plugs including lower costs and less labour input compared to plugs. Seeds are also useful for filling up bare patches in existing cattail plots. The Estate Groot Overbrugge confirmed additional seedling was successful and an effective way of filling up patches in between already adult cattails (Int. Estate Groot Overbrugge).

A problem both planting methods suffer from, especially plugs, is the risk of the young shoots being eaten by geese (Int. Geurts; Int. Mettrop; Int. Schoenmakers). A method of planting which does not suffer from geese is the use of the use of rhizomes or roots of the cattail because of the woody structure (Int. Mettrop). However, due to the lack of availability and labour intensity of using rhizomes, this is a less prevalent method, despite its benefits (Annex I: Materials of cattail cultivation explained). Overall, all three methods of planting are possible, but each faces significant challenges.

Field management

Once the plot has been prepared and planted, little field management is needed to maintain the cattails (Int. Geurts). Most important is to check water levels daily (Int. Estate Groot Overbrugge; Int. Kemp; Int. Neuberts & Wichmann; Int. Verboom). This should be between 10 and 30 cm above ground where the plant is not fully submerged (Deelexpeditie Natte Teelten, 2020). The large *Typha* generally prefers a lower water level between 20 to 30 cm, while the small *Typha* are naturally found between 30 and 50 cm (Int. Koot). Egas adds that the small cattails generally cope better with water fluctuations, which could be more beneficial if the main intended purpose of cattail cultivation is related to climate adaptation (Int. Egas).

Geurts explained that the water level is controlled with a remote sensing system to check the level from home by the Estate Groot Overbrugge. This same system was also recommended and used by the Greifswald pilot plot (Int. Neubert & Wichmann). However, in that case a paid worker was employed to carry out management activities, not the farmer himself.

''A local farmer (not the same as the landowner) is paid by the pilot to conduct management activities, including mowing the causeway and checking the water level.''– Int. Sabine Wichmann

Mowing the causeway and dikes can also be part of management activities. Verboom, who also coordinates a cattail site for the company Bouwgroep Dijkstra Draisma adds that he also checks the outlets and ditches are free of dead plant material. This is an activity he does when checking the plot every morning to check the water level. Another part of field management is continuing to check the lines spun which aim to prevent geese landing, also seen in Figure 6 (Int. Geurts). A possible issue in field management is that the plot can lose its flatness due to parts of the land swelling (Int. van Duinen). Therefore, despite levelling the ground before planting, the ground then becomes bumpy, causing parts of it to fall dry, which impacts the growth. These dry parts need additional plugs and additional sowing to improve the density of the field. This also requires a general increase in water level in order to keep the centre of the plot still sufficiently wet. Therefore, field management concerns checking if the whole plot is still receiving sufficient water and not only the outer edges which are visible. To level the field is very difficult once it is fully cultivated (Int. van Duinen).

Fertiliser application is not part of field management because fertilisation is not permitted on wet soils or elevated water levels. This could become an issue if the cattails suffer from nutrient deficiency. This will be elaborated upon in section 5.3.1. Temporal dimension. Overall, field management is largely limited to management of the water level, with possible additional tasks such as maintenance of ditches, crossways, and extra planting or sowing.

Machinery & equipment

The machinery and equipment needed for paludiculture is different to grassland or other agricultural production (Int. de Graaf). This can be explained by the combination of above ground water levels and the introduction of plants which have never been cultivated before as agricultural crops. For example, cattails are cultivated between 10 to 30 cm and is a pioneer usually found in nature areas, not as a crops to produce biomass (Deelexpeditie Natte Teelten, 2020). As stated in the previous chapter, creating a suitable water management system requires large scale equipment such as diggers to level the field or build dikes or even pipes to build a sub-irrigation system (Int. Geurts). Furthermore, the system requires a pump and a manner to power the pump, mostly done will solar energy (Int. HAS students; Int. Neubert & Wichmann). Moreover, a method is necessary to measure the water level, for instance with a gauging rod or with a remote sensing system. In order to deter geese from feeding on the cattails, lines must be spun between poles to partially cover the field (Int. Egas; Int. Geurts). In all these activities, the relative equipment is necessary to carry out paludiculture.

Apart from the necessary equipment, some machinery has already been developed for paludiculture, particularly for harvesting cattails. For planting, most sites are still carried out by hand, manually inserting each plug individually into the soil (Int. Koot; Int. Visscher). However, there have been some creative solutions to try to speed up the process. In some cases, this was done by using an old strawberry planter, and in others by men hanging on the back of a tractor (Int. Egas; Int. Wellink). Yet, such methods are not 'professional' or efficient ways of planting the plugs. Wichmann elaborates on this in their own field site, which trumps the other sites in size.

'' 'Because of the larger size of the site and because planted seedlings need watering within a certain time, manual labour to plant the Typha was too time intensive. So, we used the alternative technology of mechanised tree planting. This worked reasonably well but almost 10 ha still took 4,5 days. This needs to be made more efficient.'' – Int. Sabine Wichmann

In this case, the size of the plot already meant that mechanisation was necessary, but still using tree planting machinery cost a significant amount of time. Overall, this example shows that there are still no efficient and tailored planting machines for cattails.

To harvest the cattails there have also been examples of creative but non-effective solutions prior to the development of tailored machinery, which can be read in Annex I: Materials of cattail cultivation explained (Int. Egas; Int. Kemp; Int. Wellink). For now, it is most relevant to describe the existing machinery created by Wellink Equipment in cooperation with Wetland Products. These machines are adapted to be suitable for wet surroundings and therefore suitable for paludiculture. Wellink has demonstrated at multiple sites (estimated approximately 15 sites) that this machine works well for harvesting paludiculture, including in Helmond on the 2nd of November 2021 (Int. Fritz; Int. Wellink).

> *''The machine has a non-suction technique. Amphibians and reptiles stay put. That's a happy coincidence because it was first used for nature. That's the low-hanging fruit that comes with the machine. Normally we mow 5-10 cm above the ground. This can be controlled from the cabin. We ride on a caterpillar track for low ground pressure. Instead of 300g/cm^3 it is 100g/cm^3 (of pressure). The damage to the soil is minimal and after a while you have no traces of driving. At first you drive it a bit flat, but a month later there is little to see. Everything is collected in the back of a container. This is done in 1 working step.'' – Int. Robert Wellink*

Firstly, by using caterpillar tracks the machine minimises the pressure exerted on the ground by spreading the weight of the machine. The effect is a small trace of the machine with tracks fading within a month. Secondly, Wellink explains that the cutter bar can easily be adjusted to a different level to ensure that the plant is cut off above the water level to prevent rotting. And finally, by not using suction the machine also limits its impact on the biodiversity. As stated, this is a happy coincidence because the machine was originally developed for nature areas. Wellink later adds that the machine chops the cattails into smaller pieces to then collect them in the container. This is confirmed by Neubert (Int. Neubert & Wichmann). Wellink expressed his aim to test the machine in different seasons, as now the majority of the demonstrations have been in the winter.

> *''The (seasonal) time of harvesting is the biggest adjustment for the machine. The differences between sites are small, but there is much more difference in time (autumn, summer, etc.). It is seasonal. Age of the plant, temperature, structure, undergrowth and how wet it is. You have to test to gain experience. (To make it more efficient) you need bigger machines. We are now working on the Radboud to develop a machine with a lot of capacity.'' – Int. Robert Wellink*

Therefore, more knowledge could be gained by testing in different seasons to better understand how the machine might need to be adapted. Furthermore, to increase the efficiency Wellink is currently working with the Radboud University. There are other possible points of improvement, such as the tracks currently being wider than the cutter bar, causing cattails at the sides of the machine to be flattened (Int. Estate Groot Overbrugge). Also, Wellink is interested in developing a way to bundle the cattails instead of chopping as this could allow the cattails to be used for different purposes. Yet, the demonstrations have proven this is a successful way to harvest the cattails mechanically in a single day's work.

Overall, the continued development and finetuning of these machines can increase the efficiency of harvesting cattails. Already, harvesting 1 ha can easily be done in a single day. Yet, tailored planting equipment has not been developed, which could decrease manual labour and increase efficiency.

5.2.3. Competencies

In this section, the knowledge, skills, attitudes, and personal traits one needs to carry out paludiculture are presented. Because this is a research-dominated network of practices these competencies still largely relate to the research institutions or projects which carry out these pilots. To clarify, at the pilot site in Helmond the Estate Groot Overbrugge is mainly responsible for checking the water level each day, but the monitoring, planting, harvesting, and production is all carried out by the researchers such as Geurts and van Duinen (Int. Estate Groot Overbrugge; Int. van Duinen; Int. Geurts). Therefore, in the following section a clear distinction is made whether the competency referred to relates to the pilot researchers or to the land users.

Knowledge & skills

As stated in the conceptual framework, knowledge and skills will be taken as one bundle with an iterative nature (Stanley & Williamson, 2017). Because paludiculture is still in its research phase, a lot of knowledge still needs to be uncovered and continue to be discovered (Int. Fritz; Int. Egas). However, when interviewees were asked what competencies, a user carrying out paludiculture would need, 10 interviewees responded with knowledge-orientated answers. Geurts believes there are three main conditions for paludiculture:

> *''In my view, there are three key conditions for cattail success: planting on time, proper water management, and lines that are spanned across the field to prevent birds from harming yields.'' – Int. Jeroen Geurts*

The first condition is related to planting the seeds or plugs at the right time in the season. This is important as otherwise cattails might fail to grow successfully. Visscher and Koot, both responsible for planting the plugs in different pilot sites, add that one must know *how* to plant, also requiring the skill to handle with care. Koot also adds the factor *where* you should plant cattails. He believes it is important to look at the suitability of the plant in its natural surroundings.

> *''Look at your environment, you can see what works. … But you often have to teach them (those involved in the projects) the basics (of the plant).'' – Int. Kees Koot*

Thus, it is also useful to place cattails in their natural surroundings in order to increase the chance of success. Additionally, it is important to know the basics of the plant. Overall, this means that knowledge is necessary on how, when, and where cattails are planted. These are skills and knowledge which those already familiar with the plant, such as Visscher and Koot can share.

The second condition mentioned by Geurts is proper water management. Water management consists of regulating the water level on a day to day basis, knowing what the optimal water level is (between 10 to 30 cm above ground level where the plant is not fully submerged), as well as knowing how to slowly increase the water level after planting (Deelexpeditie Natte Teelten, 2020; Int. van Duinen; Int. Geurts; Int. Visscher). The third condition is how to limit the risk of birds eating the young shoots. Geurts mentions the use of lines. In practice, this is not fully effective and other sites have suffered losses (Int. Schoenmakers). Thus, the knowledge question on how to protect the young shoots is still one which the expert community is researching (Deelexpeditie Natte Teelten, 2020).

Other interviewees added other additional knowledge which a user must have to carry out paludiculture with cattails. One that was mentioned several times is how to harvest the crop and what machines to use for it (Int. van den Elsen; Int. van Lamoen; Int. Wellink). For this, skills of Wellink Equipment can be used due to their own harvesting experience and their own development of paludiculture machinery. All these points can be related to knowledge of the cultivation of cattails, which Egas summarises as ''practical knowledge'' (Int. Egas). Therefore, it requires the user to learn a completely new practice which they are not familiar with (Int. Osinga). Next to practical knowledge, it is also essential for users to be aware of the purposes of paludiculture and how this relates to societal issues, therefore knowledge of the meanings of paludiculture (Int. Suleiman; Int. Westerhof). These meanings should be clear to both experts and farmers in the opinion of Suleiman.

'' As scientists, we should make farmers aware of the problem in the environment. If scientists discuss the environmental problems by themselves, how can farmers then know about it (paludiculture)?'' – Afnan Suleiman

This indicates that it is essential that researchers clearly communicate the effect of paludiculture on their environment and how it can potentially help to solve problems. Westerhof adds to this that it is also important that farmers are aware how to minimise their carbon footprint in this practice (Int. Westerhof). An additional point Westerhof introduces is knowledge on whom to ask for permission, for instance water boards for water use and city governments on spatial planning. Therefore, knowledge also involves knowing whom to reach out to in order to comply with local laws and regulations. Such requests are currently submitted primarily by the researchers guiding the projects, not by the users (Int. Estate Groot Overbrugge; Int. Geurts; Int. van Duinen; Int. Neubert & Wichmann). This means that this knowledge is currently not essential for the direct users of paludiculture but will become necessary in future when the researchers are no longer managing cattail cultivation.

Clear communication and collaboration between projects and pilot sites in order to accumulate as much information as possible and to promote knowledge exchange is obviously essential for paludiculture to evolve and progress (Int. Westerhof). This tasks usually lies with a project coordinator (Int. de Graaf; Int. Sechi; Int. Westerhof). In this way, one can prevent overlaps in activities and make research on paludiculture more efficient. This was also stressed by van Naarden.

''You need someone who creates the overview. Someone who is process oriented. ... In a regional situation there is often someone who decides, 'well I want to do an innovative project'. They then look for a research agency and don't look further than their noses, yet sometimes something similar has already been done.'' – Int. Chris van Naarden

The final piece of knowledge which was mentioned in multiple interviews, was the necessity of knowing your market and potential profits (Int. van Duinen; Int. Egas; Int. Elshof; Int. Mettrop; Int. Westerhof). Without this knowledge, farmers are extremely unlikely to implement paludiculture (Int. Elshof). Therefore, it must become part of their business plan including how much it costs to start and possible end products of cattails (Int. Westerhof). This means a revenue model is key. Westerhof indicates the importance of allowing space and time for farmers to ask their own questions and voice their concerns, thereby allowing for knowledge-sharing. An example of such was when the Deelexpeditie Natte Teelten organised a 'doubt session' about cattails with farmers.

''In Nature, Typha is a phase in the natural succession, so is it possible to cultivate it at the same place for decennia? With harvest you also remove nutrients and normally you would have to use manure of fertiliser to maintain production. But how does fertilisation work in wet cultivation; currently it is not allowed to use fertilisers in water?'' – Int. Roelof Westerhof

These are questions which researchers should communicate clearly to possible future users. Overall, an array of knowledge and skills are required for paludiculture including practical knowledge such as water management conditions, planting techniques and timing, and how to minimise the chance of bird eating the shoots, business knowledge on the market opportunities and revenue model, and awareness on societal issues and the purposes of paludiculture.

Attitudes

In this research, attitudes can be understood as the way users feel or act toward paludiculture (Gawronski, 2007). In general, the attitude which was most noticeable was the commitment to research as described in Values of pilot users. This reflects the willingness to experiment. Furthermore, the need to be courageous was named by multiple interviewees (Int. van den Elsen; Int. de Graaf; Int. Osinga). De Graaf elaborates on this:

“Wet cultivation is a fairly untapped area, with a number of knowledge gaps. However, you need frontrunners to take innovations further… They (pioneers of the paludiculture) must dare to step outside the usual paths and take risks. It's partly entrepreneurship, market exploration, daring and curiosity because you have to undertake that quest yourself.” – Int. Myrjam de Graaf

Additional attitudes are named such as an entrepreneurial and curious attitude, which is explained by the need to collect knowledge at this early stage of implementation. Elshof agrees with this, stating that paludiculture needs to fit with the values of the person and their own curiosities and ambitions (Int. Elshof). Osinga believes it is beneficial to provide a community for likeminded people in order to find people with a similar attitude (Int. Osinga). In their community, Network Goed Boeren (ENG: Network Good Farming), they aim to provide this by connecting farmers looking for more sustainable practices from different areas and regions. This can also aid knowledge transfer and support. Overall, attitudes such as willingness and commitment to research, entrepreneurship, curiosity, and courage are the main attitudes which are necessary for paludiculture at this pioneer stage.

Personal traits

Personal traits are understood as ‘’people’s characteristic patterns of thoughts, feelings, and behaviours’’ (Diener & Lucas, 2019 pp. 280). This differs to attitudes as an attitude can change, while the assumption of personal traits implies consistency. Therefore, this research understands traits as consistent characteristics which not only apply to paludiculture but define someone’s personality in general. Even so, it can be difficult to distinguish whether a named characteristic is an attitude or trait (for example curiosity, entrepreneurship, etc.), but unless the trait is stated independently from the topic of paludiculture, this was assumed as an attitude and not a trait due to the risk of generalisation.

The main personal trait which was noticeable in those involved in the pilot sites was their strong ability to create and maintain their own network. The location of pilot sites, especially on plots of independent land users, has relied on the basis of personal connections. The pilot location of Greifswald was highly determined by previous working relations and trust between the pilot coordinator and the farmer (Int. Neubert & Wichmann). Kemp was also approached individually due to his previous connections with a consultancy firm who was given the job to search for a pilot site for Waternet (Int. Kemp). Due to this previous connection, the consultant already had Kemp’s contact details.

For the Estate Groot Overbrugge their previous connections were also key. They were already involved in the regional project Boer Bier Water (ENG: Farmer Beer Water) for 11 years and were a key player in this (Int. Estate Groot Overbrugge). This project concerns the Bavaria beer brewery finding ways to ensure sufficient and clean water for future generations together with other partners such as the water board Aa & Maas.

‘’I was involved in the project Boer Bier Water as the driving force behind the barley pillar and the soil pillar. I acted as the field coordinator and at one point a question came through if I knew farmers with an obsolete piece of land that is wet. Coincidentally, I myself had such a plot of land and that is when the Aa & Maas water board first contacted the CConnect project.’’ – Int. Estate Groot Overbrugge

Due to the role played in Boer Bier Water, the Estate Groot Overbrugge was initially contacted by the water board Aa & Maas as a contact point to a wider group of farmers. Coincidently, they themselves were suitable for the project. Also from the research side, van Duinen was an instrumental player between the water board and CConnect due to his role in both. Consequently, due to van Duinen’s secondment at Aa & Maas he was able to use their contacts in order to find a suitable site for CConnect (Int Geurts; Int. van Duinen). Therefore, personal traits such as cooperative and resourceful are seen.

5.3. Dimensions

In this chapter, zooming out starts by understanding the role of paludiculture in its temporal, spatial, and social dimension. Comparisons are drawn with surrounding practices and the interrationalities, understood as the linkages between practices and constellations, are explored.

5.3.1. Temporal dimension

The temporal dimension focusses on the timing of cattail cultivation and the time needed for it. The research discovered interesting patterns in cattail cultivation including delays during field preparation, the ideal sowing time, harvesting time and its relation to the intended end product, drying time of the biomass, and labour intensity. For the conciseness of the report, the results are summarised. For an extended version of the temporal dimension including quotes refer to Annex J: Temporal dimensions results elaborated.

Field preparation delays

In multiple pilot sites, delays were experienced during the preparation of the plot for different reasons (Int. Balkema; Int. Geurts; Int. Neubert & Wichmann). In Helmond, delays were caused due to a different plot being selected by the Estate Groot Overbrugge, thereby causing sowing to be delayed until September. The original plot was not as wet and had a less high peat content. The newly selected plot was bought by the estate from their neighbours, but this caused a couple of months delay (Int. Estate Groot Overbrugge; Int. Geurts). Furthermore, the wet spring season also caused a delay in field preparations as heavy machinery used to level the field and to install the sub-irrigation system would sink into the wet soil (Int. Geurts). An additional reason for delays can be the time needed to create the suitable water management system including creating dikes (Int. Egas). Furthermore, the application for permits also caused delays in Vinkerveen and for the Greifswald plot (Int. Egas; Int. Neubert & Wichmann).

An additional more unexpected reason for delays in the pilot plot that is located in the area of water board de Dommel were the presence of invasive non-native plants which had to be treated beforehand to prevent spreading (Int. Balkema). Using land which is now useless could potentially be interesting for paludiculture. Yet, these lands are at times covered which such species costing time and funds, adding an additional threshold to paludiculture (Int. Balkema). Therefore, time is not only needed for purchasing the ground, but also preparation of additional factors which might not have been considered before.

Optimal planting time

Despite most pilot sites having sown between end June and September due to delays ranging from one to three months, experts agree that the planting of cattails is most successful between April and July (Int. Egas; Int. Koot; Int. Visscher). This can be explained by the necessity of a minimal temperature in order for the roots to grow faster. In case the planting is done in the fall, larger plugs are necessary in order for them to survive in combination with more particular water management (Int. Koot). According to Egas and Kemp, the optimal planting time is in May (Int. Egas; Int. Kemp). Egas adds that for Zegveld this is the best timing due to the lower presence of geese at that time of year. This as the young geese have not yet taken flight, which usually happens halfway June (Int. Egas). So, if planting is done on time there is a lower risk of geese feeding on the young shoots before the shoots have had the chance to root. The optimal time for sowing is in the first week of June (Int. Kemp). By sowing at this time, the seeds germinated within 7 days (Int. Kemp). Also, in Helmond the additional sowing was done in springtime. Overall, to increase the potential for success sowing and planting should be done in spring. In both planting and sowing it is important that the water level is at a suitable level and can be raised efficiently at first. It is important to repeat that for a sub-irrigation system, this initial increase in water level just after planting is too slow, and therefore an additional surface pump is temporarily needed (Int. van Duinen).

It is important to consider the interrationalities with other practices which land users or farmers might carry out at this same time of year. For instance, spreading manure across the land or sowing of other crops such as corn. Because these activities have currently been carried out by researchers and not the land users there has not been an issue in time overlap with other on-farm activities. As a result, no clear results were found on potential interrationalities at this point in time. However, in future considerations should be made how cattails fits in the general planning of farmers.

Harvesting time connected to intended cattail product

The harvesting time of cattails is highly dependent on the intended end product (Int. Geurts). If the product must be dried for production, it is harvested in the winter season in November or December (Int. Kemp). If the product is used for the fibres, such as cattle feed, decorative furniture, or weaving materials harvesting takes place in the summer (Int. Egas). This section explores the pros and cons of harvesting in each season. It does not dive into the end products of cattails which is elaborated upon in section 5.4.2. Business environment.

There is an apparent dilemma between the intended purpose of cattails and the season in which cattails are harvested. If the harvest is done in the summer, more nutrients are removed with the harvest of the crop in comparison to harvesting during the winter. Especially in the first years, one should not harvest in the summer, as in the summer the stems are still green, and energy is used to bloom. By harvesting, this prevents nutrients from being stored in the rhizomes (Int. Egas). However, harvesting in the winter impacts the water storage capacity as the field must be drained to harvest. Yet, this is also most likely the time one would like to inundate the field to deal with potential flooding. Therefore, this would affect the climate adaptive purpose as explained earlier. As such, there is a potential mismatch between the purpose of cattails for climate adaptivity and the use as dry product. Additionally, in both harvest times nutrients are removed, thereby affecting the potential for consistent biomass production each year (Int. Egas). In usual agricultural practices, this issue is solved by adding nutrients in the form of manure or fertiliser. However, one cannot apply fertiliser on a wet surface due to water contamination. For more information on specific examples of harvesting and the effect on future biomass refer to the recent end report by Better Wetter (Mettrop, 2021). In this report, the speculation is made that it should be possible to harvest twice per year, each for its own intended purpose.

An additional purpose of cattails is harvesting the pollen in summer to feed natural, biologically controlling predatory mites (Int. Geurts). This is a labour-intensive task for two weeks but does not require the cattails to be harvested itself. Therefore, the issue of removing nutrients and energy from the plant is not relevant in this case. To conclude, care must be taken in selecting the end product in relation to the purpose of cattails, as these have the potential to contradict each other. Additionally, one should consider the effect of the seasonality of the harvest to the long-term biomass production.

Continuous biomass production

Another question which must be addressed is whether cattails can continue to produce the same quantity of biomass each year? This puts into question the sustainability of the practice and production. Most cultivations use fertiliser to ensure the crop receives sufficient nutrients, but in the case of paludiculture this is not allowed (Int. Egas). However, if fertiliser cannot be added, then does cattails continue to produce a consistent biomass year after year? In the pilot sites, it seems that the ground does become 'tired', and biomass quantities reduce (Int. Egas; Int. Pijlman). Of course, if the main purpose of the practice is to provide ecosystem services, one could conclude that varying biomass quantity is not an issue, since this was not the goal in the first place (Int. Pijlman). But if the aim is to have high production, then fertiliser must be added, and the water level must be high in order to create thicker stems (Int. Egas). Therefore, not only is the perennial nature of cattails questionable, but again there is an interrationality with its purpose.

Drying time

An additional temporal factor which should be considered is the time needed to dry the cattails if the intended end product requires this. For example, insulation or building material. This is particularly challenging due to the natural structure and gelatin-like contents of the plant (Int. Egas).

> *''It (cattails) doesn't even dry easily. When you open it, there is some kind of slime in it. That doesn't dry at all. Also, that slime is still frozen in the winter and only thaws when it is warmer.'' – Int. Youri Egas*

Therefore, the seasonality of harvest, which for dry materials is necessary in winter, does not help this drying process as the inside of the plant is frozen and stays frozen for a long time. At the pilot site in Ankerveen Kemp confirms this with his own experiences that the ice in the stem stayed until the end of May (Int. Kemp). Therefore, drying naturally can take up to half a year. Consequently, production needs to consider extra time in between harvesting and processing because of the time needed to dry if done naturally in the field. Drying could be sped up if brought to a factory to store and dry. This does require additional energy but could still be considered (Int. Egas; Int. Weerman).

Labour

It is important to also consider the labour time and effort necessary for cattail cultivation, also compared to other practices carried out by possible users. Firstly, extensive labour input is necessary in the preparation of the field (Int. Geurts). Secondly, due to the lack of suitable machinery much manual labour is needed to plant the plugs. This is a significant time investment. In Helmond, it took 3 or 4 days with 4 workers to plant the full cattail plot (Int. Visscher). For the pilot in Soerendonk, Koot had a similar experience having 5 workers for 2 or 3 days for 1 ha (Int. Koot). If efficient machines are developed this could be a solvable issue. Until then this is a significant time investment, in particular compared to previous land use. Many of the sites currently used for cattails pilots were originally grassland (Int. Estate Groot Overbrugge; Int. Kemp). Time needed to sow a hectare of grass is a single day at most (Int. Egas). Therefore, for a farmer planting cattail is a higher time investment as well as labour input. After planting, the time investment is less, for instance compared to dairy farming.

> *"Well, with a cow you have to work on it twice a day. ... I don't need much time for cattails. Only harvesting once per year. … But I don't spend an hour a week on it now." – Int. Wilco Kemp*

Therefore, the time and labour spent on field management is minimal, only requiring a single check per day of the water level which is many cases can be done remotely (Int. Estate Groot Overbrugge; Int. Neubert & Wichmann). The planting stage can also be reduced in time if sowing becomes more successful. However, this is not yet fully developed and to soak the seeds in order to reduce the chance of them floating also takes time (Int. Kemp; Int. Mettrop).

> *''Soaking cattail seeds is still quite a job. You really have to break the cigars into 10 pieces otherwise they will float, and then you have to submerge (the cigars) with a rake (under water). This is not surprising because they are water resistant. But sowing is much faster, so you compensate for this a 100 times compared to planting (plugs). – Int. Wilco Kemp*

Therefore, the trade-off of the labour needed to soak the seeds outweighs the labour needed to plant plugs. However, water management for paludiculture, even though not labour intensive, is more time intensive compared to grassland (Int. Westerhof). This is because water levels must be checked every day. The final part of the cultivation, harvesting, requires less labour than planting as tailored machines have been developed, as described in Machinery & equipment. Therefore, a threshold in the temporal dimension is the time necessary for planting, in particular compared to the low maintenance and planting of grassland. Unless this becomes financially viable, this high labour intensity is not worth the time (Int. Westerhof).

5.3.2. Spatial dimension

This section zooms out, firstly looking at the effect of paludiculture on the own land user's area and plot including changes in crop rotation, potential need for drying space of the cattails, and how it might fit with the practice of livestock such as dairy farming. After that, the effect on surrounding plots is discussed, potentially influencing direct neighbours. And finally, it considers how the practice of paludiculture might fit in the landscape with the main points of comparison between stream valleys and peat meadows. Again, for the conciseness of the report, the results are summarised. For an extended version of the spatial dimension refer to Annex K: Spatial dimension results elaborated.

Crop rotation

The first factor to be addressed is the inability for crop rotation (Int. Westerhof). Crop rotation is the practice of cultivating different crops sequentially on the same plot (Hijbeek et al., 2018). By carrying out crop rotation, one can increase the soil organic matter (SOM) to increase soil fertility (Hijbeek et al., 2018). This has a positive effect on crop productivity. Therefore, especially in arable farming, crop rotation is a common practice. Paludiculture inhibits the potential for crop rotation, as not many crops can cope with high water levels (Int. van Duinen; Int. Elshof; Int. Westerhof). Additionally, once the water management system has been created to sustain continued field inundation and the ground has been dug out, it is more difficult to use for anything other than paludiculture (Int. van Duinen, Int. Westerhof). Elshof, an advocate of agriculture for ZLTO, believes this flexibility and ability to go back to the original situation is essential for farmers (Int. Elshof). Also, some paludiculture crops could be difficult to remove after production. For instance, reed makes deep roots, making excavation of the crop challenging and time consuming (Int. van de Belt). Overall, this means that, once the decision has been made to cultivate paludiculture crops, it is a higher commitment compared to other (arable) practices. Therefore, these hectares also mean fewer flexible hectares for other practices.

Drying space

Another spatial challenge lies in the need for drying space for cattails if these want to be used for dry materials such as insulation. This is particularly complex due to the height of the plant which can reach up to 2 meters tall (Deelexpeditie Natte Teelten, 2020). Egas described that the plot is densely filled with cattails, meaning than the field is filled in both the horizontal and vertical direction. He even estimated that the same amount of space is needed for drying as for the production itself (if done naturally on site and laid out flat on the ground). This raises the question whether a bundling method is necessary? Perhaps this would look similar to how reed is traditionally bundled in a teepee structure. However, this might need to be done manually, unless it is possible to develop a machine which can bundle the product (Int. Wellink). But even then, the naturally insulating material and slimy consistency of the crop means that drying the crop in any stacked method is time consuming. If the conclusion is that it takes up too much space and time in natural conditions, then additional energy is necessary to dry the product. Additionally, it is not only the necessary energy requirements to dry the biomass, but also the practical implications of transporting such volumes which should be considered (Int. Weeman). If the goal is to create carbon neutral products, then adding energy to the process defeats this purpose (Int. Egas). Overall, this means that the spatial (and temporal) dimension of drying the crop must be considered with care if production is upscaled.

Dairy farming

Cattails can be a practice which is integrated into a routine of other practices. One such practice is dairy farming. Especially in a peat meadow area, as discussed in the following chapter, dairy farming is a common practice, allowing the cattle to graze on grassland. However, if (part of) the grassland becomes too wet, then an alternative practice could be cattail cultivation (Int. Pijlman). According to Kemp there is a possibility for combining cattails with dairy farming, as he himself also does (Int. Kemp). The most practical location in combination for the practice of dairy farming is to then pick a piece of land which is already far out for the cattle. In this way, it minimalizes the change in farm plan. However, the plot must still be suitable for paludiculture with peat soils and at a low elevation in the landscape (Int. Geurts). Furthermore, cattails can be used as cattle feed to substitute for the loss of grass (Bestman et al., 2019; Int. Pijlman). However, this does raise the question where manure must be deposited? If we assume that the change in this situation is from grassland to paludiculture with cattails, then part of a dry plot becomes wet and therefore can no longer be fertilised. This means that land on which previously manure could be deposited can now no longer be used for that purpose (Int. Geurts; Int. Kemp; Int. Pijlman; Int. Westerhof). Yet, this is mainly an issue if the farmer choses to keep the same number of cows instead of choosing for extensification of their farm (Int, Geurts). If this is not the case, then the extra manure must be spread across other land, which might not always be available, or to have to transport the excess elsewhere (Int. Westerhof). This is an additional investment which would make cattail less financially feasible (Int. Westerhof). To conclude, dairy farms will most likely only invest in paludiculture if the grassland is so unusable that paludiculture becomes the only viable alternative.

Neighbouring plots

Paludiculture requires a high-water level, but this increase in water levels can potentially affect neighbouring plots. This, as the water level will decrease gradually from the plot, not strictly following a stoic man-made boundary. This could impact surrounding land users (Int. van den Elsen). In a situation where the neighbouring plots are managed or owned by the same farmers, then the potential effect on neighbouring plots is for themselves. Yet, this is not always the case.

In Helmond, these effects are minimal due to the plot naturally being located at the deepest point in the area as well as a ditch being located alongside the plot (Int. van Duinen; Int. Estate Groot Overbrugge). Additionally, the neighbours are mostly 'hobby farmers', mostly having horses on their land (Int. Estate Groot Overbrugge). Therefore, the potential effects of increased water levels in this plot are not felt due to the minimal agricultural activity of the direct neighbours. Furthermore, the effects are minimalised due to the use of sub-irrigation (Int. de Graaf). Other pilot sites also did not have to consider this issue for other reasons. In Friesland, the cattails plot of Bouwgroep Dijkstra Draisma does not affect any neighbours due to the presence of a large flood dike next to the plot (Int. Verboom). The pilot site in Soerendonk also did not have this challenge, as the neighbouring land is a wet nature area (Int. Koot). In the Greifswald plot, this effect was considered due to the surroundings being grassland and crops, using ditches as the main way to minimize the effects (Int. Neubert & Wichmann). However, Wichmann did explain that there was an impact on the neighbouring plot due to construction vehicles needed to prepare the field for paludiculture. It was necessary to create a road in order to get to the pilot site. The plot used for this belonged to the same landowner as the pilot plot, meaning this was not made into a large issue. However, the route to get to the location should be considered especially if this impacts neighbouring landowners.

It is important to note that this issue would be less relevant if the decision was made to increase the water level for an entire area, for instance, increasing the water level in part of the peat meadows, as explained in Landscape type (Int. Fritz; Int. de Graaf). An additional issue for neighbouring plots, not related to the water level, is the spreading of seeds. Visscher expects that neighbouring plots might also suffer from the spread of cattail as seeds disperse through the wind. This means cattails might start to grow outside its intended boundary. However, there was little evidence in the research to make a conclusive statement. Overall, the effect on neighbouring plots should be considered, especially in relation to the increase in water level.

Landscape type

As introduced when discussing Diverging goals the purpose of paludiculture is also connected to the landscape in which it takes place. In peat meadows it is more likely that the aim is to prevent land subsidence, while in a stream valley it is more likely to be used for ecosystem services and climate adaptation of the water management system. Therefore, there is a spatial interrationality to the purpose of paludiculture (Int. Pronk). The priorities might be different in each area differ, but multiple goals can be achieved with the same practice. However, in projects often one area is taken as main point, especially in policy. In the Veenweide Programma (ENG: Peat meadow Programme) this was a conscious decision to focus on peat meadows (Int. van Naarden & Pronk). This was done in particular to create one narrative to match the Climate Programme of the Dutch government, which focusses on the large scale reduction of GHG. And also, to prevent overlap with local initiatives (Int. van Naarden).

Therefore, the stream valley setting is often associated more with nature initiatives, which more often take a regional approach. It is important to note that GHG reduction is also applicable in stream valleys as it also inundates peat but in a different landscape in smaller patches (Int. van Duinen). These smaller patches are less attractive to take as main focus point for large projects. This is because stream valleys present a more fractured landscape, creating more unique cases with less uniform water management compared to peat meadow area (Int. van Lamoen). Therefore, it is more complex to develop production oriented paludiculture cultivation in stream valleys as the plots are more fragmented and because of the less intensified form of water management. Consequently, many experts believe peat meadows have higher potential for paludiculture (Int. Egas; Int. Fritz; Int. Kemp; Int. Pijlman).

This can also explain the spatial interrationality stream valleys and paludiculture appear to have with the streams. Van Lamoen explained how the stream valleys in Brabant were adapted to suit agriculture after the World War II, but that climate change has pushed for change (Int. van Lamoen). Now, the water plans indicate more land around the streams will be used as overflow (Int. van Lamoen). Van Lamoen suggests that these areas next to the streams are most interesting to consider for paludiculture. Balkema agrees, seeing paludiculture potentially on the streambanks (Int. Balkema). Weerman adds the potential to use paludiculture as transition zones as added value for nature, thereby also suggesting a spatial interrationality between paludiculture in stream valleys and wet nature (Int. Weerman).

If we compare this to a peat meadow setting, the spatial interrationality with dairy farming is interesting. As explained earlier in this chapter, in a peat meadow setting it is most likely that grassland would be the first option for paludiculture, with the condition that there is a revenue model (Int. Kemp; Int. Pijlman). This also because this has a lower economic value compared to arable farming and horticulture (Int. Kemp). However, if it were to be the case that a larger area of peat meadow is flooded, so not just one part of a dairy farm for instance, is this possible? Westerhof speculated the feasibility of large scale paludiculture in the peat meadows of the Netherlands. Not only because of the effects on neighbouring land and urban areas, but also because of the technical feasibility of flooding the land (Int. Westerhof). Furthermore, for water boards it is complex to create areas which are flooded. Therefore, the feasibility in peat meadows is also not as simple as one might expect.

To conclude, peat meadows and stream valleys both have a clear spatial interrationality with their purpose. Additionally, paludiculture on a large scale is highly complex in both settings due to necessity for water also in the summer months. Therefore, paludiculture is most likely in very specific areas with the right water availability, peat content, elevation, and neighbours, of which most are already dedicated to nature.

5.3.3. Social dimension

In the social dimension relevant concerns and values of the wider society are presented. Furthermore, based on the SNA analysis, three interesting additional networks are created based on the answers of the interviewees reflecting important organisations for knowledge-sharing and promoting paludiculture as well as which parties and organisations feel dependent on for realising paludiculture. In case it is difficult to get a full picture of these networks, please refer to Annex L: Social dimension where each network has been given its own page.

Societal concerns

There are a number of societal concerns which should be considered about paludiculture. The first concern which was expressed by the Estate Groot Overbrugge was the potential increase in mosquitos (Int Estate Groot Overbrugge; Int. Geurts). They did not want to become a 'mosquito farmer' in the process. However, measurements of the number of mosquitos indicate that this is the case (Int. Estate Groot Overbrugge). Geurts states that to prevent mosquitos, it is important that the water level is kept relatively high, so it does not become too stagnant (Int. Geurts). Koot also expects that the aquatic environment also means there will be more natural predators such as fireflies and frogs which eat the mosquito larvae. Weerman adds that research is still being carried out on this concern.

Another concern is the alteration of the landscape, especially with cattails. Westerhof introduced two landscape factors. Firstly, the height of the cattails means your sight is blocked. This contrasts to the traditional flat Dutch peat meadow landscapes for which these areas are known for. Therefore, this changes the experience of the surroundings. Secondly, the change in practice might attract different animals, which might not be wanted. On the other hand, others argue that it introduces an addition to the landscape, allowing for recreational areas which people can enjoy (Int. Weerman; Int. Wellink). Therefore, it is all about person perspective. Westerhof also addresses a social concern for the implementers of paludiculture, namely, their position and status in society. Even in water boards Balkema notices that this is a very new and innovative practice which raises eyebrows (Int. Balkema). Therefore, this confirms again the need for an implementer to stand strong. Finally, the main concern for farmers is the existence of a revenue model, elaborated further in Market (Int. Estate Groot Overbrugge; Int. Kemp; Int. Pijlman). To summarise, the main concerns are mosquitos, the landscape changes, social status, and revenue models.

Societal values

It is also important to consider the interrationality of paludiculture with the social norms and values, in particular of farmers. As discussed in the section Values of pilot users, those already involved in pilots are willing to try something new value and value contributing to research. It is interesting to zoom-out and see how paludiculture might fit, or not fit, into the values of farmers who might later (have to) implement paludiculture. During the interviews it became clear that many experts expect that many will not be willing to implement paludiculture due to their own emotional attachment to their current practices. Westerhof compares the feeling of paludiculture to arable farming.

> *'' If you are proud of your contribution to feeding people, going from food production to biomass production is not a choice that makes you happy.'' – Int. Roelof Westerhof*

This introduces the complexity of switching from an emotionally rewarding practice, such as producing food, to producing a biomass product. The same applies to dairy farmers who take pride in producing milk (Int. Egas). Fritz recognises this need for affinity with the product as well.

> *''There are already farmers who are engaged in carbon farming and who want to become a climate product. Or buffer farmers who store water. In general people who have an affinity with their product. That's not the majority of course, but it's the same with organic farmers. It must be a draw for everyone.''- Int. Christian Fritz*

Therefore, those who will become involved in paludiculture must have an affinity with the societal purposes. Fritz compared this to the commitment of organic farmers. Only a minority will be willing to put in this additional effort because of what they believe is right. An additional factor is the need for knowledge and skills, as discussed in section 5.2.3. Competencies. In general, many farmers currently lack such competencies and prefer to stick to the crop types they know well (Int. van Duinen). Furthermore, the threshold for dairy farmers might be higher compared to arable agriculture due to the lack of affinity with plant cultivation having most experience in livestock (Int. van Naarden & Pronk). Therefore, farmers value what they know and what they have developed for years.

Additionally, farmers value efficiency and flexibility. As discussed in Crop rotation, paludiculture lacks flexibility as the field can no longer be used for different practices. Furthermore, the labour intensity of paludiculture is higher than most mechanised practices. Therefore, the Estate Groot Overbrugge is pessimistic whether farmers will cultivate cattails due to the labour intensity for planting.

> *''It (planting) is also expensive, and everything has to be done by hand. You don't have a Dutch person who does that anymore.'' – Int. Estate Groot Overbrugge*

Until now, it seems that paludiculture does not really suit the majority farmers in society. However, there are a number of interrationalities between landowners' values with paludiculture. Paludiculture is appraised as most valuable, if it is carried out in combination with other practices (Int. Kemp; Int. van Lamoen). Thus, that it is not the sole practice carried out on the land owned or management.

> *''You could see if this fits in with the design of estates. With estate you often have mixed activities for income. This type of company lends itself better to that. … At the moment I think you can only have wet cultivation if it is mixed (with other practices).'' – Int. Frank van Lamoen*

Paludiculture has the potential to merge in settings where multiple forms of income and activities are already normalised. An important concern as well as value for farmers and landowners is the need for a convincing revenue model, and thereby also the ability to receive Common Agricultural Policy (CAP) payments from the EU (addressed further in 5.4.1. Policy). For now, it is most important to state that farmers are entrepreneurs and must have a business plan in order to sustain a living (Int. Westerhof). Therefore, if a practice does not allow for this it does not fit into their value system (Int. Elshof). Overall, we can see that there are quite a few points at which paludiculture does not match the current values and practices of the majority. Still, with climate change some might develop an affinity with the product. Additionally, if there is a viable revenue model then entrepreneurial farmers might also start to cultivate cattails. However, it seems unlikely that a farmer will completely dedicate themselves as 'cattails farmer', but rather see it as an additional practice on re-wetted land.

Knowledge-sharing network

The knowledge-sharing network is presented in Figure 14 in which the colour of the edges refer to the organisation to which is referred. For instance, if pink, then the direction is towards an organisation categorised in the business environment. Overall, the knowledge-sharing network consists for the majority of knowledge institutions. In this, the Radboud University, KWR, and Stichting Bargerveen are central. Also, CConnect is the most important project which influences knowledge-sharing. Overall, this could be explained by the two main people who are involved in the Carbon Connect project and the pilot site in Helmond, Geurts and van Duinen, working for both the Radboud University, KWR, and Stichting Bargerveen. The most important organisations for knowledge-sharing from the policy environment are water board de Dommel and the province North Brabant. These are also two actors that have been, or still are, involved in paludiculture pilot sites themselves (Int. Balkema; Int. van Lamoen).

In the user environment, KTC Zegveld, Better Wetter, and Estate Groot Overbrugge are all equally important for knowledge-sharing. There is a clear spatial relation to these with their own contacts. The Estate Groot Overbrugge is more connected to organisations and institutions located in stream valleys, while KTC Zegveld and Better Wetter to those in peat meadows. The Radboud University is the most central organisation to all three user environments. Finally, the two most important actors in wider society are Staatsbosbeheer and ZLTO. In particular Staatsbosbeheer is a key actor, as they were a partner in the paludiculture pilot site in de Peel in Limburg.

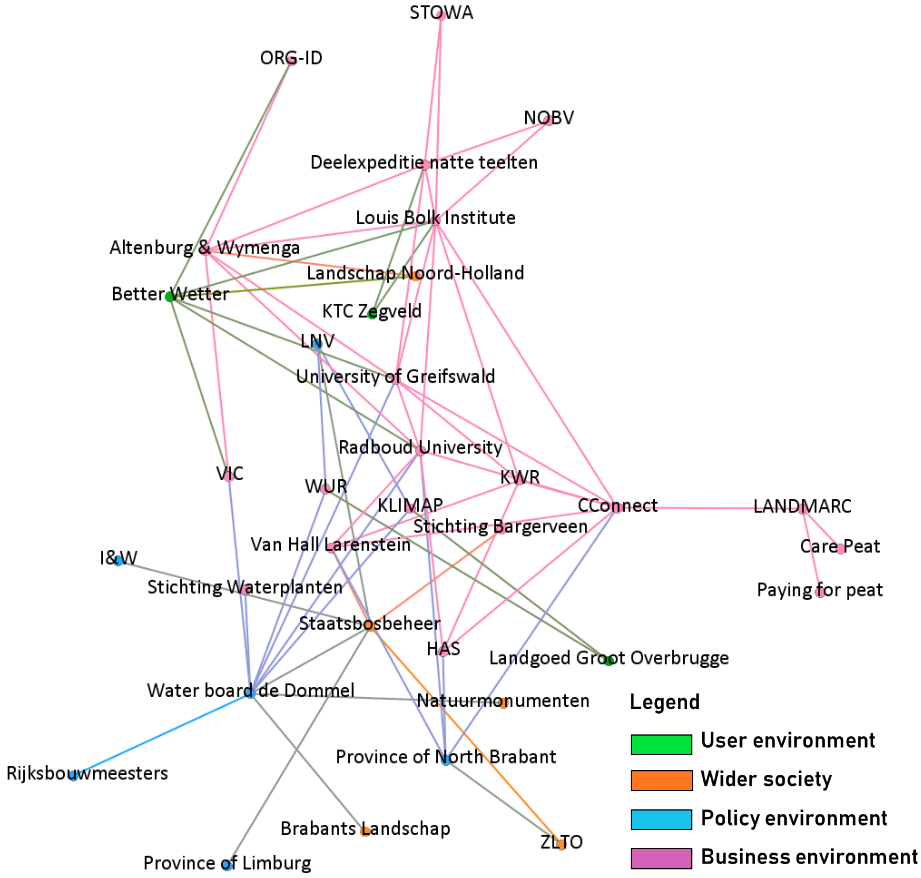


Figure 14. Knowledge-sharing network. The edges indicate 'to' which actor or organisation.

Promoting network

In order to gain better insight into the promoting network, the question was asked 'which 5 organisations are most influential in promoting paludiculture?'. The results of this analysis are seen in Figure 15. The first noticeable trend is the centrality of the policy environment. In the knowledge-sharing network it is clear that research institutions and projects are central, but in the promoting network the policy environment takes a more central stage. In this, water board de Dommel and the province North Brabant are key players. In general, many local government bodies are named, including 8 provinces and 3 water boards. LNV, the Ministry of Agriculture, Nature and Food Quality, is the most important national government body. Overall, this suggests that actors look to government bodies to take the lead in promoting paludiculture. Secondly, in the business environment research institutions are still the most important for promoting paludiculture including the Radboud University, CConnect, and KWR. This suggests that those most involved in knowledge-sharing are also those who are expected to promote the practice. The final noticeable pattern is that there is a clear spatial divide with all Friesland parties working more separately than the remainder of the country. Overall, this network shows that actors are expecting policy makers to take the lead with research institutions to support with scientific knowledge.

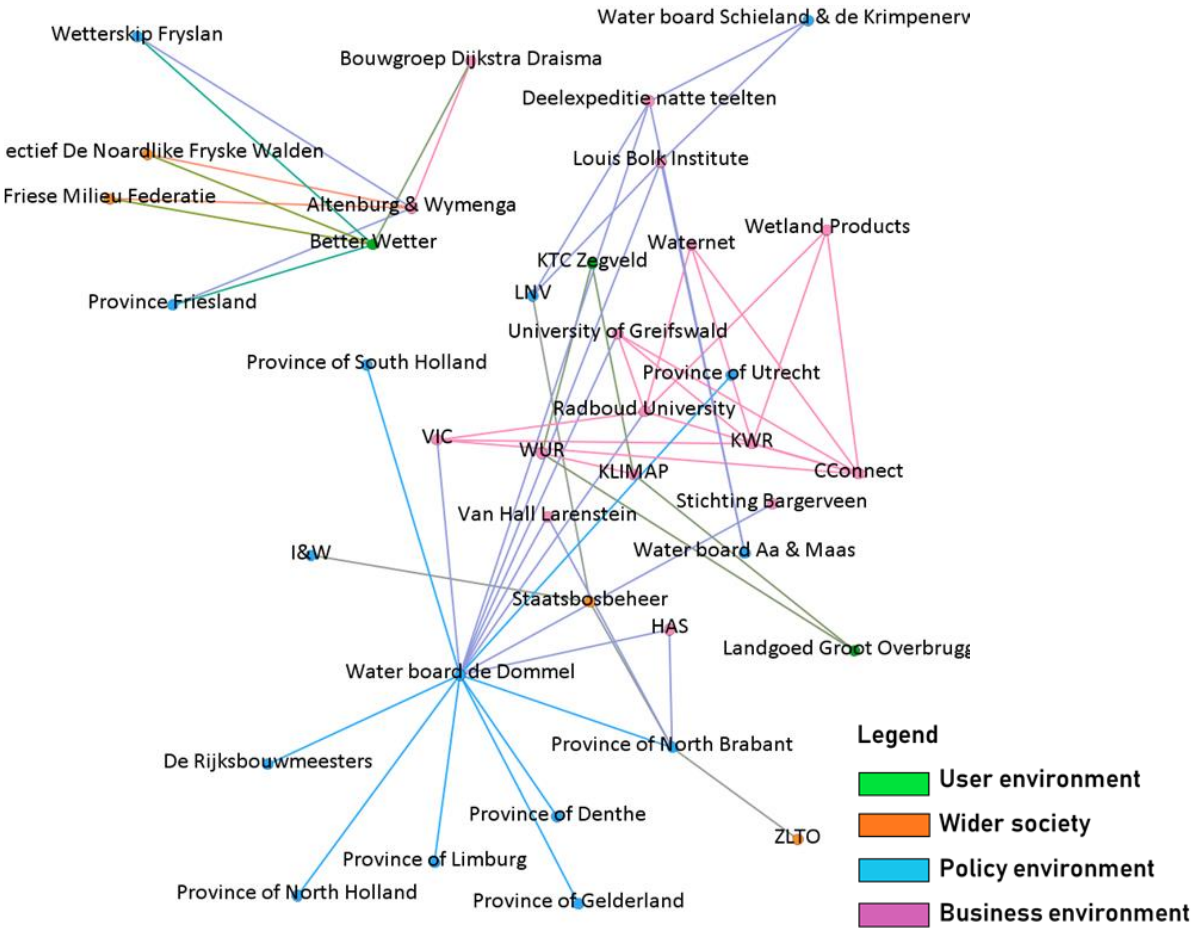


Figure 15. Promoting network based on SNA results. The edges indicate 'to' which actor or organisation.

Dependency network

The dependency network is based on the question 'which 5 organisations you think you are most dependent on for the success of paludiculture ?'. It is important to note that this network is built up of only 5 respondents. Therefore, this does not offer a solid basis for the dependency network analysis, but it can at least provide a general insight. The results of this network are shown in Figure 16. Overall, the most important actors who are important for promoting paludiculture are also most central for dependency. This means again more of the policy environment actors are included in the network such as water boards de Dommel and Aa & Maas. What is noticeable is that more institutions in the wider society are named, including ZLTO, Staatsbosbeheer, but also Brabants Landschap and Natuurmonumenten. This suggests that actors expect the success of paludiculture to also be dependent on the wider society.

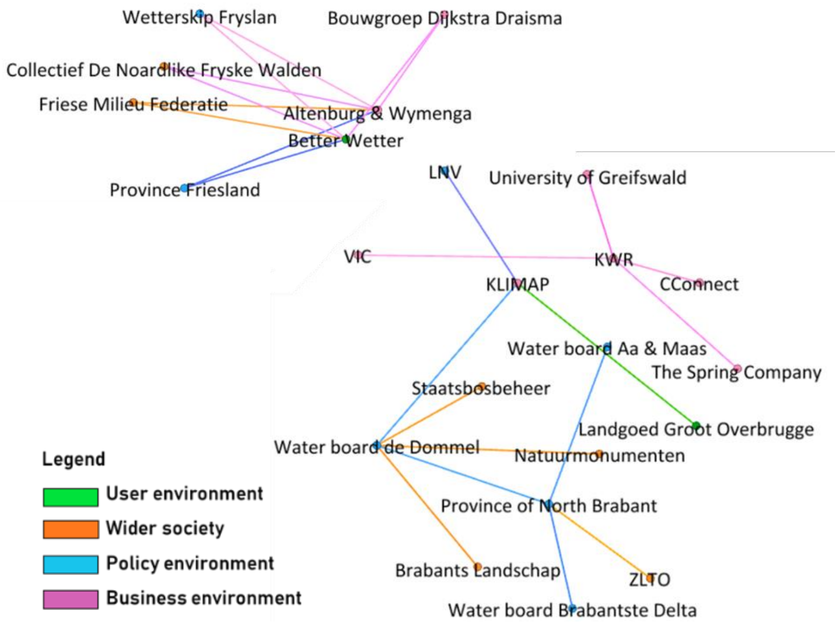


Figure 16. Dependency network based on SNA results. The edges indicate 'to' which actor or organisation.

5.4. Nexus

In this section, the research aims to give an impression of the policy and business environment. In the policy environment, this refers to how paludiculture is embedded in existing rules and regulations, as well as what policy might influence paludiculture. The business environment aims to provide an insight into the current funding of plots and market for cattail cultivation and products.

5.4.1. Policy environment

Overall, very little policy about paludiculture exists at the moment. To help analyse what policy impacts paludiculture, the work is divided into two parts. International policy, including EU policy which must be met by the Netherlands, and national policy.

Interviewees were asked the question 'who is most important for policy in paludiculture?'. Similar to the dependency network, there were only 6 respondents to this question. The results are seen in Figure 17 (enlarged in Annex M: Policy influencers SNA map). Overall, water boards and provinces are the most central local government institutions. Especially water boards de Dommel and Aa & Maas are key players. Therefore, it is important in the following headings to clearly explain the role of local governments. LNV, the Ministry of Agriculture, Nature and Food Quality, is the most important national government body. Because of the focus on the Netherlands in the SNA questionnaire, the network does not reflect the international network.

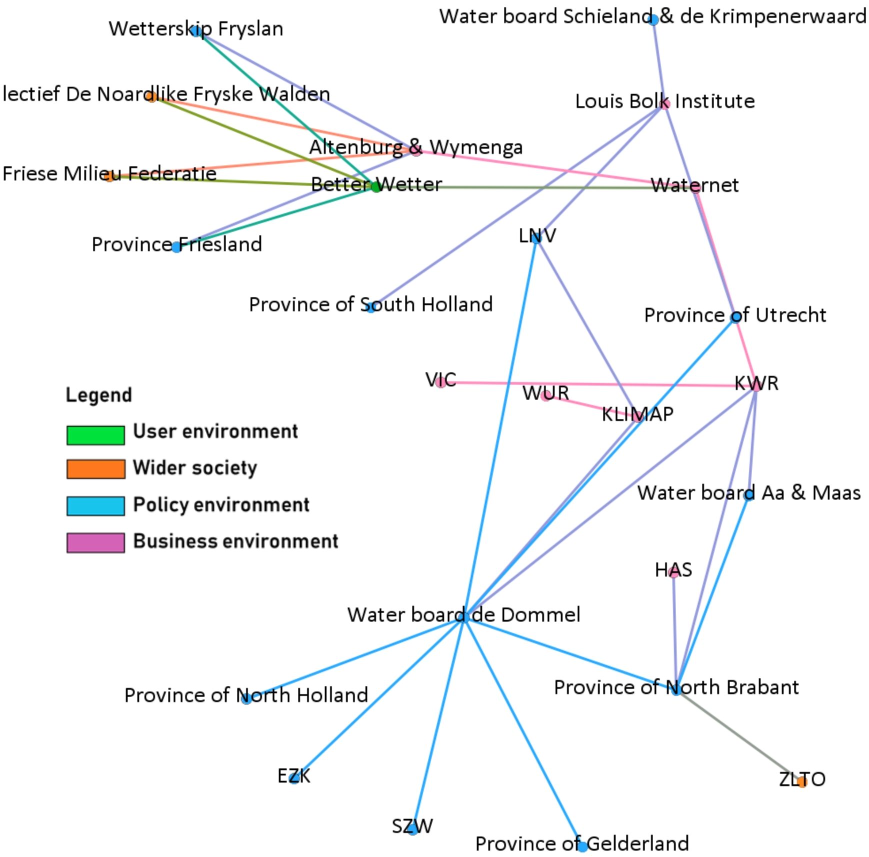


Figure 17. Policy network based on SNA results. The edges indicate 'to' which actor or organisation.

International policy

There are two international policy frameworks that must be highlighted. Firstly, at the EU-level the CAP policy, and secondly the UNFCCC Paris climate agreement. As stated, very little policy exists on paludiculture specifically, but there have been several positive developments. During the interviews, a common threshold which was named for paludiculture was the fact that until recently cattail cultivation was not recognised as an agricultural crop by the EU (Deelexpeditie Natte Teelten, 2020; EU Budget, 2020). As a result, it did not have an accepted crop code in the Netherlands. This means that CAP payments were no longer permitted on the number of hectares which were dedicated to cattail cultivation (Int. Estate Groot Overbrugge; Int. Wellink). This is a very important condition for farmers in order to agree to paludiculture with cattails.

> *''As soon as someone considers paludiculture, you get the question 'Will I still get my CAP payments?'.'' – Int. Christian Fritz*

Wichmann confirms this in her own search for a pilot site:

> *''Many were not willing to participate due to the lack of direct payments from the CAP which they would need to sacrifice in case of cattail cultivation and that it was too risky for the future as the pilot funding would only be secured for 3 years.'' – Int. Sabine Wichmann*

This shows that CAP payments are part of a system which farmers are used to that gives them a guaranteed form of income, which a new crop such as cattails did not. Therefore, not only is the market new and underdeveloped, but there was no guarantee of a subsidised income. However, since the start of most pilots, most starting around 2019, the EU has changed its policy. In 2020, reed and cattails were also recognised as agricultural crops, allowing Member States to amend their own agricultural policies. In October 2020, this news was shared in the Dutch House of Representatives and since then, farmers can apply for standard CAP payments for wet cultivation of 400 euro per ha (Ministerie LNV, 2020). However, it remains unclear whether a cattail crop code has already been made (Int. Balkema).

In future, CAP payments could change all together. Fritz speculates whether CAP payments should still continue in this form. Rather, what if part of the CAP payments were be transformed into payments for ecosystem services or dedicated to carbon credits (Int. Fritz)? De La Haye et al. (2021) state in their policy recommendations that harmful CAP payments should be transformed into conditional payments which are results-based (EU Budget, 2020). Thus, favouring conservation and maintenance. Already, new policy has been created to allow subsidies between 100 to 400 euros per hectare for carbon credits in 2030 (Ministerie LNV, 2020). This would already mean up to 800 euros per hectare guaranteed for cattail cultivation without having sold the product. However, what if additional policies are developed to promote ecosystem services such as groundwater restoration (blue credits) and biodiversity? Therefore, it is interesting to keep in mind potential bigger changes is this current policy structure.

The second international policy which is highly relevant is the UN Climate Agreement signed in Paris. When asked what international policy is relevant for paludiculture, multiple interviewees referred to international climate agreements (Int. van Duinen; Int. van den Elsen; Int. van Naarden & Pronk; Int. Pijlman; Int. Westerhof). The Paris climate agreement aims to limit the global average temperature increase to 1.5°C above pre-industrial levels (United Nations, 2015). Therefore, the EU and its Member States must find ways to limit GHG emissions. The Interreg fund, also funding CConnect, in one of such initiatives (De La Haye et al., 2021). Therefore, if carbon credits become worthwhile to invest in due to a need to meet climate agreement commitments, then paludiculture might become a more profitable investment (Int. Fritz). Still, it is important to repeat that research is being carried out to see the exact balance between carbon and methane, which might not work out in paludiculture's favour (NOBV, 2021). Additionally, other practices might be supported less by international policy in future. For instance, dairy farming is under pressure to consider more extensive and nature inclusive farming (Int. Kemp). Therefore, if dairy farmers are pushed to reduce the herd, then this would potentially free up space for cattails and reduce the manure issue, as discussed in Dairy farming. Thus, the need to achieve climate goals could potentially stimulate cattail cultivation.

National policy

A significant amount of national policy is based on international policy. Therefore, the CAP payments are also relevant at national level as well as the climate accords. In this heading, the goal is to refer to more specific examples for the Netherlands including (1) the national Climate Accord, (2) nature subsidies, (3) water boards and water level management, and (4) wet cultivation and fertiliser. Firstly, based on the Paris climate agreement, specific goals have been set in the Netherlands. The most important document for the Netherlands is the national (1) Climate Accord (NL: Klimaatakkoord). In this document, it expresses the aim to reduce GHG by 49% by 2030, of which 1 Mton CO2-eq reduction in 2030 in the peat meadow area (Rijksoverheid, 2019). Wet cultivation is explicitly mentioned as part of the strategy for 2021/2023 for about 90.000 ha of peat meadow (pp. 137). Therefore, the Climate Accord can be a potential stimulus for paludiculture in peat meadows. Overall, the agreements follow a regional approach, in which the peat meadow programme is executed and implemented by regional authorities (Int. van Naarden & Pronk). However, this is far less relevant in stream valleys such as the pilot site in Helmond (Int. van Duinen). In conclusion, the national Climate Accord currently stimulates wet cultivation in peat meadows but not necessarily in stream valleys.

The second relevant policy is related to (2) nature subsidies. Paludiculture is more suitable in locations which are already wet due to the natural features of the landscape. These locations are often already too wet for agriculture, therefore often not used productively. If used for nature and therefore not being cultivated, these areas can also receive a nature subsidy. The exact name of these subsidies were not disclosed, but it was clear that they were handled by the Ministry of LNV. For farmers, this subsidy is a method to still earn a little from 'unproductive' land. Yet, this land has the potential for paludiculture. Yet, similar to the CAP payments, farmers refused to join pilots due to the loss of subsidy.

> *''At the moment, paludiculture does not fit into existing policy, for example about milk or nature conservation subsidies. The nature subsidy in particular has caused farmers to cancel a pilot at the last minute because this would mean a loss of income, because then they would lose their green (nature) subsidy. Milk subsidies are about 400-500 euros per hectare and nature subsidies about 1200 to 1400 euros per hectare.'' – Int. Jeroen Geurts*

It is clear that the trade-off between nature and dairy farming compared to paludiculture, which currently does not receive any additional subsidies for carbon credits, blue credits, or ecosystem services, is biased. In effect, the lack of policy on paludiculture does not make it an attractive alternative to nature preservation.

The third relevant policy is (3) water boards and water level management. Water boards are responsible for regional water level management. Water boards have the obligation to prevent flooding and have clear guidelines for farmers to claim compensation in flooding cases (Int. van den Elsen). This is contrary to drought, where there are fewer guidelines for compensation. The most common method to deal with drought is a temporary irrigation ban, but this does not solve the issue of groundwater depletion (Beleidstafel Droogte, 2019). Thus, if policy becomes more oriented towards groundwater recharge, this could be beneficial for paludiculture. In general, there is little strategy for paludiculture within water boards. In the water management plan of 2022-2027, water board Aa & Maas have no mention of paludiculture, and de Dommel only one reference to wet cultivation (Waterschap Aa en Maas, 2020; Waterschap De Dommel, 2022). This single mention suggests that de Dommel will support those already trying wetter forms of cultivation but gives no explanation how it will be executed. Overall, this lack of commitment does not inhibit paludiculture, but it also does not support its development with clear rules and regulations.

> *''In addition, we will help the users where there is a disproportionate disadvantage. Some entrepreneurs are already cleverly responding to the changing circumstances, for example with extensive agriculture with innovative wetter cultivation. The water board will stimulate such solutions.''* – Waterschap De Dommel, 2022 *pp. 34*

The final policy, the national (4) Fertiliser Law (NDL: Meststoffenwet) has already been mentioned at several points (Rijksoverheid, 1986). As stated, fertiliser or manure cannot be applied to wet land (Int: Estate Groot Overbrugge). This policy aims to ensure water quality, but it has adverse effects for cattail cultivation. It inhibits the use of fertilisers, whilst it has been established that the growth of cattails could actually benefit from the use of fertilisers (Int. Egas). Therefore, the viability of cattails as a crop for long-term cultivation is questionable. Overall, this section shows the national policy still heavily favours drainage-based farming, whilst hindering re-wetting land.

5.4.2. Business environment

The goal of this section is not to provide a cost-benefit analysis, but rather to give an impression of the business context. First funding of pilot sites will be discussed, followed by an overview of the current cattails market. For more detailed information of costs, refer to the research by Nij Bijvank (2021).

Funding

In order to understand the business environment, it is important to understand how pilot sites are funded and what investments are necessary. This is firstly explained for the pilot site in Helmond, the starting point of this research. As explained in the case study background, the pilot site in Helmond was largely funded by CConnect (Int. van Duinen). CConnect itself is funded by Interreg North-West Europa (De La Haye et al., 2021). Sechi, project coordinator of CConnect explains this further.

> *''We (the project Cconnect) are funded by the Interreg NWE (Northwest Europe) program. We (Van Hall Larenstein) as leading partners for the project Carbon Connects, applied for the funding. We wrote the project saying that us and our consortium have the right expertise which would allow us to reach a certain objective on sustainable peatland management. In the project each partner applies for a certain budget. Once an Interreg NWE project get approved and starts every 6 months you need to report to the Interreg NWE controller what we've done and our progress. Once the (activity and financial) report is approved each partners get money back according to their expenditures. I can't tell what was the budget funded for Helmond. Helmond is one of the Dutch pilot sites.'' – Int. Valentina Sechi*

Therefore, the pilot site is funded by partners and then declarations are submitted to the EU Commission to reclaim costs. Sechi was unable to disclose exact values for Helmond but was aware that funds had been used there. Van Duinen confirms this, adding that CConnect was the funder for the plant material and the majority of field preparation, including the labour by Gebr. Visscher (Int. van Duinen; Int. Visscher). This high intensity labour as well as the costs of the plugs are factors which the Estate Groot Overbrugge finds an unrealistic investment for the average farmer (Int. Estate Groot Overbrugge).

Kemp also confirms that the costs of rearing the young shoots is high, especially compared to grass seeds (Int. Kemp). The Estate Groot Overbrugge purchased the land themselves, which was their only main investment in the project (Int. Estate Groot Overbrugge; Int. Geurts). Another main investment in Helmond was the sub-irrigation system. It is clear that the work was carried out by Promeco, also due to their own previous work in the area (Int. van Duinen; Int. Junggeburth). Yet, it remains unclear who exactly paid for the system and the labour. The next step of the process, the harvest, was also funded by CConnect (Int. Estate Groot Overbrugge). The harvest requires a machine, but van Lamoen and Kemp both doubt the feasibility for an average farmer to invest in such equipment (Int. Kemp; Int. van Lamoen). Kemp adds that it is only profitable if one had hundreds of hectares of cattails or otherwise you need to hire a contractor such as Wellink (Int. Kemp). Therefore, again, this is not a practice easily funded and adopted by the average land user.

LANDMARC and KLIMAP are mostly involved by doing additional measurements, as the site was already fully functional when these parties joined (Int. de Graaf; Int. Suleiman). In this, LANDMARC is also funded by the EU Commission. KLIMAP is funded by its partners with additional funding from the so-called top sectors Agri & Food and Water & Maritime in the Netherlands (KLIMAP, 2021).

For other pilot sites funding was also not the responsibility of the landowners. In the Greifswald site, it was funded by the Ministry of Agricultural from the agency for renewable resources (Int. Neubert & Wichmann). In the case of Better Wetter, the province of Friesland funds the local municipality to control funding for the pilot (Int. Mettrop). However, Mettrop addresses the risks of being funded by others.

> *''The municipality pays, it gets it back from the province. In any case, that is until December at the end of this month. It could be that it will be quiet again for a while, that has happened before. We are thinking about maybe working as a foundation. Then you can also coordinate content better, also in the long term.'' – Int. Ivan Mettrop*

Therefore, the sustainability of research funding is sometimes difficult. Yet again, both of these examples show that plots are currently not funded by the landowners themselves, by projects or local governments. Overall, these examples of funding show an unrealistic model for the average farmer. In the case of Helmond, the Estate only invested in the land, with all other material and labour costs being carried by research institutions and projects. Consequently, these funding arrangements again reflect the fact that the paludiculture network is still very research dominated as users themselves are not yet funding these projects.

In the previous headings there is already an indication that local governments also fund projects. In Better Wetter, the province funds, and the municipality coordinates these funds, while in other projects the province is involved directly as a partner. For instance, in the Peel, the province of North Brabant was for a short period closely involved. Yet, van Lamoen believes in general the province is a facilitator and financer.

> *''The province does not implement measures itself; it facilitates implementation. For area processes we sometimes set up an area coordinator, sometimes a little money, and sometimes a little regulation. … We have many more options than a municipality or farmer. You can talk about a starting capital. If everything has to be wetter, it is not possible to purchase everything as nature. Then you have to find a middle ground with a site manager (land users or manager). Then you can also talk about subsidies. It is also an option to have a kind of transition phase in which we stimulate the development of processing and sales chains. … But you need investment for that.'' – Int. Frank van Lamoen*

In this quote, the province is framed as an investor that brings in starting capital as well as a communicator between parties. Therefore, the province is not a key party directly involved at site but can act as a facilitator when needed. However, van Lamoen does specify that this role is mostly taken when policy must be realised. The flaw in this set-up with individual provinces funding individual small projects was addressed by van Naarden.

> *''Pilots of wet crops were often financed by (local) governments and the NKB (National Soil Subsidence Knowledge Programme) brought project leaders into contact with each other. Those were all separate projects. … From the 1st of December (2021) this will be financed from the national budget. Roel van Gerwen (Landschap Noord-Holland) and Jeroen Pijlman (Louis Bolk) will organise this. Provinces can then join this investigation. We (LNV) provide 62.5% of the project and then the region has to finance the rest. At first it was all separate provinces and groups and now we try to create an overview in this way.'' – Int. Chris van Naarden*

This quote specifically refers to the peat meadow area. Therefore, the role of provinces in the peat meadow area will change based on this recent decision by the Ministry of LNV. In this way, more funding will come from the national government and allow for better coordination between pilot sites. Yet, as it stands, this does not focus on stream valley areas.

Water boards are also a local authority which often become involved in projects. De Dommel is coordinating, managing, and funding multiple sites in their own area (Int. Balkema). Also, Aa & Maas is actively searching for a pilot site of their own as the site in Helmond, which is located in their area, is of CConnect. Van den Elsen explains that if they were to find a suitable site, they would be willing to compensate the landowner for its use.

> *''We also have money available if a farmer wants to experiment with it (wet cultivation). We can offset the land and income for 3 years. You have to do this to further develop the business model and to give time for market chain formation.'' – Int. Hilke van den Elsen*

Overall, provinces and water boards can be found willing to invest and fund pilot sites in order to find ways to realise policy. However, provinces place themselves in the role of facilitators rather than implementors of the practice at the moment, while water boards are more actively involved in the realisation of the sites.

Market

A developed and stable market for cattails could provide a revenue model for farmers. Currently, this market is new and underdeveloped but has potential to grow (Int. Geurts). Under this section, (1) the potential biobased products are discussed, followed by use of cattails as (2) cattle feed. Thereafter, current issues in (3) demand and profit are discussed. Firstly, cattails are an interesting biomass to create (1) biobased products (int. Pijlman). Not only is the material itself biodegradable, but also because of the effect on GHG by carbon storage in its cultivation (Int. Wellink).

> *''It is a very beautiful natural product. You can make chips trays with it, or construction material, and substrate to replace peat. There are many applications, much more CO2 absorption than grass, about 20/ton/ha/yr. And you get the opportunity to do something different with my land. And you remove nitrate from the water.'' – Int. Robert Wellink*

Wellink names multiple different uses and products that can be made from cattails, including construction material. Van Duinen, Kemp, Mettrop, and Verboom also recognise this use. The plant can be pressed into hard plates, where the slime in the stems and leaves act as a natural glue (Int. van Duinen). Kemp sees potential in this but adds that alternative products are still much cheaper. Currently wood is often used, frequently shipped from Brazil for a low price (Int. Kemp). Therefore, within this market wood is too competitive compared to cattails at the moment.

Furthermore, insulation material can be created with the chopped and dried cattails. This is interesting as it could replace glass wool, which is now often used as insulation material. Glass wool requires fossil fuels to make, therefore again contributing to lower GHG emissions. At Bouwgroep Dijkstra Draisma, they have found a way to blow the insulation material made of cattails into hollow plates without it shifting in the walls.

> *''We don't make plates from cattails. It's a loose dump. So, blow loose in walls or in wooden beams. ... Sales markets are definitely there. You can use the cigar as a concrete strengthener. And as food? There are opportunities. But it's a chicken-and-egg story. An increase in scale is needed to increase the cost price ratio. We started cultivation and applications ourselves, because then you control the chain. We can use it ourselves in our own products. Other parties have also called us, but we need it (insulation) ourselves, we already have too little. It is work in progress. But the more companies the better.'' – Int. Coen Verboom*

Verboom highlights a number of different uses for cattails, including concrete strengthener and plates, but focusses on the making of insulation material which they use in their own products. By blowing the cattails into wooden plates, they isolate the facades of their own buildings. They have also invested in a plot of cattails themselves in order to guarantee their own production. This is an interesting development as this is the first company in the Netherlands to invest heavily in cattail insulation material. However, the company is not representative of the average market as they now produce and use their own cattails in their own products. Therefore, they do not rely on any outside party to buy or sell the product as they themselves directly use the insulation material. Verboom refers to the chicken and the egg dilemma, mentioned by many other in the interviews (Int. Estate Groot Overbrugge; Int. Fritz; Int. de Graaf; Int: van Lamoen; Int. Osinga; Int. Wellink). In other words, should the production be high first or does one first wait until a market had been developed, which comes first?

There are also other products which can be made from cattails. This includes yarn for clothes, down or fuzz for in warm clothing, decorative furniture, and substrates for oyster mushrooms with the company Verbrugge Paddenstoelen (Int. Balkema; Int. van Duinen). Ideally, it would be best if this biomass production could rely on the income from the created products itself, such as those named. However, this is most likely not the case, especially since other materials are much more affordable and the current investment costs for cattails are high (Nij Bijvank, 2021). Elshof agrees with this.

> *''The purpose of cultivation is to generate income from it. So far, there is no revenue model that is positive. You have to be able to earn with it, as an independent form of income.'' – Int. Johan Elshof*

Therefore, to make this a viable market as an independent form of income, there needs to be additional compensation. Kemp refers to this as a 'carbon economy' (Int. Kemp). Van Duinen also agrees that revenue models should consider alternative forms of income.

> *''Business models are now being created and elaborated. Then costs and benefits are considered. For example, wetting the soil and retaining water, making money from biomass, and carbon credits are also worth something.'' – Int. Gert-Jan van Duinen*

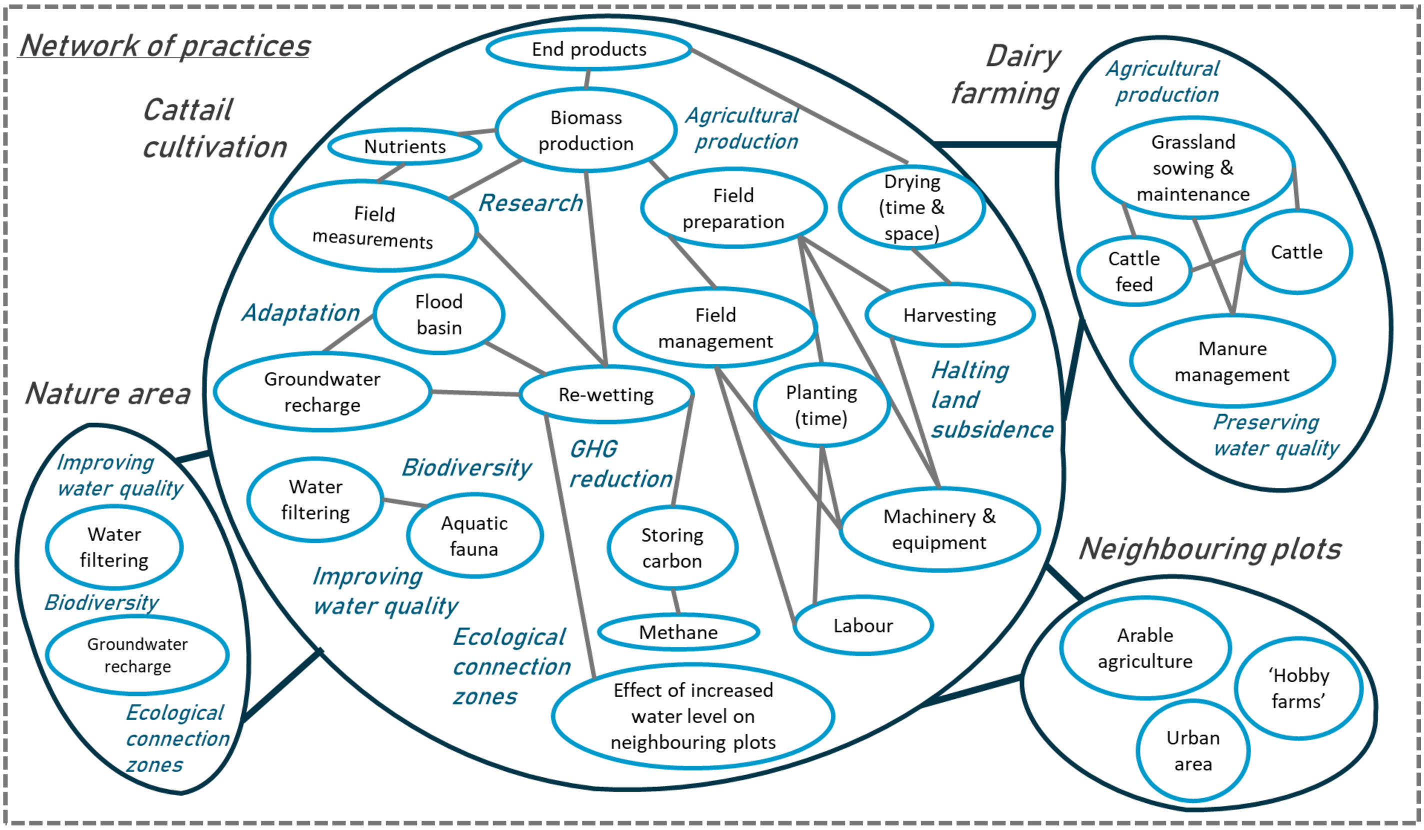
Even with these extra forms of income, the question remains whether on can sustain a livelihood from cattails (Int. de Graaf). For now, the answer appears to be no. As discussed earlier, cattails can also be used as (2) cattle feed, as an alternative to grass (Int. Pijlman). The nutritional value is sufficient to be an alternative based on the results of the project *Veen, Voer en Verder* (Bestman et al., 2019). This was also the main research objective at the KTC Zegveld until 2019. Yet, for the investment costs of cattails at the moment including field preparation, plant material, and labour investment, it is not an attractive alternative to grass. Therefore, it does not appear suitable to use for low-grade purposes such as cattle feed when there is potential to earn more from it as pressed plates, insulation material, or substrates (Nij Bijvank, 2021).

Finally, there seems to be a (3) lack of demand and a problem with low profit margins. Egas stated that the harvest from the pilot site in Zegveld of 2020 was not used for anything and went to waste, because no one wanted to use it (Int. Egas). Furthermore, profits are not guaranteed, especially without additional compensation for the services which paludiculture provide. However, it is important to ask ourselves the question whether a market must be developed for paludiculture with cattails if the purpose is not to sell it? Pijlman doubts whether cattails will become a permanent product, or rather a temporary product which acts as a way to help the transition to nature within the next decennia (Int. Pijlman). Therefore, not only is the current market underdeveloped, one can also question the sustainability of a future market if societal goals stress nature conservation.

Overall, there are a number of different biobased products which can be developed from cattails, including building materials, insulation, and substrates. Furthermore, cattle feed is a potential use of cattails which could be useful for dairy farming. Yet, despite these uses, cattails are not high in demand and suffer from low profit margins (Int. Elshof). Therefore, as it stands there barely is a market for them.

5.5. Synthesis

It is interesting to recap the key results and compile them in a similar image as presented in the conceptual framework (Figure 3). The result of the visualisation is seen in Figure 18.



Nexus (also dependent on landscape type peat meadow or stream valley):

- *Policy: CAP payments, Paris Agreement, Climate Accord, nature subsidy, water board & level management, Fertilizer Law*
- *Business: funding of pilot sites by research environment & facilitating role of local government, underdeveloped chain*

Figure 18. The network of practice of paludiculture with cattail cultivation. In the teal circles practices are indicated, written in italic turquoise the bundles are identified, and in naïve blue the constellations are distinguished.

Overall, 4 main constellations were recognised including cattail cultivation itself, nature area, dairy farming, and neighbouring plots. Starting with the main constellation, a great number of practices are included in paludiculture with cattail cultivation, many of which are also applicable for other types of paludiculture. The bundles seen include the purposes of paludiculture such as GHG reduction, halting land subsidence, agricultural production, adaptation, biodiversity, ecological connection zones, and improving water quality. From this, the first important interrationality can be identified, namely, between purposes. Multiple purposes can be combined, but often one purpose is taken as main focus point. However, in reality, bundles overlap and have no clear boundaries. Even so, there seems to be a division between the left and right of the bundle, the left focusing on adaptive and nature-based practices while the right more on agricultural production. As a result, it seems more purposes are achieved when leaning to the left of the bundle rather than the right. This puts into question why paludiculture is often framed as an agricultural production practice, while in reality more often climate adaptation, in-particular re-wetting, is more central to its success. An additional bundle which is important to note is research. This is key as all pilot plots are currently involved in some type of measurements. This also explains the centrality of research organisations in the majority of the SNA maps as well as the origin of funding of pilot sites.

An interesting interrationality to highlight is the temporal interrationality between the harvest time and the end product, as seen in the top right of the constellation. As explained, the harvesting time needs to be adapted to the intended product such as insulation materials (winter harvest) or cattle feed (summer harvest). In this, there is also an interrationality with nutrient removal, as a summer harvest has a higher impact on subsequent biomass production. This leads to the discussion of fertiliser use, which is prohibited on wet soils due to laws and regulations to protect water quality. Therefore, this also impacts the sustainability of biomass production of cattails.

This leads to the relation with the dairy farming constellation. Most important in this is the issue of depositing manure as this is prohibited on inundated land. Therefore, in the case of dairy farming this creates an issue as to where to deposit manure from cattle. This would mean reducing the herd, which is an interesting option if a dairy farmer is already considering farm extensification. However, the majority will most likely choose for a low harvest grassland which is cheaper to create, sustain, and harvest compared to cattails. On the other hand, if the land were to become too wet, cattails can be used as cattle feed. However, the production costs are too high at the moment to validate this potential use. This presents a spatial interrationality between the dairy farm and paludiculture on multiple factors including manure and labour.

The other two constellations, nature areas and neighbouring plots also have spatial interrationalities with paludiculture. Nature areas have quite some overlaps in the bundles of paludiculture, including improving biodiversity, water quality, and creating ecological connection zones. This is the case if the 'adaptive side' of the constellation is taken as purpose of paludiculture rather than the agricultural production side. Therefore, this spatial interrationality is also connected to the purpose interrationality. In the case of neighbouring plots, no clear bundles could be concluded, but the relation with the increased water level is still important to note. Other neighbouring areas which were mentioned were arable land, 'hobby' farmers, and urban areas. Despite the clarity of the image, one factor it does not clearly reflect is the spatial interrationality between the different contexts of the stream valleys and peat meadows. In peat meadows, the meaning of paludiculture differs to the meaning in stream valleys. Peat meadows are more confronted with the interrationality with dairy farming, while stream valleys are more often spatially connected to nature areas.

Another part which the figure does not reflect is the social dimension of the network of cattail cultivation. It is most important to highlight that paludiculture is appraised as most valuable when being part of a larger repertoire of practices. Therefore, finding social interrationalities is valuable in order to find synergies with existing practices, such as dairy farming and ecological buffer zones. Additionally, the most prevalent concerns found were mosquitos, the landscape change, the personal status in the area, and the revenue model. And finally, the SNA maps are useful to understand which actors are appraised as most important for knowledge-sharing, promoting, dependent on, and policy implementation. This showed that actors expect policy makers to take the lead for policy implantation, having research institutions to support with scientific knowledge. Additionally, including wider society is key as interviewees felt the wider implementation of paludiculture is most dependent on this group.

Beneath the network, the most important factors of the nexus are listed. In the policy environment, the lack of policy existing on paludiculture was most noticeable. In the business environment, it is clear that research institutions and organisations dominate funding and that the market is severely underdeveloped. This justifies the question why agricultural production is often taken as the main purpose of paludiculture, when there is in fact no strong market demand for its biomass. On the other hand, there is potential for payment for ecosystem services. This debate will be elaborated upon further in the discussion. Overall, the resulting image is that of a complex intertwined network of cattail cultivation.

6. Discussion of findings

After using the network of practices approach to understand the practice of paludiculture with cattail cultivation, it is time to reflect on the learning points of the research. First, the results are discussed, with a reflection on their implications for possible upscaling. Secondly, the use of the network of practices approach in this context is evaluated. Thirdly, the limitations are discussed including decisions made by the researcher. And finally, recommendations are given to the research community as well as for policy makers.

6.1. Discussion of results

In section 5.5. Synthesis the main results of the research are summarised and visualised in the network of practices framework. Overall, it is noteworthy that most of the interrationalities are spatially related. This reflects the highly spatial nature of agricultural practices and the influence paludiculture has on its surroundings. Relating this observation to the potential of upscaling, particular attention must be given to recognise the role of paludiculture in its wider surroundings. This also provides opportunities for joint purposes, for instance, paludiculture and nature areas potentially achieving similar goals. Therefore, there is clear potentials for synergies in nature-oriented areas. This is an interesting opportunity to consider in upscaling cattail cultivation. In particular, for farmers or landowners already bordering nature areas.

In the results it also became clear that the current network of practices is unusual due to the strong presence of research institutions. Relating this finding to the principle of the pilot paradox, it makes paludiculture particularly vulnerable. The discussed pilots explored in this research operate in safe and controlled boundary space in very specific conditions (Buuren et al., 2018). In these spaces, the pilot users need to tick specific boxes, including (1) having a suitable plot, (2) connecting value to development of a new innovation, (3) having a trustful working relationship with the researchers, and (4) aiming to contribute to something good in relation to carbon storage and protecting wider society. These are conditions which allow the research to thrive and be successful but are a hard ask when implemented on a wider scale. Furthermore, the network of practices lacks societal embedding not only in the user environment, but also in wider society. This was shown by the predominance of the business and policy environment in all the SNA maps. This seriously puts into question how paludiculture could effectively be upscaled in the future since the current pilot plots do not represent a realistic situation.

Another part of upscaling is the translation of a pilot's results into policy goals and content (Buuren et al., 2018). In the nexus, it became clear that paludiculture is currently not firmly embedded in the policy environment. There have been some positive moves at international and national level, such as the inclusion of cattails and reed in CAP payments and the integration of wet cultivation in the water management plan of water board de Dommel (Ministerie LNV, 2020; Waterschap De Dommel, 2022). Yet, in general the policy environment still favours drainage-based practices, thereby hindering re-wetting (De La Haye et al., 2021). This means that the current policy environment does not support, or even impedes the upscaling of paludiculture. Yet, the actors interviewed felt that parties such as water boards, provinces, and central government should take responsibility to develop suitable policy instruments. Overall, this reinforces the need for the nexus to adapt in order for any upscaling to occur.

The second part of the nexus which should be discussed is the business environment. Research institutions and organisations dominate the funding of pilot sites, again reflecting the conditions for pilot paradoxes to occur. The costs of the cattail cultivation are currently too high for individual farmers, including field preparation, expensive plugs, and labour input, compared to the potential income. Therefore, cattail cultivation is not yet suitable for individuals to invest in. Furthermore, it remains unclear how tailored planting and harvesting equipment could be shared or invested in by farmers and other land users engaged in paludiculture.

Furthermore, the market for cattails is currently still underdeveloped, with no strong demand for cattail products. Therefore, it is peculiar that biomass production is taken as key part of most research, while the adaptive and nature-based purposes of cattails appear to offer better opportunities for synergies. This purpose can be strengthened if payments for ecosystem services were to be developed. In this way, there is a revenue model for cattail production, without high biomass being the main purpose. The research concludes there is more potential in developing a market for ecosystem services including blue credits and carbon credits purposes, rather than a production chain for cattail biomass. This would also negate the issues of potential nutrient deficiencies. Relating this to the concept of societal embedding, this would mean the business environment would become the government trying to 'sell' climate adaptation to the users, i.e. farmers and land users. This selling could also be achieved through the introduction of appropriate rules and regulations. As a result, one could consider framing paludiculture with cattail cultivation as a climate adaption practice instead of an agricultural practice.

6.2. Use of the network of practices approach

In this section, the use of the network of practices approach is discussed. First, the success and challenges of the integration of the concept societal embedding is examined. And secondly, a comparison of the practice-based approach is made with the multi-level perspective. For more information on the multi-level perspective, please refer to section 2.2.1. Multi-level perspective

6.2.1. Integration with societal embedding

Motivated by the PhD research by Giller (2021), the research opted for a network of practices approach. There were a number of challenges which had to be dealt with before using the network of practices and societal embedding concept in this context. Firstly, in order to build a more complete story on the elements of practice, the researcher was forced to also draw information from other pilot sites. Additionally, the user environments of the pilot sites spoken to all had different contexts. For instance, the Estate Groot Overbrugge is located in a stream valley and is a 'hobby' farm, while Kemp had 99 ha of dairy farming with 1 ha cattails in the peat meadow area in Ankerveen (Int. Estate Groot Overbrugge; Int. Kemp). This meant that even the 'zooming-in' already required looking beyond the scope of the Helmond pilot. Therefore, it proved difficult in this context to define a clear boundary between zooming-in and zooming-out.

Secondly, the skewed structure of the network meant that the definition of the user and business environment were unconventional. Usually, the user would be the 'buyer' of a product, for instance a consumer purchasing cattail insulation. The business environment would comprise the farmer and processors selling the product. However, this appraoch would mean the practice of cattail cultivation would not be central to the research, but rather the agricultural production and market. However, as the network is dominated by the research community, these definitions are not suitable. Since this was not the main goal of the research, the usual interpretations of the societal embedding environments had to be adapted. Even though this approach introduced some complexity, it did allow for interesting conclusions to be drawn on the role of the policy environment as possible future 'sellers' of paludiculture to farmers.

Finally, there were no previous literature examples of the use of network of practices for an agricultural practice. Therefore, operationalisation had to be based on Castelo et al. (2021) referring to the practice of eating. Yet, due to the innovative nature of paludiculture Castelo's steps were insufficient without the integration of societal embedding concepts. Yet, due to the imbalance in societal embedding definitions, this meant that the starting point of the research was also farm-level. This meant that the business environment, which is a key reason why the network is not socially embedded, had to be stressed in the nexus of the network. Overall, this did enable a clear insight into the funding and market of cattail cultivation.

However, following the network of practices approach allowed the researcher to take a single starting point and zoom-out from there. This enabled the researcher to identify a multitude of different interrationalities including spatial interrationalities in particular, with dairy farming and nature areas, as well as interrationalities between the purposes of paludiculture (Hui et al., 2016). Furthermore, the structure of the network of practices approach allowed for the integration of the concept societal embedding. An important part of this concept is considering the pre-existing environment (Geels & Johnson, 2018). By doing so, it enabled the network of practices approach to analyse an innovation.

It appears that network of practices has not been used yet in this manner in previous research, as no comparable literature was found. The practice-based approach has been used before to investigate innovation, but not related to societal embedding (Nicolini, 2009). Therefore, this paper also provides a valuable addition to research, enabling a different approach to researching upscaling. Another theory which could be considered is that of communities of practice. Communities of practice take a different perspective as it refers to groups of people who share and participate in the same practice (Farnsworth, Kleanthous, & Wenger-Trayner, 2016). Through regular interaction, people learn how to do the practice better. Therefore, this theory departs from the people surrounding a single practice, while the network of practices searches for relations between practices, to which certain actors are connected. As a result, network of practices offers a different perspective compared to communities of practice.

6.2.2. Comparison with the multi-level perspective

It is interesting to compare the network of practices approach to the multi-level perspective approach of Geels & Kemp (2000). In previous research, the multi-level perspective has often been used to understand transitions and the diffusion of new innovations and practices (Geels & Kemp, 2000; Geels, 2019). Geels & Johnson (2018) even integrate the concept of societal embedding in the multi-level perspective, which inspired this research to do the same in the network of practices approach. It worked well.

The findings of this research suggest that the network of practices does allow for less pre-defined boundaries of the research compared to the multi-level perspective. In the multi-level perspective, it is important that the regime and niches has been defined beforehand. As a result, Smith, Voß, & Grin (2010) argue that the niche and regime distinction fails to recognise the complexity and contingency of (un)sustainable developments. This as the structured perspective can fail to recognise the co-evolution and interactions between niches. In the network of practices, these co-evolutions and synergies can be clearly evaluated as shown in the results of intertwined purposes and interrationalities in space, time, and society. In the network of practices, one must define when zooming out starts, but make no distinction between niche, regime, and landscape. In this research, this enabled an unbiased perspective on the multiple purposes of paludiculture. Thus, this is complementary to a weakness of the multi-level perspective as discussed by Smith, Voß, & Grin (2010).

Therefore, the practice-based theory provides a more detailed and careful analysis of the constitution of the niches and their regime without placing then in strict separate frames. This does not discount the use of the multi-level perspective, which is also a method which can be used to understand transitions in situations with clear regimes (Geels & Johnson, 2018). Rather, it shows that the network of practices approach can be more effective to understand the situation from the bottom-up in cases where the regime cannot yet be clearly defined in advance of the research.

6.3. Limitations

After discussing the use of the network of practices and the general results of the research, the results' limitations can be addressed. This section elaborates on limitations of the concepts used, decisions made in the interviews, and the SNA decisions and results.

6.3.1. Limitations of the business environment definition

The challenges of the conceptual framework have already been discussed, but it is important to explain the limitations of the business environment. At the start of the research, the expectation had been that more companies would already be actively engaged in paludiculture. However, this was not the case as paludiculture is currently strongly dominated by research institutions and organisations, including universities, consultancy firms, and projects. Therefore, the decision was made to broaden the definition of business environment to include entities paying for or funded by research institutions. This enabled a better representation of the current funding of paludiculture pilot plots, but it does not reflect a realistic future scenario. Rather, it reflects the peculiar network as discussed earlier. If paludiculture were to scale up, then research bodies cannot be the only financers as this is not sustainable (Janssen & Braunschweig, 2003). Therefore, in future research it might be the case that research institutions become less relevant, thereby meaning the definition of the research environment should again be adapted.

6.3.2. Decisions made in interviews

Firstly, the choice was made to use semi-structured interviews. This created a structured conversation while allowing flexibility to ask further in-depth questions. This was suitable for the qualitative nature of the research. Furthermore, because of the semi-structured nature, answers could be compared between interviewees, thereby increasing the internal reliability of the results. However, before each interview, the interview guide was adapted according to the interviewee. For instance, with a planter more questions were asked concerning field preparation and planting, while with the water board more time was spent on questions relating to the policy context. This means the internal validity could be challenged, since not all interviewees had the same interview experience.

Furthermore, semi-structured interviews have a high risk of bias (O'Keeffe et al., 2016). In this research, it was important to assume that paludiculture has the potential to become socially embedded. Therefore, the questions were already directed by the assumption that paludiculture can be a success, which is not necessarily the case. In interviews, it also become clear that paludiculture is in its early stages, with no guarantee that it will be implemented at a wider scale in future (Int. van Naarden & Pronk). Furthermore, in semi-structured interviews there is always the risk of socially desirable responses (O'Keeffe et al., 2016).

Additionally, due to the time limitations of a thesis research, the data collection consisted of 27 semi-structured interviews and one open interview. This means one can question whether the point of data 'saturation' has been reached. Saturation refers to ''the point at which no new information or themes are observed in the data'' (Guest, Bunce, & Johnson, 2006 pp.59). One can see this as a thematic exhaustion, when no more additional themes are added to the results. Guest et al. (2006) estimate this to be about 12 interviews, therefore suggesting this research should have reached data saturation. However, the results appear to be biased towards stream valleys compared to peat meadows. This can be explained by the combination of snowball sampling and taking a stream valley case as starting point. As a result, the research appears to have reached saturation in the stream valley setting, but not quite in the peat meadow setting, thereby questioning the external validity of the research. Furthermore, while validation of collected data through objective measures such as previous research is a necessary step in data collection, it is outside the scope of this thesis. Therefore, the results are based almost in their entirety on the interviews and SNA results.

The final limitation of the interviews is the snowball collection method. The snowball collection method also has the potential for a sampling bias as people refer to those who they already know and are found in similar contexts (Parker, Scott, & Geddes, 2019). Therefore, no statistical analysis can be extrapolated from the results due to its non-random nature. Furthermore, the starting point of the snowball sampling is dependent on the researchers own personal connections (Parker et al., 2019). In this case, this started in the research context rather than at the user level with the Estate Groot Overbrugge themselves. This could have potentially influenced the 'direction' of the sample. Finally, because of time constraints of the research, the final referrals of the last 7 interviews could not be followed up. However, this does not mean that insufficient results were collected in order to draw some interesting conclusions.

Overall, the interview results can be questioned for their reliability, external validity, results bias, and sampling bias. Yet, due to the highly social nature of the results, the goal is not to generalise the findings, but rather provide an insight into this particular network of practices.

6.3.3. SNA decisions and results

To create the SNA images, a number of assumptions and decisions had to be made. Firstly, as stated in the previous heading, the SNA maps were not suitable for statistical analysis. This is due to the snowball sampling used, thereby meaning the non-random sampling is not suitable for independent analysis (Parker et al., 2019). Therefore, only general patterns can be seen in the SNA. Even so, useful conclusions could be drawn from the SNA maps including the expectations of policy makers to take the lead for policy implantation, research institutions to share knowledge, and wider society to be taken on board in wider implementation.

Secondly, due to the limited number of responses to the SNA exercise, the decision was made to assume the snowball contacts named during the interview would be part of the full SNA list. For example, Westerhof was unable to fill in the SNA, but did give 5 snowball contacts. Therefore, these 5 snowball contacts were assumed as the SNA list. Additionally, actors and organisations mentioned as important during the interview were also added to this list. In this way, the full network was more representative of the real-life situation. Otherwise, certain actors and institutions who were discussed during the interviews would not be shown in the network. However, one could say this tampered with the results and thereby reduces this reliability of the SNA.

Thirdly, in the answers sent by interviewees often general expressions were used. For example, the general terms 'water boards' or 'provinces'. In this case, the decision was made to take specifically named water boards and provinces by other interviewees and to not include any organisations not named so far. For instance, if the term 'water boards' was used, this was assumed as water boards de Dommel, Aa & Maas, and Schieland & de Krimpenerwaard, as these were already named by others. However, this means that such general statements might not be fully reflected in the SNA maps.

Fourthly, the decision was made to count the answers of certain interviewees for both institutions which they are connected to. For instance, van Duinen works for CConnect, water board Aa & Maas, and Stichting Bargerveen. This means that the answers of van Duinen were used from all three organisations and added on to other answers given by people in the same organisation. For instance, the answers of van den Elsen and van Duinen were combined for Aa & Maas as both work for the water board. As a result, some institutions are more prominent in the network due to double counting answers. Additionally, this made it unsuitable to place weighting in the SNA due to this bias. Therefore, there is a bias in the SNA towards institutions which employ multiple of the interviewees. As many of the interviewees were questioned due to their connection to the stream valley location, this also means the SNA is more biased towards stream valleys. Overall, the SNA maps were useful to create an insight into the existing networks, but many decisions and assumptions had to be made in order for them to be useable. Therefore, the use of SNA maps was valuable given the purpose of the research but are not to be generalised.

6.4. Recommendations

First recommendations are given for the research community, after which recommendations are given to policy makers.

6.4.1. Recommendations for the research community

Overall, the research community must place more focus on making the solutions they uncover scalable (De La Haye et al., 2021). This can be facilitated through clear communication including terminology, preparing for a transition of responsibility to farmers and companies, and future research on upscaling.

Clear terminology

Firstly, the terminology of paludiculture is ambiguous, especially the distinction between 'paludiculture' and 'wet cultivation'. It became apparent very early on in the research that the practice can have a multitude of purposes which can exist side-by-side including halting land subsidence, storing CO2, and climate adaptation of the water management system. The existing definitions both do not fully encompass these purposes. This results in an unclear message to the general public, policy makers and the business environment as to what do we mean when we speak of paludiculture. Therefore, the research recommends the research community to clarify their terminology in order for clearer communication on the purposes of paludiculture.

Transitioning role to farmers and companies

Because paludiculture with cattails is dominated by research at the moment, it is important to already consider a possible transition to its intended executing actors. Farmers and companies should be involved in the early stages of research. In the current pilots, users are well compensated for their work in pilots, but it appears that the development of planting and harvesting technology is lagging behind. Wellink explained that he invested in developing the harvesting technology because of his own belief that the market will develop, but these costs were initially not included in the research budget (Int. Wellink). As a result, the research community focused on cultivating the crop, but lacked perspective on the next steps of cultivation. At the moment, there is no efficient machine to plant the cattails. Therefore, for future innovations, it would be useful to both have a cultivation project as well as a machine project running alongside each other. De La Haye et al. (2021) add that agri-cooperative or machinery rings should be created to ensure single farmers do not need to bear the full costs of equipment. This research also supports this recommendation.

Methodology

The use of the network of practices approach gave interesting results based on observations in a structured manner. Therefore, this is a useful method to understand a practice from the bottom-up, allowing researchers to explore interrationalities the further they zoom-out. In particular, this method did not require a pre-defined regime of paludiculture, thereby allowing the research to uncover the full web of purposes. However, it is important to recognise the necessity to include the business environment. In this, the definition of the business environment must be clarified and evaluated continuously throughout the research in order to fully reflect the market and funding of the practice. Furthermore, the methodology must reflect the intent of the research. In this case, the aim was to understand the current status of paludiculture in society and its characteristics. By combining the concepts of societal embedding in the network of practices approach this goal was achieved. Finally, combining the SNA maps with the interview results was effective. The SNA maps were a useful method to provide an initial overview of the existing network on which the answers of the interviews could build. For example, in the SNA maps the research environment was a very prominent type (Figure 12). This resulted in the redefinition of the term business environment in order to also include research funding. Therefore, the SNA is a useful way to introduce the results and allows for cross comparison.

Future research

In future research, it would be useful to increase the number of large-scale demonstration sites, also suggested by (De La Haye et al., 2021) . Not only will this support research on the scalability of the practice, but it will also enable a better understanding of the interrationalities with other practices. Additionally, the research recommends focusing on researching ecosystem services to create a more synergetic revenue model. Furthermore, it would be interesting to take a different starting point in the peat meadow area. In this way, the network could be expanded to also include more in this spatial context. Moreover, in order to understand the full characteristics of paludiculture, other paludiculture crops should be investigated in the same manner, for instance, peatmoss, reed, cranberries, or azolla. In particular reed is an interesting comparison, also due to its insulating properties and similar growing conditions to cattails (Int. van de Belt; Int. Westerhof). In several interviews, interviewees commented on the cattail's 'hype', while reed is more sturdy, less nutrient dependent, and already has a history of cultivation in the Netherlands (Int. Egas; Int. Fritz; Int. Westerhof). Therefore, it is recommended to research the network of practices of reed to compare to cattails. Of course, a completely different agricultural practice could be selected to test and further improve the framework. It would also be interesting to investigate how cattail cultivation can be upscaled using a multi-level approach.

6.4.2. Recommendations for policy makers

Overall, paludiculture is not integrated into mainstream policy, with several policies even inhibiting its implementation. Policy is biased towards drainage-based farming, thereby hindering re-wetting land. Thus, the research suggests paludiculture must be better integrated into policy and the policy environment should play a more prominent role in supporting innovators as well as spreading awareness.

Integrating paludiculture into policy

As it stands, there is little to no reference to paludiculture in Dutch policy documents. Even if mentioned, there is no clear strategy or specific budget available for this development. It is already a major step that cattails sites can now apply for CAP payments, but other than this there is no clear policy to support or stimulate paludiculture. If research confirms the potential of the practice, for any of its purposes, clear rules and regulations should be provided by the policy environment. The results suggest that these should be oriented towards the climate adaptive qualities of cattails, rather than its biomass qualities. In order to become less reliant on the CAP payments and to support an agricultural transition to more sustainable practices, new forms of subsidies should continue to be developed (EU Budget, 2020). This could include carbon credits, blue credits, and ecosystem services, all of which paludiculture with cattails can provide, or the *polluter pays principle* (de Jong et al., 2021). This would also reduce the pressure to quickly develop a cattails market chain, as this would already allow for production of cattails to get a head start. This could provide a way out of the chicken and the egg circle. Furthermore, if the playing field is equalised by making fossil-based products more expensive, then biobased products have a fighting change in the market (EU Budget, 2020). In this way, economic incentives for farmers to implement paludiculture can be increased.

De La Haye et al. (2021) also stress the importance of integrating peatlands across policy. Because of the multi-purpose quality of paludiculture, it crosses multiple sectors thereby making the risk of contradictory policy higher. Therefore, policy should be assessed holistically using referring to existing policies such as the Water Framework Directive, Flood Directive, the Paris climate agreement, and the EU's Green Deal. Additionally, such policies should be reviewed to integrate paludiculture as a method to achieve their goals. This is also relevant for national policy, such as the national Climate Accord and water board plans.

Providing support for innovators and awareness to others

In the social dimension, a number of concerns were discussed including mosquitos, change of landscape, and standing out from you neighbours. It is important to offer a platform in which potential implementors can ask their questions and voice their concerns (Int. Westerhof). Furthermore, to reduce the potential feeling of ostracization of those implementing paludiculture, it is useful to build a stronger network between pilot sites in which landowners or managers are involved. Such a network could be similar to the concept of Netwerk Goed Boeren, allowing a support network for those willing to step outside the traditional agricultural boundaries. Government agencies can play a leading role in facilitating such a network. Based on the results of the SNA maps, most see water boards as key players in stimulating and implementing policy on paludiculture. Furthermore, policy institutions can play a leading role in facilitating agri-cooperative or machinery rings (De La Haye et al., 2021). Overall, no landowner or manager should be socially or economically disadvantages for maintaining or developing peatlands (EU Budget, 2020).

So far pilots are largely connected through the researchers involved, as shown in the SNA maps. This means communication is often limited to pilot sites that belong to the same project or institution. Additionally, less contact is stimulated between field managers and users such as landowners. Therefore, it is useful to involve more land managers across different spatial contexts to exchange learning experiences. In the Deelexpeditie Natte Teelten, the first step was made towards such as structure to exchange experiences between sites. However, Kemp was the only 'practical' oriented member of the Deelexpeditie with other in the group being research oriented. However, based on the results, it shows the importance of considering the practical implications of the practice, especially in combination with other practices a farmer might be carrying out. Therefore, policy should not only support innovators but also include their input in such expeditions.

7. Conclusion

The need to upscale successful and innovative solutions for a climate adaptive landscape is increasingly important, thereby making upscaling a key part in understanding and stimulating wider implementation. In this research, the aim was to investigate the characteristics of the network of practices of cattail cultivation in the Netherlands, taking the pilot site in Helmond as its starting point. In doing so, the research aimed to better understand the potential for upscaling through a practice-based approach.

Several conclusions were drawn based on the findings relating to the practice of cattail cultivation, paludiculture in general, its linkages and incompatibilities with other practices, and the policy and business environment in which it resides. For an overview of all the results visualised, please refer to Annex N: Full results overview. Firstly, in the full actor network of cattail cultivation in the Netherlands it already became evident that research institutions and organisations are predominant in paludiculture. As a result, the network of practices also includes practicing research. Another interesting finding was the multitude of purposes which can be associated with cattail cultivation. These purposes include halting land subsidence, storing CO2, climate adaptation of the water management system, ecological connection zones, biodiversity, and water quality. In order to achieve any of these purposes, a number of steps must be followed in order to stimulate a successful cattail cultivation. A number of practices which were found included field preparation and maintenance, planting and harvesting. Most of these steps relate to either re-wetting of the land or to stimulate or start biomass production.

By zooming out from the field level, the research found that there are many challenges in cattail cultivation, including delays in field preparations, inability to add fertiliser and manure or to practice crop rotation, drying time and space, and (manual) labour needs. A further concern is the impact of neighbouring plots due to increased water levels and the change which the tall plants bring to the landscape. Additionally, the practice-based approach was successful in finding a number of relations between practices. This includes linkages and incompatibilities between different practices of paludiculture and surrounding practices. Both are important to consider as linkages can potentially provide synergies, while incompatibilities can cause barriers in wider implementation. The most interesting relations were found in the spatial relations with surrounding practices including nature areas, dairy farming, and neighbouring plots. Other relations to highlight are the temporal relationship between the harvest time of cattails and the intended end product and most importantly the overlapping purposes of paludiculture. Overall, this not only shows the effectiveness of the practice-based approach, but also provides insights into opportunities and challenges for upscaling.

Interesting conclusions were also drawn related to expectations as regards responsibilities. Research institutions and organisations play a central role in knowledge-sharing, while the policy environment is essential for the promotion of paludiculture. Actors feel most dependent on the policy environment and wider society to become successful. Therefore, those in the policy environment are expected to take responsibility for facilitating growth of paludiculture, while research institutions support its development. However, both the policy environment and the business environment are not ‘paludiculture-friendly’. Policy is geared towards drainage-based practices, therefore often inhibiting re-wetting. Furthermore, the market is underdeveloped and there is no strong demand for cattail products as yet. Therefore, the research challenges the view that cattail cultivation should be framed primarily as an agricultural product but sees more prospects in it and an adaptation measure, since more synergies exist in this area. As a result, the main recommendation is for the research community and policy makers to find ways to develop payments for ecosystem services, including blue credits and carbon credits.

The method used, the network of practices approach, enabled the exploration of these key relations, defined as ‘interrationalities’ in the research. Furthermore, through the successful integration of the societal embedding concept in this approach it proved possible to conduct an effective analysis of an innovative practice such as paludiculture with cattail cultivation. This methodology is an interesting addition to research on upscaling of practices.

To conclude, the research revealed that paludiculture with cattail cultivation in the Netherlands is largely controlled by and dependent upon research institutions and organisations. Under current conditions, it is not deemed suitable for large-scale implementation. There are still too many thresholds in the cultivation and production stages. Therefore, the research recommends a re-consideration of the framing of paludiculture towards a climate adaptation practice in which more opportunities for synergies exist. Overall, upscaling of paludiculture might only become a viable option for the future if the major obstacles can be effectively removed. But for now, landscapes with fields upon fields of cattails are not quite around the corner.

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Annex

Annex A: Social network analysis exercise

As sent by e-mail to interviewees after the interview.

Social network analysis exercise

Name:

List all organisations and individuals you have interacted with about paludiculture/wet cultivation in the past 2 years. For example, think of:

- Citizens' groups (volunteer organisations, local action groups, etc.)
- NGOs, donors, civil society organisations, development organizations, etc.
- Private sector (input suppliers, processors, etc.)
- Government (various ministries, departments at national, regional, district level, etc.)
- Research and training ((inter)national research organisations, universities, training institutes, etc.)

1.____

2.____

3.____

4.____

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8.____

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15.____

16.____

17.____

18. ____

19. ____

20. ____

If abbreviations are used, please also provide full names.

Next steps

1. Out of all written organisations, underline the 5 organisations that are most important for knowledge exchange regarding paludiculture e.g.

Organisation A

Organisation B

2. Of all written organisations 'check' the 5 organisations that are most influential in promoting paludiculture e.g.

Organisation A

Organisation B

3. Of all written organisations write a 'cross' sign next to the 5 organizations you think you are most dependent on for the success of paludiculture e.g.

Organisation A X

Organisation B X

4. Of all written organisations write an exclamation mark next to the 5 organizations that you think have the most influence on the policy environment of paludiculture e.g.

Organisation A X

Organisation B X !

Annex B: Decisions made to create SNA maps

A number of decisions and assumptions had to be made during the creation of the SNA maps. It is important to clarify exactly what these were.

1. Due to the use of snowball sampling, the SNA maps are not suitable for statistical analysis. The non-random sampling method is not suitable for independent analysis. Therefore, only general patterns can be seen in the SNA.
2. Due to the limited number of responses to the SNA exercise it was necessary to substitute a list for interviewees who did not send in any responses. Two methods were used to construct this list:
    a. The snowball contacts named during the interview. For example, Westerhof was unable to fill in the SNA, but did give 5 snowball contacts. Therefore, these 5 snowball contacts were assumed as the SNA list.
    b. Actors and organisations mentioned as important during the interview were also added to this list.,
3. In answers sent by interviewees often general expressions were used. For example, the general terms ‘water boards’ or ‘provinces’. In this case, the decision was made to take specifically named water boards and provinces by other interviewees and to not include any organisations not named so far. For instance, if the term ‘water boards’ was used, this was assumed as water boards de Dommel, Aa & Maas, and Schieland & de Krimpenerwaard, as these were already named by others.
4. Answers of certain interviewees were counted for multiple institutions which they are connected to. For instance, van Duinen works for CConnect, water board Aa & Maas, and Stichting Bargerveen. This means that the answers of van Duinen were used from all three organisations and added on to other answers given by people in the same organisation. For instance, the answers of van den Elsen and van Duinen were combined for Aa & Maas as both work for the water board.
5. Because Suleiman was interviewed for her work at LANDMARC her SNA list was only used for LANDMARC, not Bioclear Earth. This also as Bioclear Earth was not mentioned by any other interviewee and therefore is not prominent in the network.

Annex C: Interview guide

As explained in the main body of text, the following interview is a compilation of all question asked. Therefore, not every person had the exact same interview, but rather got asked questions to which they had more expertise.

Introduction

- Thank you for accepting this interview. The interview will last a maximum of 1 hour.
- The aim of the research is to map the network of practices and actors surrounding the paludiculture pilot. This is done on the basis of these types of interviews where questions are asked to start the conversation, after which follow-up questions are asked. This is done in the context of KLIMAP, which is a project working on solutions for more climate adaptive solutions of sandy soils. The starting point of this research is the paludiculture pilot plot with cattail cultivation in Helmond.
- Afterwards there will be an opportunity to give me feedback about the interview and to add final points. Of course, you can always send an email afterwards with questions or comments.

Questions before starting interview

- Before we start, I would like to ask whether I may quote you in the report? (Yes/No)
- And secondly, do you prefer to remain anonymous? (Yes/No)

(These answers may be modified after the interview)

Basic information

Date of interview:

Name of interviewee:

Functions and projects:

1. Elements of paludiculture

1. How is your own organisation involved in paludiculture? With which pilot plots?

2. From which initiative was the pilot in Helmond started?
   a. How were you/your organisation involved in the set-up of pilot site(s)?
   b. What is the connection between Cconnect, LANDMARC, KLIMAP, and Boer Bier Water?

3. What had to be planned and approved before the pilot could start in Helmond?
   a. Hydrological feasibility study i.e., flat surface (<20cm difference)
   b. Nature conservation law: Mapping breeding birds, Natura 2000 preliminary impact assessment, Exception landscape protection area regulation, Intervention compensation balancing
   c. Approval according to the water law (water law permit)
   d. How many hectares is the site?

4. How is the location itself prepared for paludiculture?
   a. Have dikes/ditch excavations/irrigation infrastructure.sub-irrigation been constructed?
   b. How is the soil prepared? E.g. new top layer, levelling, etc. What is the soil composition?

c. Has the water level been raised? If so, to what level?
d. How quickly did you flood the plot and when (e.g. before or after sowing/summer)?
e. Which machines and tools were used to carry out these activities?
f. Where do the plants come from? i.e. seed nursery. What sowing density? Which machines (hand/drone)?

5. How is the pilot managed from day to day?
   a. How is the water level regulated? (pumping/draining)
   b. Are solar panels used to power the system?
   c. Is the site protected from wildlife? E.g. geese. If so, how?
   d. Is the location fertilised? If so, how much? (depending on water quality?)
   e. What other maintenance tasks are performed? E.g. additional seeding, mowing, maintenance equipment.

6. Of these activities, who perform them? And why are these people suitable to perform these tasks? E.g. which skills (knowledge/qualities/attitude) and (personal) characteristics?

7. Why would a landowner or farmer implement paludiculture?
   a. Why was the landowner of this pilot site selected? What makes them suitable/unique?

8. Are other types of machines and equipment needed for paludiculture due to the higher water level?
   a. How do these differ from the previous form of land use?
   b. What challenges are there in using these machines?

9. What economic inputs are needed/were used for the pilot site?
   a. Is this input available?

10. Is there a market for cattail cultivation? If yes which one?
    a. What products can you make from cattails?
    b. Is there still room for growth in this market?

11. In addition to the elements already mentioned, what is needed for a farmer or landowner to implement paludiculture?

12. Why would someone (a landowner or farmer) implement paludi-culture?

13. What do you think is the added value of paludiculture (in a stream valley setting)?

2. Overlap in time and space

1. What is the main land use in the region of the pilot area?

2. How has the difference in land use on the plot site (in Helmond) influenced surrounding practices?
   a. Adjacent agriculture with higher water levels?
   b. Mosquitos?

3. When are the main management activities carried out for cattail cultivation? (Think of sowing, harvesting, fertilising)?

a. How long do these activities take?
b. How much labour?
c. What time of year must this activity be carried out?

4. How much time does it take to manage cattail cultivation? Per day/month/year?

5. Do the management activities overlap with other land use/agricultural activities over time?

6. How does paludiculture fit into existing farmers' practices? (Think of practical materials, but also of standards and values)

7. How is the pilot site linked to other pilot sites in the Netherlands?

3. Policy context

1. What existing international policy is relevant for paludiculture?
    a. Are there subsidies for paludiculture (from the EU)?
    b. How does the EU's Common Agricultural Policy further influence the implementation of paludiculture/cattails farming?
    c. Are new rules and standards already being created based on this new form of agriculture?

2. What national policy is relevant for paludiculture?
    a. Are their subsidies for paludiculture in the Netherlands? i.e. nature subsidy
    b. How does it fit in with the Environmental law (NDL: Omgevingswet)?
    c. How does paludiculture fit in the water management plans of water boards?

3. In addition to those already mentioned, which policy documents do you think have the most influence on the implementation of paludiculture?

4. In your opinion, what policy should be developed in future to enable the wider implementation of paludiculture in future?

4. Snowball contacts

- Which two (or more) people or organisations would you advise me to interview next?
- What are their contact details?

5. End of the interview

- These were the main questions, thank you for all your answers and insights during this interview. Do you have any final questions or points of feedback?

- Ask if they would like to receive the report. If they do, ask for their email address.

- Thank for your time and leave own contact details.

Annex D: Interviewees & organisations

All interviews took place in 2021. On average each interview took about 1 hour. With Roelof Westerhof two interviews were held due to his extensive background knowledge of the topic and willingness to meet again a week later. The overview is given in Table 3. In Table 4 an overview is given of all the institutions and organisations linked to the interviewees.

Table 3. List of Interviewees, dates, and functions.

Interviewees numbered in order spoken to		Date of interview	Employers/project(s) of interviewee
1	Jeroen Geurts	12th of October	- KWR Water - CConnect - KLIMAP - Radboud University (guest lecturer)
2	HAS students	18th of October	- HAS University of Applied Sciences of Applied Biology
3	Sabine Wichmann & Josephine Neuberts	20th of October	- University of Greifswald - CConnect
4	Walter Schoenmakers	21st of October	- Staatsbosbeheer
5	Myrjam de Graaf	25th of October	- Wageningen University & Research - KLIMAP
6	Robert Wellink	26th of October	- Wellink Equipment
7	Jeroen Pijlman	28th of October	- Louis Bolk Instituut - Deelexpeditie natte teelten
8	Gert-Jan van Duinen	28th of October	- Stichting Bargerveen - Radboud University - Water board Aa & Maas - CConnect
9	Frank van Lamoen	10th of November	- Province North Brabant
10	Annelies van Balkema	10th of November	- Water board de Dommel - KLIMAP
11	Hilke van Elsen	11th of November	- Water board Aa & Maas
12	Afnan Suleiman	17th of November	- Bioclear Earth - LANDMARC
13	Roelof Westerhof	19th & 24th of November	- ORG-ID - Deelexpeditie natte teelten
14	Kees Koot	22nd of November	- Stichting Waterplant
15	Ellen Weerman	22nd of November	- HAS University of Applied Sciences
16	Valentina Sechi	22nd of November	- Van Hall Larenstein University of Applied Sciences - Wetsus - CConnect
17	Marthijn Junggeburth	23rd of November	- Royal Swinkels Family Brewers - Boer Bier Water
18	Wout van de Belt	24th of November	- Reed grower in Overijssel
19	Youri Egas	25th of November	- KTC Zegveld
20	Johan Elshof	29th of November	- ZLTO
21	Wilco Kemp	1st of December	- Dairy farmer Ankerveen participator in pilot site cattails - Deelexpeditie natte teelten

22	Ivan Mettrop	3rd of December	- Altenburg & Wymenga - Better Wetter
23	Yvette Osinga	6th of December	- Brabantse Mileu Federatie - Netwerk Goed Boeren
24	Chris van Naarden & Sabine Pronk	8th of December	- Ministry Agriculture, Nature, and Food Quality (LNV)
25	Coen Verboom	8th of December	- Bouwgroep Dijkstra Draisma
26	Christian Fritz	9th of December	- Radboud University - CConnect
27	Julian Visscher	10th of December	- Gebr. Visscher
28	Estate Grote Overbrugge	13th of December	- Pilot site cattails CConnect/KLIMAP/LANDMARC - Participator Boer Bier Water

Table 4. Overview institutions and organisations and relevant interviewees.

Name	persons involved/workplace			
KWR	Jeroen Geurts			
CConnect	Jeroen Geurts	Gert-Jan van Duinen	Valentina Sechi	Christian Fritz
University of Greifswald	Sabine Wichmann	Josephine Neuberts		
Staatsbosbeheer	Walter Schoenmakers			
Wellink Equipment	Robert Willink			
Radboud University	Jeroen Geurts	Christian Fritz	Gert-Jan van Duinen (guest speaker)	
KLIMAP	Myrjam de Graaf	Jeroen Geurts		
Stichting Bargerveen	Gert-Jan van Duinen			
Province of North Brabant	Frank van Lamoen			
Water board de Dommel	Annelies Balkema			
Water board Aa & Maas	Gert-Jan van Duinen	Hilke van Elsen		
Bioclear	Afnan Suleiman			
LANDMARC	Afnan Suleiman			
ORG-ID	Roelof Westerhof			
Deelexpeditie natte teelten	Roelof Westerhof	Jeroen Pijlman	Wilco Kemp	
Stichting Waterplanten	Kees Kot			
HAS University of Applied Sciences	Ellen Weerman	HAS project group		
Van Hall Larenstein University of Applied Sciences	Valentina Sechi			
Boer Bier Water	Marthijn Junggeburth	Estate Groot Overbrugge (participant in project)		
Wout van der Belt (reed grower)	Wout van de Belt			

KTC Zegveld	Youri Egas			
ZLTO (ENG: The Southern Agriculture and Horticulture Organization)	Johan Elshof			
Altenburg & Wymenga	Ivan Mettrop			
Better Wetter	Ivan Mettrop			
Brabantse Milieu Federatie	Yvette Osinga			
Netwerk Goed Boeren (ENG: Network good farming)	Yvette Osinga			
Ministry of Agriculture, Nature and Food Quality	Chris van Naarden	Sabine Pronk		
Bouwgroep Dijkstra Draisma	Coen Verboom			
Gebr. Visscher	Julian Visscher			
Estate Groot Overbrugge	Anonymous			
Wageningen University & Research	Myrjam de Graaf			
Louis Bolk Institute	Jeroen Pijlman			
Pilot Ankerveen	Wilco Kemp			

legend	
	Spoken to
	Participated in project or guest speaker, but not appraised as sender for SNA (reason given in brackets)

Annex E: Explanation of research steps

This annex is the extended version of the research steps explained in the methodology.

Step 1: Defining the unit of analysis

Step 1 concerned defining the unit of analysis, thereby defining what practice or what group of practices are investigated and what the boundary of this practice (group) is. In this, it must be clarified at what point the zooming-out starts. In this research, the practice investigated is the paludiculture on agricultural land. The case taken as a central example to explore this is the pilot in Helmond on the Estate Groot Overbrugge. Initially, the boundary of this practice was appraised as the Helmond pilot plot and those directly involved in its operation and continuation of the pilot at the farm level. This meant that zooming-out started at the point where people are no longer involved at field level and are not hands on with the practice in any way. However, during the research it became clear that also experiences of other pilot sites should be included in this zoomed in part of the results, despite the fact that they are in a different location. This is due to the fact that in later interviews additional valuable information was shared which can also be applicable for paludiculture in a stream valley setting. Therefore, the boundary condition for zooming in was changed to those that are directly involved in the operation and continuation of wet cultivation, even if in a different plot. Therefore, the chapter elements was defined as the user environment as explained in the conceptual framework. The second map of the SNA (separating the four components of social embeddedness) also clarifies this distinction.

Furthermore, the social embeddedness perspective also introduced a clear general boundary for the research. This means the research did not elaborate on hydraulic discussions or in-depth economic debates on the feasibility of paludiculture using cattails, but rather aimed to provide insight into the business environment, user environment, policy environment, and wider society.

Step 2: Elements of practice

Now the practice is clearly conceptualised, step 2 zooms in on the ‘elements of practices’, the first of the four components of practices as earlier stated in the theoretical framework. These elements can be appraised as the basic units of a practice-as-entities, such as the materials, meanings and competencies used or needed in the daily performance of the practice, thereby focussing on the social embeddedness in the user environment. From this perspective, step 2 aimed to understand bundles of practices and constellations of practices with the farm as the boundary (refer back to Figure 3).

To uncover such bundles and constellations, interviews were held with those directly involved in the pilot site in Helmond and the pilot site was visited once. Those directly involved in the site in Helmond consisted of one open structured interview and six semi-structured interviews. The open interview was with 5 students from the HAS University of Applied Sciences working in the field for their own research project on macro biodiversity in cattail cultivation. The other interviews were all semi-structured. These semi-interviews were the main basis of the research where the first section focused on questions related to the elements of practise. For this section the most relevant six interviews were held with the estate (1), pilot experts (3), the planter (1), and the harvester (1). However, during the research it became clear that also experiences of other pilot sites should be included in this zoomed in part of the results.

The semi-structured interviews covered the three parts of elements (materials, meanings, and competencies) while still allowing enough room for in-depth question why these elements are important. The questions were oriented towards understanding why those involved decided to engage in paludiculture, and what materials, competencies, and meanings they associate with paludiculture based on their own personal experiences. By understanding why paludiculture was adopted and works at the pilot level, it enabled a better understanding why paludiculture might clash with other practices in a different social context due to different elements. During these interviews, contact details for new interviewees (snowball sampling) were collected as explained in the following section.

Steps 3 & 4: Dimensions and interrationalities

The following steps, steps 3 and 4, started zooming-out, where the pilot site itself was still central but the focus lay on how this practice fits into its direct surroundings of practices and people. Step 3 explored the other three components of a practice, namely the temporal, spatial, and social dimension, while step 4 consisted of finding the interrationalities between and within these dimensions. This recognised that the performance of practices is context-specific and that practices are adjusted based on different context and are not self-isolated, as described in the theoretical framework (Scheurenbrand et al., 2018). As in step 2, experiences of other pilot sites were also integrated to build a stronger picture.

Two main methods were used to collect data for this section: the semi-structured interviews and the SNA. Firstly, the semi-structured interviews are the same interviews as mentioned in step 2 of which the second section consisted of questions on the temporal, spatial, and social dimensions of paludiculture. These were be held with a wide group of actors (Figure 10), including other farmers involved in paludiculture, experts, and business owners. This section aimed to understand which farmer practices are in general important for a farmer, how these are practiced over time, and how these are divided in space. At the end of this step, the constellation of the estate as well as those of the key actors could be formed, placing paludiculture in the wider context of the surrounding landscape. Due to the goal to map networks and the limited time span of the research the choice was made to use snowball sampling. Simply put, snowball sampling is the gathering of new interview contacts based on recommendations from the previous interviewee. Noy (2008) states that snowball sampling can generate a unique type of social knowledge and interactional quality by allowing actors themselves to determine who is relevant to talk to. In this case, exponential non-discriminative snowball sampling was used, meaning each interviewee was asked for multiple refers whom were all approached.

The semi-structured interviews were also the input for the interrationality between practices, which really starts to build the links between the constellations (Castelo et al., 2021). In Castelo et al. (2021) this is divided in three steps which are difficult to distinguish and introduce confusing semantics. Therefore, it was chosen to keep this as one bigger step. Overall, the formed constellations are grouped together in this step, finding the links between them and possible clashes. This aimed to reveal possible co-dependence between actors and practices, for instance sequences in which practices usually occur, shared elements between practices, or even the need to co-exist, or simply that practices usually interact (in time and space). Overall, steps 3 and 4 incorporated the factors wider society of social embeddedness.

Secondly, the social network analysis (SNA) was carried out. As described earlier, the first two maps show the entire network. To create this, the interviewee were asked to create a full list of individuals and organisations with which they had had contact with about paludiculture in the past two years. Besides visualising the full network, the SNA also aimed to provide insight into the social dimension. To do so, four specialised maps were formed by asking superlatives within the created long-list:

1. Which individuals and organisations are the most important for *knowledge-sharing* on paludiculture?
2. Which individuals and organisations are most influential in *promoting* paludiculture?

3. On which individuals and organisations is the implementation of paludiculture most *dependent*?
4. Which individuals and organisations have the most influence on the *policy environment* of paludiculture?

For each of these questions the interviewee was asked to fill in their top five individuals and/or organisations. To see the full exercise, refer to Annex A: Social network analysis exercise. In total, 12 fully filled out SNA lists were completed of which 8 had completed answers to the superlatives. However, these results did not fully encompass the total of 28 interviews. In order to make these networks complete, in particular the full network (the first two maps) the choice was made to also include their snowball contacts if they had not included them already in their list themselves. Furthermore, if the interviewee did not hand in the SNA at all, for whatever reason, the choice was made to compile their list as their snowball contacts as well as key actors named by themselves during the semi-structured interview. These choices were made consciously as drafted maps which did not take these names into consideration were not representative of the networks reflected in the semi-structured interviews and therefore not of the reality. By combining these results, it enabled a basic qualitative SNA to be carried out which could support findings of dimensions and interrationalities.

Step 5: Nexus of the network of practices

Finally, step 5 aims to identify the context of the network of practices, and thereby the nexus of practices. This explored how the network of practice is shaped and influenced by broader influences. This could consider pre-existing external arrangements, political, socio-cultural norms, economic agreements, and so on. In this research, the focus was on the policy and business environment, the first and third component of social embeddedness.

To uncover relevant policies influencing paludiculture, the semi-structured interviews were used as main input. The third and final section of the interview guide was used for this purpose. For the basic interview guide please refer to Annex C: Interview guide. In order to better understand these relevant policies, a short (grey) literature study was carried out. In this was an impression of the political landscape could be created.

The business environment is the final part in order to fully understand societal embedding. This can be understood as part of the nexus of practices as it can explain why paludiculture does or does not function independently. The results of the business environment were constructed based on the answers provided in the semi-structured interviews. Two main components of the business environment were focussed on. Firstly, the current funding and financing of paludiculture sites and its implications for future funding. And secondly, the current market for cattails products. Overall, multiple methods were used in this research including extensive semi-structured interviews based on snowball sampling, a SNA, and a short (grey) literature study.

Annex F: Abbreviations and translations of SNA maps

To simplify the SNA network images, abbreviations have been used and at times the Dutch name of the institution. For clarity, all abbreviations and Dutch labels are explained in Table 5.

Table 5. Abbreviations used in SNA network images.

Abbreviation	Full name/ English translation (ENG)
KWR	KWR Water
CConnect	Carbon Connects
Staatsbosbeheer	ENG: State forest management
KLIMAP	Climate Adaptation in Practice project
Stichting Bargerveen	Foundation Bargerveen
LANDMARC	Land Use Based Mitigation for Resilient Climate Pathways
ORG-ID	ORG-ID consultancy
Deelexpeditie natte teelten	ENG: Partial Expedition Wet Cultivation
Stichting Waterplanten	ENG: Foundation Water Plants
HAS	HAS University of Applied Sciences
Van Hall Larenstein	Van Hall Larenstein University of Applied Sciences
Wout van der Belt	Individual reed grower
KTC Zegveld	Kennis Transfer Centrum Zegveld (ENG: Knowledge Transfer Centre Zegveld)
ZLTO	Zuidelijke Land- en Tuinbouworganisatie (ENG: The Southern Agriculture and Horticulture Organisation)
Brabantse Milieu Federatie	ENG: Brabantse Environment Federation
Netwerk Goed Boeren	ENG: Network Good Farming
LNV	Ministerie van Landbouw, Natuur, en Voedselkwaliteit (ENG: Ministry of Agriculture, Nature and Food Quality)
WUR	Wageningen University & Research
Natuurmonumenten	ENG: Dutch Society for Nature Conservation
ILVO	Instituut voor Landbouw-, Visserij- en Voedingsonderzoek (ENG: Flanders Research Institute for Agriculture, Fisheries and Food)
VIC	Veenweiden Innovatiecentrum (ENG: peat meadow innovation centre)
Landschap Noord-Holland	ENG: Landschap North-Holland
I&W	Ministerie van Infrastructuur en Waterstaat (ENG: Ministry of Infrastructure and Water Management)
Brabants Landschap	ENG: Landscape of Brabant
EZK	Ministerie van Economische Zaken en Klimaat (ENG: Ministry of Economic Affairs and Climate Policy)
SZW	Ministerie Sociale Zaken en Werkgelegenheid (ENG: Ministry of Social Affairs and Employment)
Land van Ons	ENG: Land of ours
Groen Ontwikkelfonds Brabant	ENG: Green development fund Brabant
Nederlandse Landgoederen	ENG: Dutch Estates
De Rijksbouwmeesters	ENG: Government architects
Nationaal Kennisprogramma Bodemdaling	ENG: National Soil Subsidence Knowledge Programme

Innovatie Programma Veen	ENG: Peat Innovation Programme
Collectief De Noardlike Fryske Walden	ENG: Collective De Noardlike Fryske Walden
B-Ware	Research centre B-Ware
Friese Milieu Federatie	ENG: Frisian environmental federation
Kenniswerkplaats Noordoost Fryslân	ENG: Knowledge workshop Northeast Fryslan
LTO Noord	Land- en Tuinbouworganisatie Noord (ENG: The Northern Agricultural and Horticultural Organisation Netherlands)
NOBV	Nationaal Onderzoeksprogramma Broeikasgassen Veenweiden (ENG: National Research Program Greenhouse Gases Peat Pastures)
STOWA	STOWA (ENG: Foundation for Applied Research on Water Management)

Annex G: Purposes of paludiculture explained

As discussed, the terms paludiculture and wet cultivation are frequently used interchangeable, leading to confusion as to what the purpose is of the practice. Not only is this relevant to clarify before larger scale implementation of a practice, but even at pilot level this should be defined clearly. During the interviews it became apparent that different actors had different primary goals for paludiculture. These goals included reduction of carbon emissions, reducing land subsidence, agricultural production of a crop (in this case cattails), water storage for peak discharge and/or groundwater restoration, improving water quality, and biodiversity.

Land subsidence & greenhouse gases

Firstly, when peatlands are drained the organic material will decompose due to oxidation resulting in land subsidence and the release of carbon dioxide (CO2). A way to prevent both is by re-wetting peatlands, thereby storing carbon and halting land subsidence (Joosten et al., 2012). This is significant as peatlands contain large amounts of carbon. For comparison, peatlands contain more than twice the carbon stored in all forests, despite covering only 3% of land globally (De La Haye et al., 2021). Yet, many peatlands are drained or damaged, currently emitting more CO2 than shipping & aviation combined (De La Haye et al., 2021). In the Paris climate agreement, adopted at the Paris climate conference (COP21) in December 2015, agreed on the need to limit the global average temperature increase to 1.5°C above pre-industrial levels, thereby increasing the pressure to mitigate GHG including CO2 (United Nations, 2015). The EU and its Member States, including the Netherlands, must work together to achieve this goal.

Land subsidence is also a mayor issue for the Netherlands, especially in the peat meadow area, also known as fenlands, of the Netherlands (Dutch: veenweidegebied). This includes a large part of the province North-Holland, the West of Utrecht, Friesland, and the head of Overijssel (Renes, 2012). In these areas the rate of land subsidence is high as shown in Figure 19 (Platform Slappe Bodem, 2021). This is causing mayor issues related to biodiversity, soil quality and water quality, and thus resulting in extensive economic damages presently and in the future (Raad voor de leefomgeving en infrastructuur, 2020).

CO2 reduction and land subsidence are often linked to each other as common goals of paludiculture which can exist side by side. However, Westerhof nuances this due to the fact methane must also be considered in the GHG balance.

> *''(Water levels) at 20 cm below ground level your CO2 emissions are the lowest and your methane emissions are not yet very high. Water levels at 20 cm below ground level also can seriously reduce subsidence but to completely stop subsidence, you have to flood it. With the risk of increasing methane emissions and you also have to talk about other land uses and another landscape.'' – Int. Roelof Westerhof*

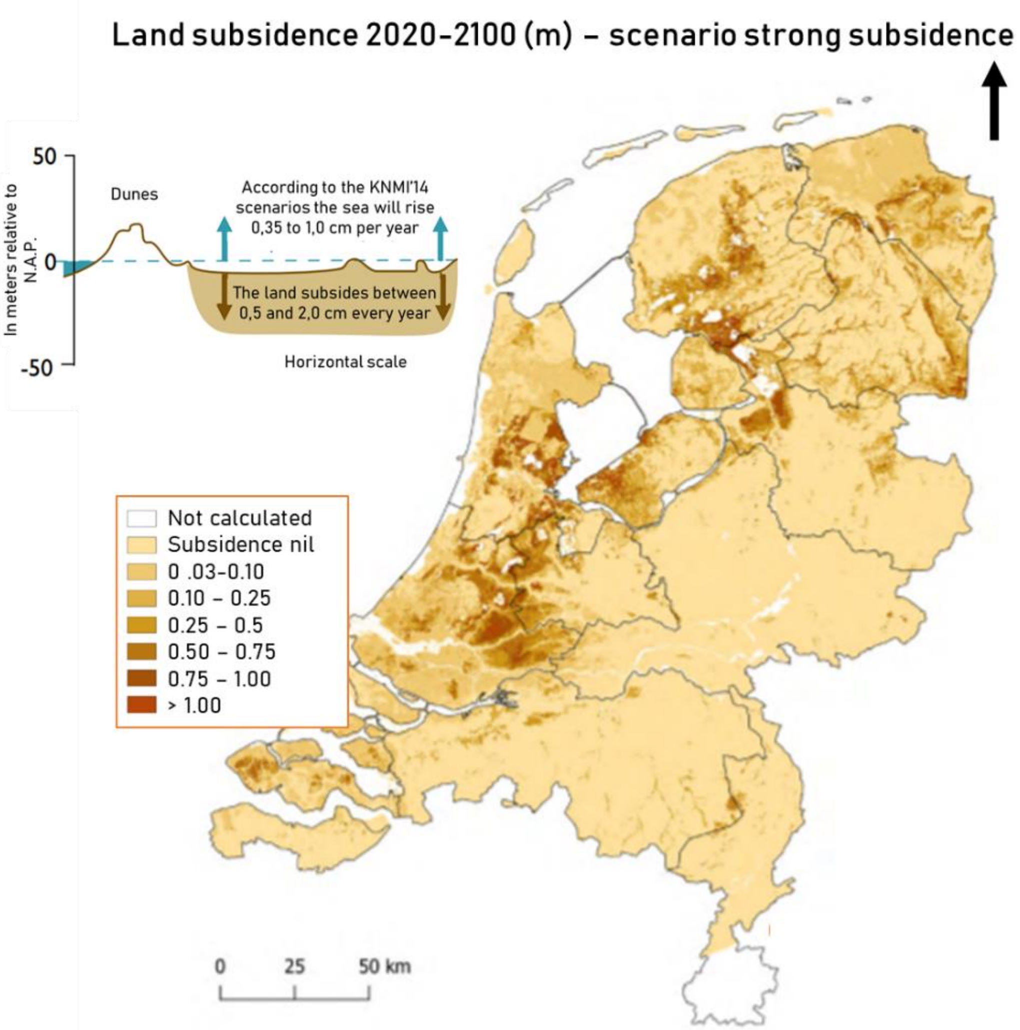

Figure 19. Expected land subsidence 2020-2100 in meters in strong subsidence scenario. N.A.P. refers to 'Normaal Amsterdams Peil' (ENG: Amsterdam Ordanance Datum) used to define the height above sea level.

Essentially, if we accept that cattail cultivation conditions usually consist of water levels at or above ground level, this means that the main purpose is land subsidence, not mitigation of GHG. As if the main goal is to mitigate GHG, the ideal water level is at 20 cm below ground level (Wichtmann et al., 2016). This as the more aggressive GHG methane then becomes an issue if peat is fully submerged in water (Int. Suleiman). However, this balance differs with other types of paludiculture crops such as reed, peat moss and alder trees (Fritz, Lamers, Dijk, Smolders, & Joosten, 2014). The final call has not been made whether this trade of is worth it, but research is still being carried out on the effect of paludiculture on the overall GHG balance (NOBV, 2021). LANDMARC, one of the other projects using the Estate Groot Overbrugge as pilot site, is currently researching how this methane balance works in practice.

> *''In paludiculture, the aim is to avoid CO2 emissions, however at the same time we should be certain about the CH4 (methane) emission as this gas is considered more aggressive to the environment.'' – Int. Afnan Suleiman*

Overall, this means that the goals to halt land subsidence and GHG emissions might not go hand in hand after all. Therefore, when implementing paludiculture one should be aware of the negative effects it might have on climate mitigation. This again leads to confusion in the purpose and therefore the meaning of paludiculture. If we relate this to the previous chapter, one could relate both wet cultivation and paludiculture to land subsidence and C02 reduction. If land is flooded and then used for production then it can be appraised as wet cultivation, yet if it is then kept as natural peatlands as paludiculture. If the GHG balance is at its most beneficial for climate mitigation at 20cm below ground level then again it could be stated as paludiculture, or as production if a different paludiculture crop can be cultivated at this water level. However, for cattails it is already quite clear that land subsidence and CO_2 cannot go hand in hand because of the need for the water level to be higher for production to be optimal and therefore making methane an issue. This shows that even the current definitions of paludiculture are incomplete to the complexity of the purposes.

If the conclusion is that submerging land is necessary for whatever reasons named above, then the question of what can still be done on soaked land arises. This is where the purpose of agricultural production starts. For some, re-wetting is appraised as something that must happen even against the will of the commons. For example, raising the water level will mean grassland will be too wet for grazing livestock and the grass will not survive these conditions (Int. Egas). Thus, this means paludiculture as wet cultivation is often meant as an alternative to land which can no longer be used for its original purpose. At this point, paludiculture is understood as something you can still do with the land even in submerged conditions to still produce something of material value. In this case, one would assume it would then be discussed under the term wet cultivation.

It is important to note that the main starting purpose of the pilot site in Helmond was carbon storage. CConnect is one such project aiming to reduce high emissions from traditional agricultural practices on drained peatlands, which is also the party which started the pilot site on the Estate Groot Overbrugge (De La Haye et al., 2021). However, due to its location in a stream valley the land subsidence discussion is less prominent compared to the peat meadows of the Netherlands. This difference in spatial factors will be elaborated further upon in 5.3.2. Spatial dimension.

Climate adaptation of the water management system

Another purpose mentioned, often in the stream valley context, is the climate adaptation of the water management system. This purpose is less prominently mentioned and often snowed under by the first named purposes land subsidence and CO_2 retention.

> *''There is not enough attention for it (climate adaptive properties of paludiculture), especially in high laying peat areas and stream valleys, because in low peat meadows CO_2 retention is more obvious.'' – Int. Walter Schoenmakers*
>
> *''I often run into the fact that it is only about (land) subsidence.''- Int. Ivan Mettrop*

KLIMAP joined itself to the pilot site in Helmond to explore the possibilities of climate adaptation for recharging groundwater levels and allowing for inundation of the plot in moments of peak discharge (Int. de Graaf). This became apparent in an interview with the project coordinator of KLIMAP, de Graaf.

> *'' The area of high sandy soils is the area where you have to 'hold up your own pants'. The importance of conserving (water) is much higher there, to hold onto a big rain shower, than in lower areas. You can expect inundations in relative lows like stream valleys, but how do you manage it? Discharging or taking it as an opportunity? Therefore (the pilot) fits in completely with KLIMAP's objectives.'' – Int. Myrjam de Graaf*

De Graaf refers to sandy soils having to 'hold up of their own pants', referring to the regional groundwater level and the experienced drought for the past years. Therefore, there is a necessity to capture and store water locally in these areas before it discharges to large waterways and lost to the sea. Paludiculture is a potential way to allow for slow and effective infiltration of discharge into the groundwater. Van Duinen, the main initiator of the pilot in Helmond confirms this and explains how this is related to peak rainfall, thereby also reducing potential flooding.

''It is also possible to retain water in this area instead of draining it quickly after a peak rainfall. After a peak there are long dry periods. This way you can retain water even during dry periods. Keeping your stream valley wet is also good for your high sandy soil, because the groundwater level in the area is higher. … It is also interesting for peak discharge to lead it somewhere if you have a crop that can handle that (being submerged underwater)''– Int. Gert-Jan van Duinen

Wichmann adds that paludiculture on a larger scale could also have a cooling effect, thereby also contributing to climate adaptation (Int. Neubert & Wichmann).

Overall, this shows that the nature of paludiculture, especially cattails which are inundated almost all year round, also lends themselves as a potential basin. However, very specific spatial conditions must apply for this to also be a purpose of paludiculture as the subsoil of the plot must be permeable and allow for groundwater recharge. Since this is sand for the pilot in Helmond, this is the case here (Int. Geurts). If the initial plan was to submerge the land for this purpose, then again paludiculture can be understood as something you can still do with the land even in submerged conditions to still produce something of material value, similar to land subsidence of CO2 storage. In this case, one would again assume the term wet cultivation. This contradicts the natural purpose to restore groundwater levels which can be more closely related to the restoration of peatland environments which should then we termed paludiculture. Again, the real-life complexity is not reflected in the definitions of the terms.

What was noticeable was that some experts involved in paludiculture were not aware of the potential purpose to contribute to the climate adaptation agenda (Int. Mettrop; Int. Elshof). This shows that the purpose of the same practice can be significantly different depending on what actor is spoken to and that this particular purpose is not as recognised by the wider research community.

Ecological connection zones

Another purpose proposed for paludiculture is using it as ecological connection zones between agricultural land and nature. This is particularly interesting as there is a movement to also increase groundwater levels in nature areas (Int. Weerman). This directly impacts the direct neighbours to these nature areas, which is often agricultural land (Int. Schoenmakers). Any agricultural land directly bordering nature might become too wet to continue current activities, thereby forcing farmers to consider an alternative type of production (Int. Osinga). A particular pilot of which the main purpose was this was the Peel located in Northeast Brabant.

"It is increasingly recognised that the ring around a forest or nature reserve is important. Many wells have been drilled at the Peel (by farmers), so the Peel is emptying. So, you would also like to have a higher water level around it. So paludiculture has potential in the fringe areas.'' – Int. Walter Schoenmakers

Therefore, paludiculture is also appraised as a way to protect nature areas in which water levels must be increased.

Biodiversity

An additional effect of paludiculture which is sometimes taken as a smaller additional purpose is increasing biodiversity. There is ongoing research whether paludiculture significantly increases biodiversity due to the fact it introduces a wet landscape into an otherwise dry landscape (Int. HAS students). Van Duinen explains this clearly:

''In this area (biodiversity in paludiculture) we have projects underway at the HAS with student groups and also ourselves (Stichting Bargerveen). With us its mainly student projects. For example, a WUR student at the VICC and Interreg projects CConnect and Better Wetter sites researching biodiversity in cattail sites and reference sites. Biodiversity is different in a drained

landscape. In a wetter landscape there are always other things, for example more coots, ducks, and dragonflies. On a landscape scale, it always adds something to add new land uses.'' – Int. Gert-Jan van Duinen

Currently, this is not the main purpose of projects and pilot sites, but it is interesting to see what the results of the current research the HAS students will be (Koper et al., 2021). Weerman expects that it will have a positive impact on the insect biodiversity due to the fact many insects have an aquatic phase (Int. Weerman).

Water quality

Because cattails are *helophytes,* they have a natural ability to biologically filter water and remove nitrates and thereby reduce eutrophication (Int. Neubert & Wichmann). This means cattails have a beneficial effect for the water quality. In most pilots, this is not the main reasons why cattails are chosen and rather come as an additional benefit. However, there are a few examples of pilots conducted by water board de Dommel which selected cattails specifically for this ability including Soerendonk (Int. Balkema).

''For water board De Dommel, paludiculture can be used for biological filtering and water retention and wet crops because there are less peat soils than in i.e. the Peel region managed by water board Aa and Maas. In de Dommel region peat soils are in the brook valleys.'' – Int. Gert-Jan van Duinen

Annex H: Values analysis of pilot users

In this annex, the quotes used to deduce the values requires of pilot users are highlighted and analysed. For this, quotes of the Estate Groot Overbrugge, Kemp, and Wichmann and Neubert are used.

For the Estate Groot Overbrugge there were two main motivators:

> *''Two ingredients, owning the plot, and being motivated to invest in an unknown piece of development.'' – Int. Estate Groot Overbrugge*

This shows the combination of and having a suitable plot, a material necessity, and connecting value to development of a new innovation. All three parties have this common characteristic of valuing research development. This is apparent in the fact that they had all been involved in some form of research project before paludiculture. Wichmann confirms this in the following statement:

> *'' The main reason why the farmer joined in in the project was because he had been involved in previous projects with Greifswald University and a trustful cooperation had been established over many years. I had also worked with him before. His own conviction of wanting to do something good and his awareness of the carbon issue also meant he was aware of why this project was important to carry out. Also, he is a religious man who wants to preserve God's creation.'' – Int. Sabine Wichmann*

This quote also suggests that trust can be an important factor to agree to such a research cooperation. Furthermore, it also reflects the will to contribute to something good in relation to carbon storage and protect wider society, a goal connected to the religious background of the farmer involved. Therefore, it is not only the need to understand the problem, but also seeing the value investing in a possible solution which can contribute to society. Kemp confirms his own curiosity in cattails and his own motivation to agree to the project on his land:

> *''There is a lot of talk about it (paludiculture with cattails) and wanted to try it myself. All scientists agree that cattail is the only crop that is possible for the future and also contributes to a new peat layer. … I have 100 ha (for livestock) of which 1 ha is cattails. It's more of a hobby project. It is especially real to learn from it.'' – Int. Wilco Kemp*

Again, this statement indicates the value held to the opinion of scientists and his own motivation to give it a try himself. Furthermore, Kemp values cattails as an additional crop to do besides his livestock. The statement also clearly reflects the fact it is a hobby project and not the main form of livelihood. It is important to note that this is the case for all three parties involved in cattail cultivation. Therefore, it is an additional project next to their usual practice which does not take up significant time compared to their other activities. These factors are discussed more in depth in 5.3. Dimensions.

Annex I: Materials of cattail cultivation explained

In this annex, the supporting quotes and explanation of conclusions are given concerning the materials needed for cattail cultivation. This is an extended version of the results chapter.

Preparation of the field

Before being able to start planting or sowing the seeds, the field needs to be prepared for paludiculture. This includes selection of the field, creation a suitable water management method, levelling the plot, and preparing the water level for planting.

Selecting a suitable location is an essential part of the process due to the necessity of regulating water levels throughout the year. This means that there must be an available source of water and that it is an area which is naturally already quite wet, for instance due to a low position in the landscape.

> *''That it stays wet easily and that you get it wet easily is the most important.''- Int. Christian Fritz*

To access this water, permission must be asked from the water board in order to draw water from a water way (Int. Geurts; Int. van Lamoen; Int. Neubert & Wichmann). Furthermore, it might require permission from the city government in order to comply with other rules and regulations such as spatial planning (Int. van Lamoen). Additionally, the soil must be peat in order for it to be called paludiculture in the definition of this research. In general, this means the location must be in peat meadows or close to the stream valley where peat soils can also be found (Int. Geurts).

Once the location is selected it requires adaptation in order to allow for water management suitable for paludiculture. In general, a basin is created by levelling the field and building small dikes around the field in order to pond water (Int. Kemp; Int. Neubert & Wichmann). Levelling the field is important, as a slope could mean a dry patch could form due to water ponding on one side. This would decrease the yield of the cattails. Therefore, the water level should be equal throughout the plot. The field is levelled by using diggers. The plot can be divided into separate 'ploughing boxes', allowing for more independent water management between them (Int. Kemp). Once these conditions are created, the dikes and ditches can be created around the flattened plot in order to minimize the effect of the raised water level on neighbouring (grass) land (Int. Kemp; Int. Neubert & Wichmann).

A pump is then used to increase water levels. Due to the remote location of the plots and lack of electrical supply, most pilot sites use solar panels to power the pumps (Int. HAS students; Int. Kemp; Int. Neubert & Wichmann). The pumps are combined with a method to check the water level of the plot. This is possible using a gauging rod and reading it manually or by using a remote system (Int. Geurts; Int. Verboom). The remote system can be operated off-location and can regulate the water level independently, including remote operation of the pumping system (Int. Neuberts & Wichmann).

In Helmond, unique conditions apply due to the use of a sub-irrigation system (Int. Geurts; Int Van Duinen; Int. Estate Groot Overbrugge). The research found no other pilot site which uses this irrigation technique. Van Duinen explains why this system was chosen in Helmond:

> *''The plot has a sub-irrigation system. This was done from the rationale of the Boer Bier Water project so that water is also available at a dry moment (due to water withdrawal ban). It is true that Promeco and Emonds Group carried out this as they were also involved in the Boer Bier Water project and the design of other locations in the area with sub-irrigation. In principle, the system would work, only after planting, we pumped the water into the field because the sub-irrigation system was too slow.'' – Int. Gert-Jan van Duinen*

Van Duinen explains that the sub-irrigation system was chosen due to the area already being involved in sub-irrigation systems from the already running project Boer Bier Water. This project aimed to find ways for farmers to continue irrigation even when there is a water withdrawal ban for agriculture due to dry conditions (Int. Junggeburth). When it is dry, agricultural no longer is a priority and are one of the first actors to suffer (Beleidstafel Droogte, 2019). Therefore, there were worries that when there is a temporary withdrawal ban that the cattails would become too dry and suffer losses. By using sub-irrigation, plants are watered from below instead of above thereby conserving water. This is done by running pipes under the soil. Therefore, before levelling the field the system must be installed underground. It is important to note that van Duinen indicates that the sub-irrigation pump was too slow to bring the water up to the necessary level right after the planting. Therefore, an additional surface pump was used at the start of the process (Int. van Duinen).

The Estate Groot Overbrugge confirms that the use of sub-irrigation was a major condition in order for them to agree to the project. This as the chance of success had to be made as high as possible (Int. Estate Groot Overbrugge). An additional point motivating the implementation of a sub-irrigation system was their own familiarity with sub-irrigation systems due to their own involvement in Boer Bier Water. The design of the system was carried out by the engineering bureau Promeco, the same contractors as the project Boer Bier Water.

The final point of preparation before planting is allowing for the water level to be raised just above ground level. Visscher described what he believes are the best conditions for planting:

> *''Conditions are best if you just have flat grass with a layer of water that is a bit fatty. A little nourishment in the ground. The poorer the ground, the harder the start is.''- Int. Julian Visscher*

Therefore, a flat surface with grass, a layer of water, and a nutrient sufficient soil are also essential points to consider when starting paludiculture. Often the selection and preparation phase of the field suffers from significant delays. The reasons for such delays are described in 5.3.1. Temporal dimension. Overall, the preparation is dependent on the type of water management system selected, whether traditional surface irrigation or sub-irrigation. But both are beneficial in naturally wet areas, require a level ground to start with, and need water ponded to start planting.

Planting

There are multiple ways to start cattail cultivation of which the most common is the use of seeds and plugs. In both cases, a layer of water must already be on the field (Int. Visscher). Seeds are taken from the cigar of the cattails which in natural conditions is spread through the wind (Int. Egas). In natural conditions, many of these seeds never develop into plants, but because of the sheer volume of seeds still some will succeed. Egas compares this to Russian roulette as there is little clarity which will germinate, and which do not (Int. Egas).

Plugs are cultivated in greenhouses by growers on request with seeds that already have been sprouted in controlled conditions (Int. Visscher). These plugs are usually between 15 to 20 cm tall when planted directly into the soil (Int. Koot). Kemp stated that for 1 ha, about 50.000 plugs are necessary (Int. Kemp). In Helmond, plugs were the main method of planting followed with some substitutional seeds. The main reason for this was stated by the Estate Groot Overbrugge.

> *''Sowing is still in development so now everything is planting... There was also a bad story from Staatsbosbeheer of the Peel. There it failed twice. Yes, sorry you can make a mistake for 1 year but 2... If you want to get people 'over the dam' (on board) then you will not get it done that way. … We have (also) sown a lot, Jeroen (Geurts) threw in some more and it did well'' – int. Estate Groot Overbrugge*

The quote shows that the main reason to use plugs was to increase the chance of success. For the Estate Groot Overbrugge one of the main conditions to agree to the pilot site on their property was to make the chance of success as large as possible, meaning that risks had to be limited at every point in the cultivation, including planting (Int. Estate Groot Overbrugge). They were discouraged to use only seeds due to examples of other pilot sites failing to sow successfully. One such example was of the pilot in Ankerveen which is being carried out on the property of Kemp, a dairy farmer working together with Waternet.

> *''… but the seeds were not soaked well, and all blew to 1 corner. Well then you now know that if you want to start sowing, they must be really well soaked. Otherwise, they will not sink to the bottom. But it is also a pilot for that, it can also go wrong.'' – Int. Wilco Kemp*

Due to wind and the light weight of the seeds they easily drift to a corner of the field, meaning they are not well dispersed across the allotted space (Int. Wellink). Already Kemp mentions the fact the seeds must be heavily soaked in order to sink and thereby reduce the chance of them floating on top of the water, but there are many more conditions which must be met. The company Gebr. Visscher are known for their work with nature-friendly banks and helophytes and were hired by CConnect to acquire the pugs and plant them at the Estate Groot Overbrugge. Visscher, the owner of Gebr. Visscher, confirmed in his interview many additional complex conditions in his own experiences with cattails.

> *''Sowing is very difficult; the conditions have to be right for that. … The temperature, humidity, the water level, something almost always goes wrong.'' – Int. Julian Visscher*

Visscher confirms the higher risk of sowing by refer to many unpredictable weather conditions which must also be right. As a result, many pilots have used plugs provided by multiple suppliers and planters, of which Gebr. Visscher are just one. The Gebr. Visscher were also used by the project Better Wetter as suppliers and planters and Water board de Dommel used Koot of Stichting Waterplant (Int. Balkema; Int. Mettrop). The suppliers of the plugs either grow or acquire them from other planters.

> *''We use different parties for the plugs. For small quantities I take some from another breeder and otherwise you have to ask, and it has to be specially grown. If I think about it, we must have put thousands (of plugs) in it (the pilot site in Helmond).'' – Int. Julian Visscher*

This quote shows that for Helmond, the plugs had to be specially grown beforehand at a number of different suppliers in order to acquire the large number of plugs necessary for the 1 ha. Visscher later clarifies that this number is not so large in his experience, but rather that it is simply not being produced at that scale at the moment by any single supplier (Int. Visscher). This reflects the current niche that cattail cultivation is at the moment.

However, there are a few successful examples of sowing when the conditions are right and when the water level is managed precisely. Mettrop explained that in a number of the pilot sites of Better Wetter the cigars of the cattails were pushed into the soggy ground with a low water level, so the seeds are submerged but do not drift on top on the water and then gradually increase the water level (Int. Mettrop). This gave the most promising results for sowing. They are still planning on testing with previously soaked seed, for instance by dunking the cigars in a bucket for several days. This suggests that there is potential for sowing to work in the future if research finds a way to deal work with all difficult conditions. However, it is important to note that if seeds are used, one cannot harvest in the first year (Int. Mettrop).

On the other hand, there are clear reasons to opt for sowing instead of plugs. Firstly, the seeds have a much lower costs than the plugs. The details of this are elaborated upon in the heading F. Secondly, it requires a significantly lower labour input. For plugs, each must be planted directly into the soil which is often still done manually due to the lack of machinery. This will be elaborate upon further in Machinery & equipment. Seeds are also very useful for filling up bare patches in existing cattail plots. As stated earlier, Helmond used seeds after the initial plugs had been placed. The planting took place in the autumn and the extra planting of some additional plugs and sowing of seeds in the spring of the following year (Int. van Duinen). Additional seeds were also sown more recently by Jeroen Geurts, researcher at KWR and also closely involved in this pilot site, to fill up patches (Int. Geurts). The Estate Groot Overbrugge confirmed adding additional seeds was successful and an effective way of filling up patches in between already adult cattails (Int. Estate Groot Overbrugge). Therefore, it is always useful to consider seeds even if plugs are the initial starting phase of the plot. For an overview of the factors of plugs or seeds refer to Table 2.

Table 2. Comparison of plugs and seeds

Factors	Seeds	Plugs
Costs	low	high
Labour needed	low	high
Chance of geese feeding	medium	high
Chance of successful production	low – medium (depending on weather and water level conditions)	high
Possible to harvest in first year	no	yes

An issue both forms of planting suffer from, especially the plugs, is the risk of the young shoots being eaten by geese (Int. Geurts; Int. Mettrop; Int. Schoenmakers). The pilot site mentioned in the first quote, the Peel is one of the most frequently mentioned less successful examples of a cattails pilot site (Int. van Duinen; Int. Estate Groot Overbrugge; Int. Fritz; Int. Schoenmakers). In this case, the goal was to find alternatives next to wet nature areas. However, the site failed to thrive two years in a row due to geese eating the young shoots. This was also the case in the pilot site with cattails in Scheiendsven (Int. Balkema). A method of planting which does not suffer from geese is the use of the use of rhizomes or roots of the cattail because of the woody structure (Int. Mettrop). Mettrop explained how some pilot sites of Better Wetter used this method and how they were able to acquire the rhizomes:

> *You cut off mature plants and plant them. This is labor intensive. But then not 1 shoot grows but 4 or 5. It will then grow like cabbage, and you can harvest the first year. You already have a lot of energy in the rhizomes. ... But we excavated it all from nature reserves, we did that ourselves with students. At the time, that was only possible because we had students (from Radboud) who helped. The nice thing about it is there is much less (weeds). – Int. Ivan Mettrop*

Mettrop explains that this method is highly effective against geese, had less weed competition, and has a high guarantee of successful growth with instantly high production compared to plugs and seeds due to the high amount of energy already stored in the root. Yet, in this case it was possible to free labour availability and the allowance of removing it from a nature reserve. In general, access to nature reserves and especially the removal of cattail material proves difficult in most cases and is not allowed (Deelexpeditie Natte Teelten, 2020). Therefore, despite the potential in this method, the availability of the roots and the labour intensiveness of it prove difficult.

Overall, research must still continue to explore the best method of planting, but three potential methods have been used. In Helmond, plugs were the main method of planting with substitutional seeds to fill bare patches, a trend other sites have also explored. It is important to note that cattails are a pioneer plant, meaning it often is the first to spread quickly in an area. This means, once the first are settled, it will usually spread with little difficulty. However, this characteristic also means cattails are not a strong perennial crop with the same biomass after a number of years. This factor will be addressed further in 5.3.1. Temporal dimension.

Field management

Once the plot has been prepared and planted, little field management is needed to maintain the cattails (Int. Geurts). Most important is to check the water level daily (Int. Estate Groot Overbrugge; Int. Kemp; Int. Neuberts & Wichmann; Int. Verboom). This should be between 10 and 30 cm above ground where the plant is not fully submerged (Deelexpeditie Natte Teelten, 2020). The large *Typha* generally prefers a lower water level between 20 to 30 cm, while the small are naturally found between 30 and 50 cm (Int. Koot). Egas adds that the small cattails cope better with water fluctuations, which could be more beneficial if the intended purpose of cattails in climate adaptation.

> *''We have used large cattail from the beginning. But it is best to plant small and large cattails when there is 15 to 20 cm (water level) on the field. The large cattails are more of a pioneer. We looked at drought of -20cm and then put it full to 5cm. If you do this, the large cattails will be completely gone after 3 years, but there some of the small cattails still stay. So, if you have flexible (water) conditions, the small cattails are always better.''- Int. Youri Egas*

Geurts explains that the water level is controlled with a remote sensing system to check the level from home by the Estate Groot Overbrugge. This same system was also recommended and used by the Greifswald pilot plot (Int. Neubert & Wichmann). However, in that case a paid worker is used to carry out management activities, not the farmer himself.

> *''A local farmer (not the same as the landowner) is paid by the pilot to conduct management activities, including mowing the causeway and checking the water level.''– Int. Sabine Wichmann*

Therefore, mowing the causeway and dikes can also be part of management activities. Verboom, who also coordinates a cattail site for the company Bouwgroep Dijkstra Draisma, also adds that he checks the outlets and ditches are free of dead plant material. This is an activity he does when checking the plot every morning to check the water level. Another part of field management is continuing to check the lines spun to prevent geese landing in the plot as described in the previous chapter (Int. Geurts). A possible issue in field management is if the plot loses its flatness as described by van Duinen in Helmond:

> *''When it was delivered the ground level was flat and smooth but some of the land has clumped or swollen since then. There were also weeds because the top layer was still present and not dead, so weeds started to grow again from the remaining roots. … (To improve the density of the field) A few extra plants were added in the spring by the Gebr. Visscher and part of the cattails was sown extra in the bad part. The water level has also been raised. In the middle (of the plot) is the highest part, there the water is about ground level.'' – Int. Gert-Jan van Duinen*

Therefore, despite levelling the ground before planting, the ground became bumpy causing parts to fall dry and fail the grow. These parts needed additional plugs and additional sowing to improve the density of the field. This also required a general increase in water level in order to keep the centre of the plot still sufficiently wet. Therefore, field management concerns checking if the whole plot is still receiving sufficient water and not only the outer edges which are visible. To level the field is very difficult once it is fully cultivated (Int. van Duinen).

Fertiliser application is not part of field management because fertilisation is not permitted on wet soils or elevated water levels. This could become an issue if the cattails suffer from nutrient deficiency. This will be elaborated upon in 5.3.1. Temporal dimension. Overall, field management is largely limited to management of the water level with possible maintenance of ditches, crossways, and possible extra planting or sowing if necessary.

Machinery & equipment

The machinery and equipment needed for paludiculture is different to grassland or other agricultural production (Int. de Graaf). This can be explained by the combination of above ground water levels and the introduction of plants which have never been cultivated before as crops. For example, cattails are cultivated between 10 to 30 cm and is a pioneer usually found in nature areas, not as a crops to produce biomass (Deelexpeditie Natte Teelten, 2020).

As stated in the previous chapter, creating a suitable water management system requires large scale equipment such as diggers to level the field or build dikes or even pipes to build a sub-irrigation system (Int. Geurts). Furthermore, the system requires a pump and a manner to power the pump, mostly done will solar energy (Int. HAS students; Int. Neubert & Wichmann). Moreover, a method is necessary to measure the water level, for instance with a gauging rod or with a remote sensing system. And to deter geese from feeding on the cattails, lines must be spun between poles to partially cover the field (Int. Egas; Int. Geurts). In all these activities, the relative equipment is necessary to carry out paludiculture.

Apart from the necessary equipment, some machinery has already been developed for paludiculture, particularly for harvesting cattails. For planting, most sites are still carried out by hand, manually inserting each plug individually into the soil (Int. Koot; Int. Visscher). However, there have been some creative solutions to try to speed up the process. The use of a strawberry planter has been used in a number of pilot sites, including a site in Vinkerveen (Int. Egas).

> *''Planting is sometimes done with an old strawberry plant... In North Holland I even saw two men laying behind a tractor planting. That doesn't help, it's fine for a test field, but it's not going to work professionally.'' – Int. Robert Wellink*

Wellink confirms the use of a strawberry plant and also describes a situation with two men hanging on the back of the tractor to put in the plugs. Both methods are not 'professional' and efficient ways of planting the plugs. Wichmann elaborates on this in their own field site, which trumps the other sites in size.

> *'' 'Because of the larger size of the site and because planted seedlings need watering within a certain time, manual labour to plant the Typha was too time intensive. So, we used the alternative technology of mechanised tree planting. This worked reasonably well but almost 10 ha still took 4,5 days. This needs to be made more efficient.'' – Int. Sabine Wichmann*

In this case, the larger size of the plot already meant that mechanisation was necessary, but still using tree planting machinery cost a significant amount of time. Overall, this shows that there still is not an efficient and tailored planting machine for cattails.

To harvest the cattails there have also been examples of creative solutions prior to the development of tailored machinery. Kemp explains that the one time they have harvested they used an ice re-surfacer with a chopper in front (Int. Kemp).

> *''One load was unloaded with a lot of weeds with 2 to 3 meters long cattails. A lot of cattails ended up in the garbage and a lot of snow and plant remains.''- Int. Wilco Kemp*

This quote suggests that this method of harvesting was not very successful, resulting in a loss of biomass and gathering of additional unnecessary mass including snow and weeds. Another complexity in harvesting cattails is the consistency of the soil. Even if water is drained, the soil is wet and fragile.

> *''The ground is not strong. A machine must have very wide tracks and be lightly built.'' – Int. Wilco Kemp*

Therefore, there is a high risk of damaging the soil and biomass. In Zegveld, Egas described how their harvest attempts suffered from several problems.

> *''As soon as you enter the field with a machine, you destroy everything. You break the plant underwater. ... We tried different harvesting methods. You have to do it from the side. With a crane and a mowing kart, it came 6 or 7 meters into the field (most plots 10 by 10 meters). But some points are 30 meters wide, so you can't get to the middle. I did the middle part by hand, but that is not really the point either.'' – Int. Youri Egas*

Multiple issues are seen in these experiences. In the first experience using a heavy machine, which was compared to a tank by Fritz, caused the cattails to be broken underwater, thereby allowing water into the stems which causes rotting from the inside out (Int. Fritz). This is an issue for re-growth of the plant, thereby effecting the biomass for the following harvest. The second experience aimed to harvest from the side of the field in order to prevent machines on land. This was motivated by the negative previous experience and by the deteriorating strength of the weak sod caused by weak rooting of the cattails.

> *''The bottom is really too soft for us (In Zegveld). It is really peat. But the bottom has softened. At first you have a grass sod, but you lose it when it becomes that wet and then it becomes a kind of swamp. The large cattails have very weak roots, and you sink through them. It doesn't become land either. The small cattails seem to be a bit firmer.'' – Int. Youri Egas*

Therefore, due to the breakdown of the original grass sod and lack of strong roots, it makes its extra challenging to support machinery on the plot. The weak roots are also confirmed by van de Belt and adds that cattails also do not intertwine their roots with other plants contrary to reed (Int. van de Belt). Additionally, cattails roots to not branch out as far and deep as reed, again not creating a strong platform for machinery (Int. van de Belt). These issues are seen in very peat dominated soils in particular. Kemp explains this is less of an issue on his own plot since the soil there is also part sand (Int. Kemp). Fritz also speculated that Zegveld suffers from bad rooting due to the area being fertilised expensively in the past (Int. Fritz). Therefore, this could be a local issue. Overall, this challenge pushed the pilot in Zegveld to try a different method by harvesting at the side of the plot using a crane and a mowing cart (Int. Egas). However, this was effective to protect the plants and soil, but did include manual labour as Egas had to harvest the middle of the plot by hand.

Based on these previous experiences, it is clear that non-tailored machines are unsuccessful in harvesting cattails, especially at scale (Int. Fritz). Now, tailored machines have been developed by Wellink Equipment in cooperation with Wetland Products and are continuously being improved (Int. Wellink). These machines are adapted to be suitable for wet surroundings and therefore suitable for paludiculture. Wellink has demonstrated at multiple sites (estimated approximately 15 sites) that this machine works well for harvesting paludiculture, including in Helmond on the 2nd of November 2021 (Int. Fritz; Int. Wellink).

> *''The machine has a non-suction technique. Amphibians and reptiles stay put. That's a happy coincidence because it was first used for nature. That's the low-hanging fruit that comes with the machine. Normally we mow 5-10 cm above the ground. This can be controlled from the cabin. We ride on a caterpillar track for low ground pressure. Instead of 300g/cm^3 it is 100g/cm^3 (of pressure). The damage to the soil is minimal and after a while you have no traces of driving. At first you drive it a bit flat, but a month later there is little to see. Everything is collected in the back of a container. This is done in 1 working step.'' – Int. Robert Wellink*

Firstly, by using caterpillar tracks the machine minimizes the pressure exerted on the ground by spreading the weight of the machine. The effect is a small trace of the machine with tracks fading within a month. Secondly, Wellink explains that the cutter bar can easily be adjusted to a different level to ensure that the plant is cut off above the water level to prevent rotting. And finally, by not using suction the machine also limits its impact on the biodiversity. As stated, this is a happy coincidence because the machine was originally developed for nature areas. Wellink later adds that the machine chops the cattails into smaller pieces to then collect in the container. This is confirmed by Neubert (Int. Neubert & Wichmann).

Wellink expressed his aim to test the machine in different seasons, as now the majority of the demonstrations have been in the winter.

> *''The (seasonal) time of harvesting is the biggest adjustment for the machine. The differences between sites are small, but there is much more difference in time (autumn, summer, etc.). It is seasonal. Age of the plant, temperature, structure, undergrowth and how wet it is. You have to test to gain experience. (To make it more efficient) you need bigger machines. We are now working on the Radboud to develop a machine with a lot of capacity.'' – Int. Robert Wellink*

Therefore, more knowledge could be gained by testing in different seasons to better understand how the machine might need to be adapted. Furthermore, to increase the efficiency Wellink is currently working with the Radboud University. There are other possible points of improvement, such as the tracks currently being wider than the cutter bar, causing cattails at the sides of the machine to be flattened (Int. Estate Groot Overbrugge). Also, Wellink is interested in developing a way to bundle the cattails instead of chopping as this could allow the cattails to be used for different purposes. Yet, the demonstrations have proven this is a successful way to harvest the cattails mechanically in a single day's work.

Overall, the continued development and perfectioning of these machines can increase the efficiency of harvesting cattails. Already, harvesting 1 ha can easily be done in a single day. The question of finances still remains, as such as specialised machine is now not widely available and is expensive to buy. This issue will be further elaborated upon in F. To conclude, tailored planting equipment has not been developed, with manual labour and old strawberry plants used as alternatives, and harvesting is now quite successfully carried out with tailored machinery from Wellink Equipment.

Annex J: Temporal dimensions results elaborated

This annex includes the specific quotes used to support the text in the temporal dimension.

Field preparation delays

In multiple pilot sites, delays were experienced during the preparation of the plot for different reasons (Int. Balkema; Int. Geurts; Int. Neubert & Wichmann). In Helmond, delays were caused due to a different plot being selected by the Estate Groot Overbrugge, thereby causing sowing to be delayed until September. The original plot was not as wet and had a less high peat content. The newly selected plot was bought by the estate from their neighbours, but this caused a couple of months delay (Int. Estate Groot Overbrugge; Int. Geurts). Geurts elaborates on this and additional delays in Helmond.

> *''Organising the pilot took a long time from November (2018) to planting the following year in September (2019). This was due to a wet spring that prevented machines from entering the site to prepare the site. The preparation also included levelling the field so that the water stays in the cattail field and does not sit in a corner. This meant that the planting was rather late as the plot was not ready until the end of August.'' – Int. Jeroen Geurts*

Thus, the wet spring also caused a delay in field preparations as heavy machinery used to level te field and to install the sub-irrigation system would sink into the wet soil. An additional reason for delays can be the time needed to create the suitable water management system including dikes (Int. Egas). Furthermore, the application for permits also caused delays in Vinkerveen and for the Greifswald plot (Int. Egas; Int. Neubert & Wichmann).

An additional more unexpected reason for delays in the pilot plot in the area of water board de Dommel were the presence of invasive non-native plants.

> *''At the fourth location, the process is delayed by invasive plant species. In river restoration projects, province, and water authorities, buy land in the project area this can take several years. In this case land bought was infected with Tuber Cyperus an invasive weed. To avoid spreading, treatment of this weed is required prior to any project activity or agricultural use.'' – Annelies Balkema*

Before being allowed to use the land, the invasive species must be removed completely. Using land which is now useless could potentially be interesting for paludiculture. Yet, these lands are often covered which such species costing time and funds, adding an additional threshold to paludiculture (Int. Balkema). Therefore, time is not only needed for purchasing the ground, but also preparation of additional factors which might not have been considered before.

Optimal planting time

Despite most pilot sites having sowed between end June and September due to delays ranging from one to 3 months, experts agree that the planting of cattails is most successful between April and July (Int. Egas; Int. Koot; Int. Visscher).

> *''The best time to plant is late April to early July. It is sometimes possible in March if you have a weak winter, but it is not possible if the ground is frozen. It doesn't grow that fast when it's cold. It is best if you do it in then (April/July) because that is when the root grows the fastest. Biest-Houtakker did plant in the fall, but with a larger plant because then it was no longer possible with plugs. Then they kept the water low all winter and they took off well.'' – Kees Koot*

Therefore, the cattails need a minimal temperature in order for the roots to grow faster. In case the planting is done in the fall, as in Biest-Houtakker, larger plugs are necessary in order for them to survive in combination with more particular water management.

According to Egas and Kemp, the optimal planting time is in May (Int. Egas; Int. Kemp). Egas adds that for Zegveld this is the best timing due to the lower presence of geese at that time of year as the young geese have not yet taken flight, which usually happens halfway June (Int. Egas). So, if planting is done on time there is a lower risk of geese feeding on the young shoots before they have had the chance to root.

According to Kemp, the optimal time for sowing is in the first week of June. By sowing at this time, the seeds germinated within 7 days (Int. Kemp). Also, in Helmond the additional sowing was done in the spring. Overall, to increase the potential for success sowing and planting should be done in spring. In both planting and sowing it is important that the water level is at a suitable level and can be raised efficiently at first. It is important to repeat that for a sub-irrigation system, this initial increase in water level just after planting is too slow, and therefore an additional surface pump is temporarily needed (Int. van Duinen).

It is important to consider the interrationalities with other practices which land users or farmers might carry out at this same time of year. For instance, spreading manure across the land or sowing of other crops such as corn. Because these activities have currently been carried out by researchers and not the land users there has not been an issue in time overlap with other on-farm activities. As a result, no clear results were found on potential interrationalities at this point in time. However, in future considerations should be made how cattails fits in the general planning of farmers.

Harvesting time connected to intended cattail product

The harvesting time of cattails is highly dependent on the intended end product (Int. Geurts). If the product must be dried for production, it is harvested in the winter. If the product is used for the fibres, then in the summer. This heading aims to distinguish the pros and cons of harvesting in each season, not to dive in on the end products of cattails. For more explanation on the exact products and their potential, refer to Market. To understand the pros and cons of each season, we will first look at the pros and cons of harvesting in winter and summer.

> *''You must have the right harvest time. In the summer it is green and in September it will die. If you do that, it will be dry in November or December. They all collapse in February. When it storms, they fall over and rot. But then you create more peat on it.'' – Int. Wilco Kemp*

Kemp explains that for dry products, the harvest can be done in November or December. According to Mettrop, this allows all the energy of the plant to be stored in the rhizomes and not to be removed if harvested in winter. This as the rhizomes are not removed from the soil. This is more complex while harvesting in the summer. For harvest in the summer, other products can be created such as threads for weaving materials, decorative furniture, and cattle feed (Int. Egas; Int. Kemp; Int. Pijlman). However, one should not harvest in the summer in the first years as explained by Egas.

> *In the first years you should not harvest while it is blooming, because then the nutrients cannot reach the rhizome. Cattail is not suitable for that, then it cannot stand. You can also let it die itself (so for a harvest in the winter). But then you don't have the water-storing capacity, because then the water has to be removed in the winter. If you harvest in the summer, you interrupt the cycle, so that is bad for the roots. If you want it for construction, then you have to do it before the end of winter. But even then, it is still wet. Coincidentally, the weather was good in March, so we dried it in the field. – Int. Youri Egas*

Egas introduces a dilemma here. In the first year, cattail is too fragile and has too little nutrients and energy stored in the roots in order to re-grow after a harvest. This as in the summer the stems are still green, and energy is used to bloom. However, harvesting in the winter effects the water storage capacity as the field must be drained in winter to harvest. This is also most likely the time one would like to inundate the field to deal with potential flooding. Therefore, this would affect the climate adaptive purpose as explained earlier. Therefore, there is a potential mismatch between the purpose of cattails for climate adaptivity and the use as dry product.

If the harvest is done in the summer, more nutrients are removed with the harvest of the crop in comparison to harvesting in the winter. However, in both cases nutrients are removed, thereby affecting the potential for consistent biomass production each year (Int. Egas). In usual agricultural practices, this issue is solved by adding nutrients in the form of manure or fertiliser. However, as stated, one cannot apply fertiliser on a wet surface due to water contamination. This is commonly known as slurry.

For more information on specific examples of harvesting and the effect on future biomass refer to the recent end report by Better Wetter (Mettrop, 2021). In this report, the speculation is made that it should be possible to harvest twice per year, each for its own intended purpose.

An additional purpose of cattails is harvesting the pollen in summer to feed natural, biologically controlling predatory mites (Int. Geurts). This is a labour-intensive task for two weeks but does not require the cattails to be harvested itself. Therefore, the issue of removing nutrients and energy from the plant is not relevant in this case. To conclude, care must be taken in selecting the end product in relation to the purpose of cattails, as these have the potential to contradict each other. Additionally, one should consider the effect of the seasonality of the harvest to the long-term biomass production.

Continuous biomass production

Another question which must be addressed is the question whether cattails can continue producing the same biomass each year? This questions the sustainability of the practice and production. As stated in the previous chapter, most cultivations use fertiliser to ensure the crop receives sufficient nutrients, but in this case is not allowed (Int. Egas). However, if fertiliser cannot be added, then does cattails continue to produce a consistent biomass year after year? In the pilot sites, it seems that the ground does become ‘tired’, and biomass reduces (Int. Kemp; Int. Pijlman).

> *‘’Paludiculture with Cattail (Typha latifolia) seems to have a dilemma. The more you aim for high production, the more nutrients you need and a water level above surface is required to be maintained. But this can lead to more methane and nutrient rich water, at the cost of ecosystem services. … Cattail had a clear nutrient response; reed had that less in our experiments. In a former peat meadow, there has always been peat decomposition, and the soils do contain nutrients from historic fertilisation, but the question is whether it is enough for long term Cattail cultivation.’’ – Int. Jeroen Pijlman*

Pijlman introduces the dilemma whether the main goal is production or ecosystem services. If the aim is to have high production, then the water level must be high creating thicker stems and fertiliser must be added (Int. Egas). Egas also confirms from his own experiments in Zegveld that cattails positively respond to nutrients. Therefore, the perennial nature of cattails is up for discussion due to legal restrictions to prevent slurry.

Drying time

An additional temporal factor which should be considered is the time needed to dry the cattails if the intended end product requires this. For example, insulation or building material. This is particularly challenging due to the natural structure and gelatin-like contents (Int. Egas).

> *‘’It doesn't even dry easily. When you open it, there is some kind of slime in it. That doesn't dry at all. Also, that slime is still frozen in the winter and only thaws when it is warmer.’’ – Int. Youri Egas*

Therefore, the seasonality of harvest, which for dry materials is necessary in winter, also does not help this drying process as the inside of the plant is frozen and stays frozen for a long time. At the pilot site in Ankerveen Kemp confirms this with his own experiences.

> *''It is about 5 cm thick and inside there is ice. That ice block survived until the end of May. That shows how insulating it (cattails) is. It only melted because of the warm rain in May.'' – Int. Wilco Kemp*

Therefore, drying naturally can take up to half a year. Consequently, production needs to consider extra time in between harvesting and processing because of the time needed to dry if done naturally in the field. Drying could be sped up if brought to a factory to store and dry. However, this does require additional energy but still could be considered (Int. Egas; Int. Weerman).

Labour

It is important to also consider the labour time and effort necessary for cattail cultivation, also compared to other practices carried out by possible users. An impression of the labour needed has already been given in section 5.2.2. Materials. Firstly, extensive labour input is necessary in the preparation of the field and time to design the water management system (Int. Geurts). Secondly, due to the lack of suitable machinery much manual labour is needed to plant the plugs. This is a significant time investment. For the 1 ha of cattails in Helmond it took 3 or 4 days with 4 workers to plant the full plot (Int. Visscher). For the pilot site in Soerendonk, Koot had a similar experience having 5 workers for 2 or 3 days for 1 ha. If efficient machines are developed this could be an issue that could be solved. Until then this is a significant time investment, in particular compared to previous land use.

Many of the sites currently used for cattails pilots were originally grassland (Int. Estate Groot Overbrugge; Int. Kemp). Time needed to sow a hectare of grass can be done in a single day (Int. Egas). Therefore, to convince a farmer of investing in cattails is also a higher time investment, especially in the starting phase of the crop. From that point on, the time investment in minimal. Kemp compares this to his main practice dairy farming.

> *"Well, with a cow you have to work on it twice a day. ... I don't need much time for cattails. Only harvesting once per year. … But I don't spend an hour a week on it now." – Int. Wilco Kemp*

Therefore, the time and labour spent on field management is minimal, only requiring a single check per day of the water level which is many cases can be done remotely with a remote sensing system (Int. Estate Groot Overbrugge; Int. Neubert & Wichmann). The planting stage can also be reduced in time if sowing becomes more successful, as then the seeds can be spread similar to grass seeds. However, this is not yet fully developed and to soak the seeds in order to reduce the chance of them floating also takes time (Int. Kemp; Int. Mettrop).

> *''Soaking cattail seeds is still quite a job. You really have to break the cigars into 10 pieces otherwise they will float, and then you have to submerge (the cigars) with a rake (under water). This is not surprising because they are water resistant. But sowing is much faster, so you compensate for this a 100 times compared to planting (plugs). – Int. Wilco Kemp*

Therefore, the trade-off of labour to soak the seeds outweighs the labour needed to plant plugs. However, water management for paludiculture, even though not labour intensive, is more time intensive compared to grassland (Int. Westerhof). This as it must be checked every day. The final part of the cultivation, harvesting, requires less labour than planting as tailored machines have been developed, as described in Machinery & equipment. Therefore, a threshold in the temporal dimension is the time necessary for planting, in particular compared to the low maintenance and planting of grassland. Unless this becomes financially viable, this high labour intensity is not worth the time (Int. Westerhof).

Annex K: Spatial dimension results elaborated

This annex includes the specific quotes used to support the text in the spatial dimension.

Crop rotation

The first factor to be addressed is the inability for crop rotation (Int. Westerhof). Crop rotation is the practice of cultivating different crops sequentially on the same plot (Hijbeek et al., 2018). By carrying out crop rotation, one can increase the soil organic matter (SOM) to increase soil fertility (Hijbeek et al., 2018). This has a positive effect on crop productivity. Therefore, especially in arable farming, crop rotation is a common practice. Paludiculture inhibits the potential for crop rotation, as not many crops can cope with high water levels (Int. van Duinen; Int. Elshof; Int. Westerhof). Additionally, once the water management system has been created to sustain continued field inundation and the ground has been dug out, it is more difficult to use for anything other than paludiculture.

> *''You lack a certain flexibility with paludiculture; you can't easily put up something else.'' – Int. Roelof Westerhof*
>
> *''Switching from paludiculture to carrots is not easily possible anymore, so it is a major change.''- Int. Gert-Jan van Duinen*

Westerhof refers to this as a lack of flexibility and van Duinen describes it as a major change. Therefore, both recognise the drastic change paludiculture requires. However, the ability to go back to the original situation is a value which Elshof, an advocate of agriculture for ZLTO, believes is important for farmers.

> *''... and that it can go back to the old situation. Imagine, your soil has to be excavated, so you can't do anything with that hole afterwards.'' – Int. Johan Elshof*

Elshof refers to the plot becoming a hole, thereby inhibiting the ability to go back to your old practices if the production is not successful. Additionally, some paludiculture crops could be difficult to remove after production. For instance, reed makes deep roots, making excavation of the crop challenging and time consuming (Int. van de Belt). Overall, this means that, once the decision has been made to cultivate paludiculture crops such as cattails, it is a higher commitment compared to other (arable) practices. Therefore, the dedicated hectares also mean fewer flexible hectares for other practices.

Drying space

Another spatial challenge lies in the need for drying space for the cattail if these want to be used for dry materials such as insulation. This is particularly complex due to the height of the plant which can reach up to 2 meters tall (Deelexpeditie Natte Teelten, 2020). This potential issue was discussed in particular by Egas:

> *''But you also actually need the same surface (as the plot size) to dry it, and you don't want to use more energy to dry it. That field is completely full. I can imagine that you still need the same surface area because they are 1.5 meters high. Or you have to stack them, but then still they have to dry. Or you have to put them upright, but that will probably be manual work.'' – Int. Youri Egas*

Egas addresses multiple issues in this statement. Firstly, this is only an issue if the processing of cattails requires it to be dried beforehand. Therefore, this is an issue in particular for insulation and building material which must be dried completely before processing. Secondly, the plot is densely filled with cattails, meaning than the field is filled in both the horizontal and vertical direction. He even estimates that the same amount of space is needed for drying as for the production itself (if done naturally on site and laid out flat on the ground). This would require cattails production to have 1 ha of wetted area and 1 ha of dry ground where the harvested crop can be laid out to dry. This raises the question whether a bundling method is necessary, and if so, how would the cattails be bundled? Perhaps this would look similar to how reed is traditionally bundled (Figure 20) (RTV Oost, 2021).

However, this might need to be done manually, unless possible to develop a machine which can bundle the product (Int. Wellink). But even then, the naturally insulating material and slimy consistency of the crop means that drying the crop in any stacked method is very difficult and time consuming (as described in 5.3.1. Temporal dimension). Finally, if the conclusion is that it takes up too much space and time in natural conditions, then additional energy is necessary to dry the product and to move the product to a drying location. Weerman confirms this as well.

Figure 20. Reed stacked to dry (RTV Oost, 2021)

> *'' Currently, you need a lot of storage space for the Typha and to transport it from the agricultural site to a storage space is not a sustainable way of creating a biobased economy. If storage and biobased material sites are close to the agricultural sites, you can create a local supply chain.'' – Int. Ellen Weerman*

Therefore, it is not only the necessary energy requirements, but also the practical implications of transporting such volumes. Additionally, if the goal is to create carbon neutral products, then adding energy to the process defeats this purpose (Int. Egas). Overall, this means that the spatial (and temporal) dimension of drying the crop must be considered with care when potentially implementing cattail cultivation on a wider scale.

Dairy farming

Cattails can be a practice which is integrated into a routine of other practices. One such practice is dairy farming. Especially in a peat meadow area, as discussed in the following chapter, dairy farming is a common practice, allowing the cattle to graze on grassland. However, if (part of) the grassland becomes too wet, then an alternative practice could be cattail cultivation (Int. Pijlman).

> *''How are you supposed to compete with a dairy farm? It could be a combination (of cattails and dairy farming). A farmer in Zegveld might say that their furthest land can be for cattails because this is the furthest for the cows to walk. And then possibly sell part of your herd.'' – Int. Wilco Kemp*

Kemp addresses the possibility for combining cattails with dairy farming, as he himself also does (Int. Kemp). The most practical location in combination for the practice of dairy farming is to then pick a piece of land which is already far out for the cattle. In this way, it minimalizes the change in farm plan. However, the plot must still be suitable for paludiculture with peat soils and at a low elevation in the landscape (Int. Geurts). Furthermore, cattails can be used as cattle feed to substitute for the loss of grass (Int. Pijlman). For more information of the nutrient values of cattails as cattle feed, refer to the findings of the 'Veen Voer Verder' which took place between 2015 and 2019 in Zegveld (Bestman et al., 2019).

Cattails could be combined with the practice of dairy farming to provide an alternative for grassland which becomes too wet, allowing it also to be used as cattle feed. However, this does raise the question where manure must be deposited? If we assume that the change in this situation is from grassland to paludiculture with cattails, then part of a dry plot becomes wet and therefore can no longer be fertilised. This means that land on which previously manure could be deposited can now no longer be used for that purpose (Int. Geurts; Int. Kemp; Int. Pijlman; Int. Westerhof).

> *''There is a suspicion that there may be a problem with manure. If land is converted to wet crops, you can no longer add fertiliser. This means that there may be a manure surplus if the farmer chooses to keep their cows anyway. Usually this would be added to grassland. ... It is a change in the usual practice. Farmers could have problems with their manure, even if cattails can be used instead of grass to feed cows. Therefore, existing practices need to change if you look at the proposed agricultural transition. – Int. Jeroen Geurts*

As Geurts states, this is mainly an issue if the farmer choses to keep the same number of cows instead of choosing for extensification of their farm. However, if this is not the case then the extra manure must be spread across other land, which might not always be available, or to have to transport the excess elsewhere (Int. Westerhof). This is an additional investment which would make cattail less financially feasible (Int. Westerhof).

To conclude, paludiculture with cattails has the potential to fit in as an additional practice with dairy farming. This can be explained by the flexible purpose as cattle feed when harvested in summer. Care must be taken in this case due to the additional nutrients removed due to a summer harvest. However, if implemented on a larger scale, it would mean that farms most likely must reduce the number of cattle due to the reduced availability of land on which manure can be disposed. Therefore, dairy farms will most likely only invest in paludiculture if the grassland is so unusable that this becomes the only viable alternative.

Neighbouring plots

Due to the nature of paludiculture, it requires a high water level, often above ground. Therefore, the effect of increased water levels is often not only limited to the dedicated plot itself, but also on the neighbouring plots.

> *''For a successful pilot, you need a very steerable plot. And neighbours who also approve of this because water levels know no boundaries.'' – Int. Hilke van den Elsen*

Van den Elsen immediately recognises the potential impact of the adapted water management system on the neighbours of the paludiculture plots. In a situation where the neighbouring plots are managed or owned by the same farmers, then the potential effect on neighbouring plots is for themselves. However, in some cases other land users might be affected as the water level will decrease gradually from the plot, not strictly following a stoic man-made boundary. In Helmond, these effects are minimal due to the plot naturally being located at the deepest point in the area as well as a ditch being located directly alongside the plot (Int. van Duinen; Int. Estate Groot Overbrugge). Additionally, the neighbours are mostly 'hobby farmers', mostly having horses on their land (Int. Estate Groot Overbrugge). Therefore, the potential effects of increased water levels in this plot are not felt due to the minimal agricultural activity of the direct neighbours. Furthermore, the effects are minimalised due to the use of sub-irrigation (Int. de Graaf). De Graaf estimated that within 7-8 meters the water levels could be back to normal.

Other pilot sites also did not have to consider this issue for other reasons. In Friesland, the cattails plot of Bouwgroep Dijkstra Draisma does not affect any neighbours due to the presence of a large flood dike next to the plot (Int. Verboom). The pilot site in Soerendonk also did not have this challenge, as the neighbouring land is a wet nature area (Int. Koot). In the Greifswald plot, this effect was considered due to the surroundings being grassland and crops.

'' We hope as little as possible due to the ditches around the pilot site to catch seepage water and prevent neighbouring grassland from becoming to wet for conventional farming. However, the main impact was during the construction of the site where vehicles had to cross the grassland every day and damaged vegetation. Because part of the grassland thus became a temporal access road the landowner (the same as for the pilot land) had to reduce the land area size for which he applied for CAP subsidies. In case the authorities would conduct a check, there would otherwise by a high risk of sanctions for the whole farm. This had rather little effect in this case but could have been more difficult if the landowner had been a different farmer.'' – Int. Sabine Wichmann

Therefore, the created ditches are the main method to limit the impact on the surroundings. However, Wichmann does explain that there was an impact on the neighbouring plot due to construction vehicles needed to prepare the field for paludiculture. It was necessary to create a road in order to get to the pilot site. The plot used for this was of the same landowner as the pilot plot, meaning this was not made into a large issue. However, the route to get to the location should be considered especially if this impacts neighbouring landowners.

It is important to note that this issue would be less relevant if the decision was made to increase the water level for an entire area, for instance, increasing the water level in part of the peat meadows (Int. Fritz; Int. de Graaf). The potential factors relating to this are considered in the next chapter. An additional issue for neighbouring plots which is not related to the water level is the spreading of seeds. Visscher expects that neighbouring plots might also suffer from the spread of cattail. Once the cattail is settled, the cigars start spreading their seeds in the wind (Int. Visscher). This means cattails might start to grow outside its intended boundary. However, there was little evidence in the research to make a conclusive statement. Overall, the effect on neighbouring plots should be considered, especially in relation to the increase in water level.

Landscape type

As introduced in Diverging goals the purpose of paludiculture is also connected to the landscape in which it takes place. In peat meadows it is more likely that the aim is to prevent land subsidence, while in a stream valley it is more likely to be used for ecosystem services and climate adaptation of the water management system. Therefore, there is a spatial interrationality to the purpose of paludiculture (Int. Pronk). However, in projects often one area is taken as main point, especially in policy. In the Veenweide Programma (ENG: Peat meadow Programme) this was a conscious decision to focus on the peat meadows (Int. van Naarden & Pronk). This was done in particular to create one clear narrative to match the Climate Programme of the Dutch government, which focusses on the large scale reduction of GHG. And also, to prevent overlap with local initiatives by more local government institutions.

''In addition, the department of nature, the water boards and the province are already working on rewetting stream valleys, often from a nature point of view. For example, (water board) de Dommel. That is why we have chosen to work from one perspective in the Veenweide Programme, on coastal plain peat bogs (peat below 1 meter NAP) (ENG: Peat meadow programme).'' – Int. Chris van Naarden

Therefore, the stream valley setting is often associated more with nature initiatives which are more often take a regional approach. It is important to note that GHG reduction is also applicable in stream valleys as it also inundates peat but in a different landscape in smaller patches (Int. van Duinen). These smaller patches are less attractive to take as main focus point for large scale projects. This as stream valleys are a more fractured landscapes, creating more complex and unique cases with less uniform water management compared to peat meadow area (Int. van Lamoen).

''Stream valleys are different from peat meadow areas. In a polder it is normal to regulate the level. There are also plots here (in Brabant), but they are more fragmented. It therefore takes more effort to set up by the stream. It's not hardcore technical water management.'' – Int. Frank van Lamoen

Therefore, it is more complex to development production oriented paludiculture cultivation in stream valleys as the plots are more fragmented and because of the less intensified form of water management. For these reasons, many experts believe peat meadows have the higher potential for paludiculture (Int. Egas; Int. Fritz; Int. Kemp; Int. Pijlman). This can also explain the spatial interrationality stream valleys and paludiculture appear to have with the streams. Van Lamoen explained how the stream valleys in Brabant were adapted to suit agriculture after the World War II, but that climate change has pushed for change (Int. van Lamoen). Now, the water plans indicate more land around the streams will be used as overflow.

''In the water plans there are a number of overflow areas around the stream, often meadows. You can also make it permanently wet, for example a kind of frame.'' – Int. Frank van Lamoen

Van Lamoen suggests that these areas next to the streams are most interesting to consider for paludiculture. Balkema agrees, seeing paludiculture potentially on the streambanks (Int. Balkema). Weerman adds the potential to use paludiculture as transition zones as added value for nature, thereby also suggesting a spatial interrationality between paludiculture in stream valleys and wet nature (Int. Weerman).

If we compare this to a peat meadow setting, the spatial interrationality with dairy farming is interesting. As explained earlier in this chapter, in a peat meadow setting it is most likely that grassland would be the first option for paludiculture, with the condition that there is a revenue model (Int. Kemp; Int. Pijlman). This also because this has a lower economic value compared to arable farming and horticulture (Int. Kemp). However, if it were to be the case that a larger area of peat meadow is flooded, so not just one part of a dairy farm for instance, is this possible? Westerhof expresses his own doubts based on a consultancy report made for the water boards.

'' If you rewet peat soils by raising ground water levels, you will reduce the water storage capacity for intense rainfall. And there is a huge water demand for water supply in summer. ... So, you then come up with the question, should you supply water or find a way to retain it in some way? And what is the effect on the adjacent land, including urban areas, for example? Water boards are, understandably, reluctant to increase risk of flooding.'' – Int. Roelof Westerhof

In this quote, Westerhof speculates the feasibility of large scale paludiculture in the peat meadows of the Netherlands. Not only because of the effects on neighbouring land and urban areas, but also because of the technical feasibility of flooding the land. Furthermore, there is a significant water requirement to flood the land. Additionally, for water boards it is complex to create areas which are flooded. Therefore, the feasibility in peat meadows is also not as simple as one might expect of the uniform landscape.

To conclude, peat meadows and stream valleys both have a clear spatial interrationality with their purpose. Additionally, paludiculture on a large scale is highly complex in both settings due to necessity for water also in the summer months. Therefore, paludiculture is most likely in very specific areas with the right water availability, peat content, elevation, and neighbours. These areas are most likely already wet by nature and perhaps located on the edge of wet nature areas making drainage no longer an option. Overall, perhaps van Lamoen summarised it best.

''Cattails are not a silver bullet. These will be fairly specific locations.'' – Int. Frank van Lamoen

Annex L: Social dimension SNA maps

To see the exact connections between the organisations, it is easier for the reader to see them on a full page. Therefore, the following networks have been enlarged for the comfort of the reader. In all figures, the edges indicate 'to' which actor or organisation. For the analysis, please refer to the main text.

Knowledge-sharing network (figure 14 enlarged)

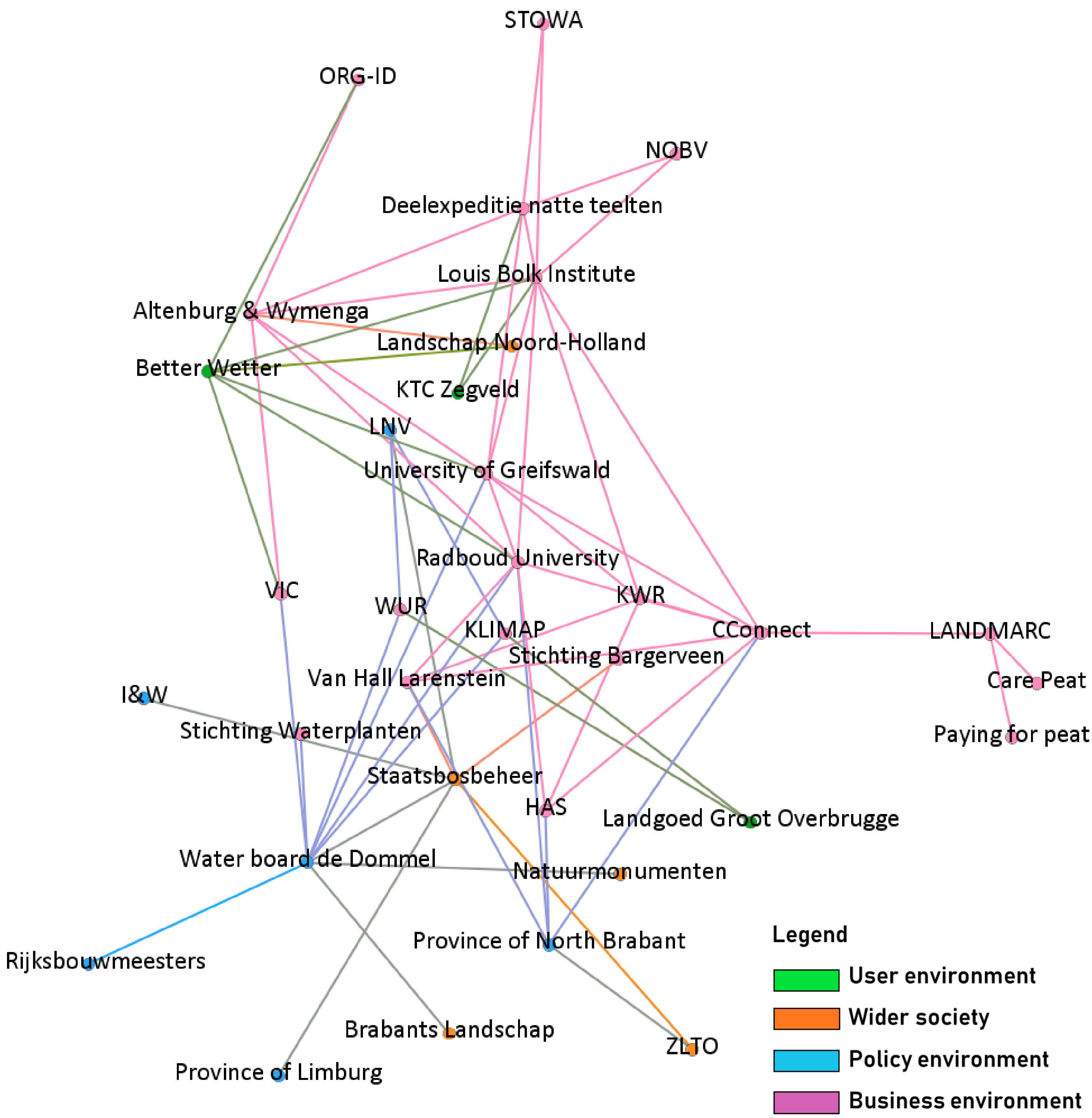

Figure 14. Knowledge-sharing network. The edges indicate 'to' which actor or organisation.

Promoting network (figure 15 enlarged)

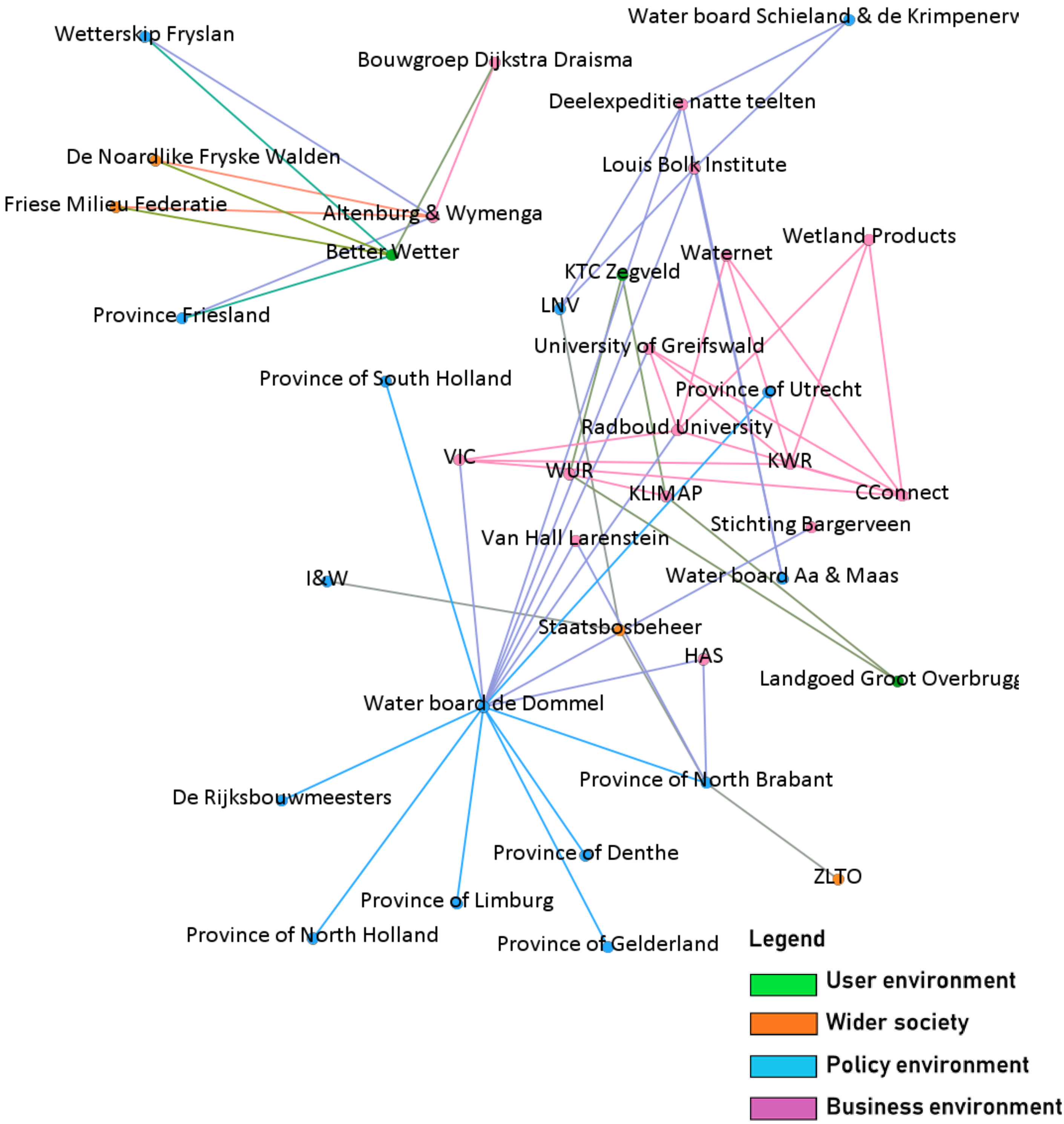

Figure 15. Promoting network based on SNA results. The edges indicate 'to' which actor or organisation.

Dependency network (figure 16 enlarged)

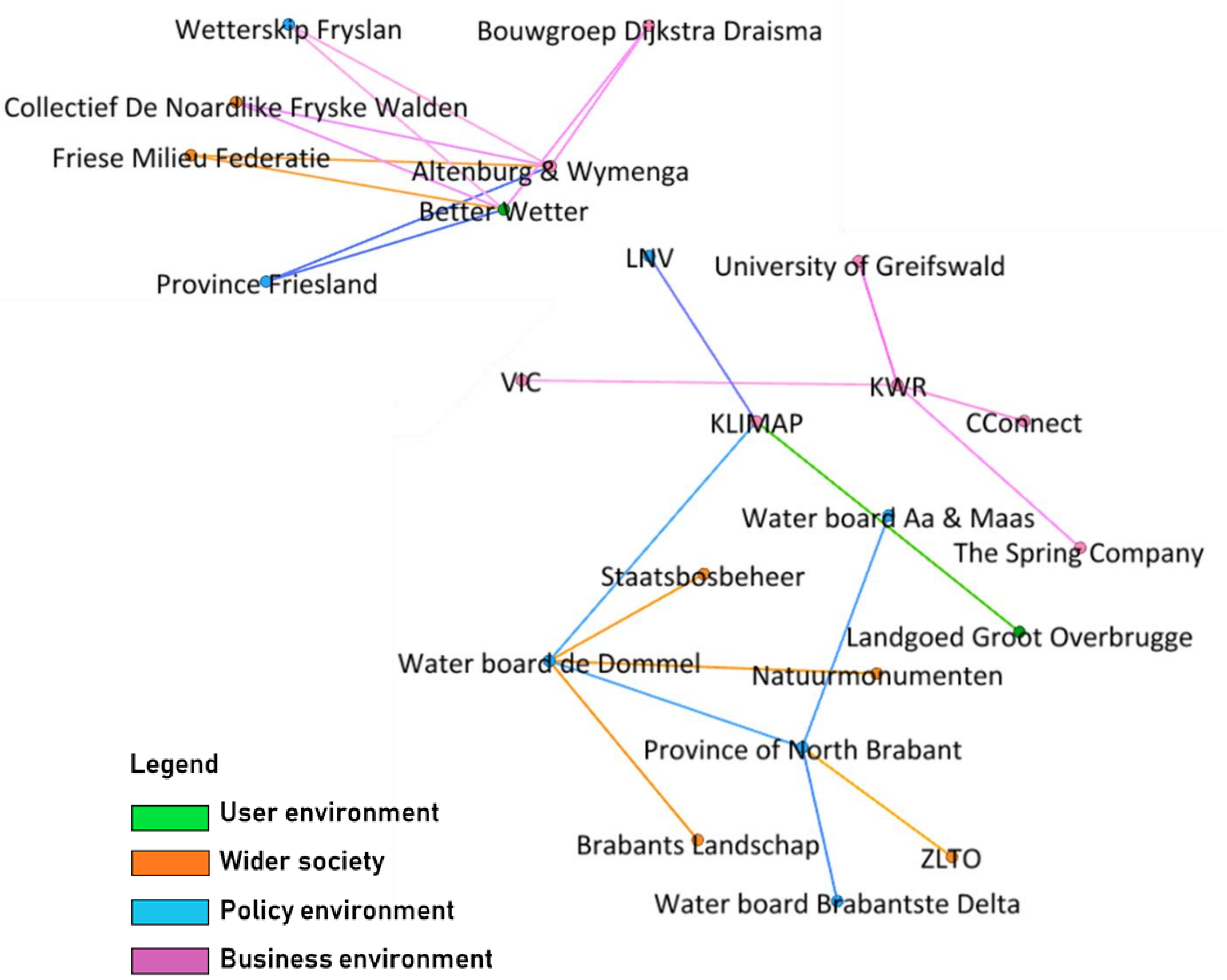

Figure 16. Dependency network based on SNA results. The edges indicate 'to' which actor or organisation.

Annex M: Policy influencers SNA map

To see the exact connections between the organisations, it is easier for the reader to see them on a full page. Therefore, the following network has been enlarged for the comfort of the reader. In the figure the edges indicate 'to' which actor or organisation. For the analysis, please refer to the main text.

Policy network (figure 17 enlarged)

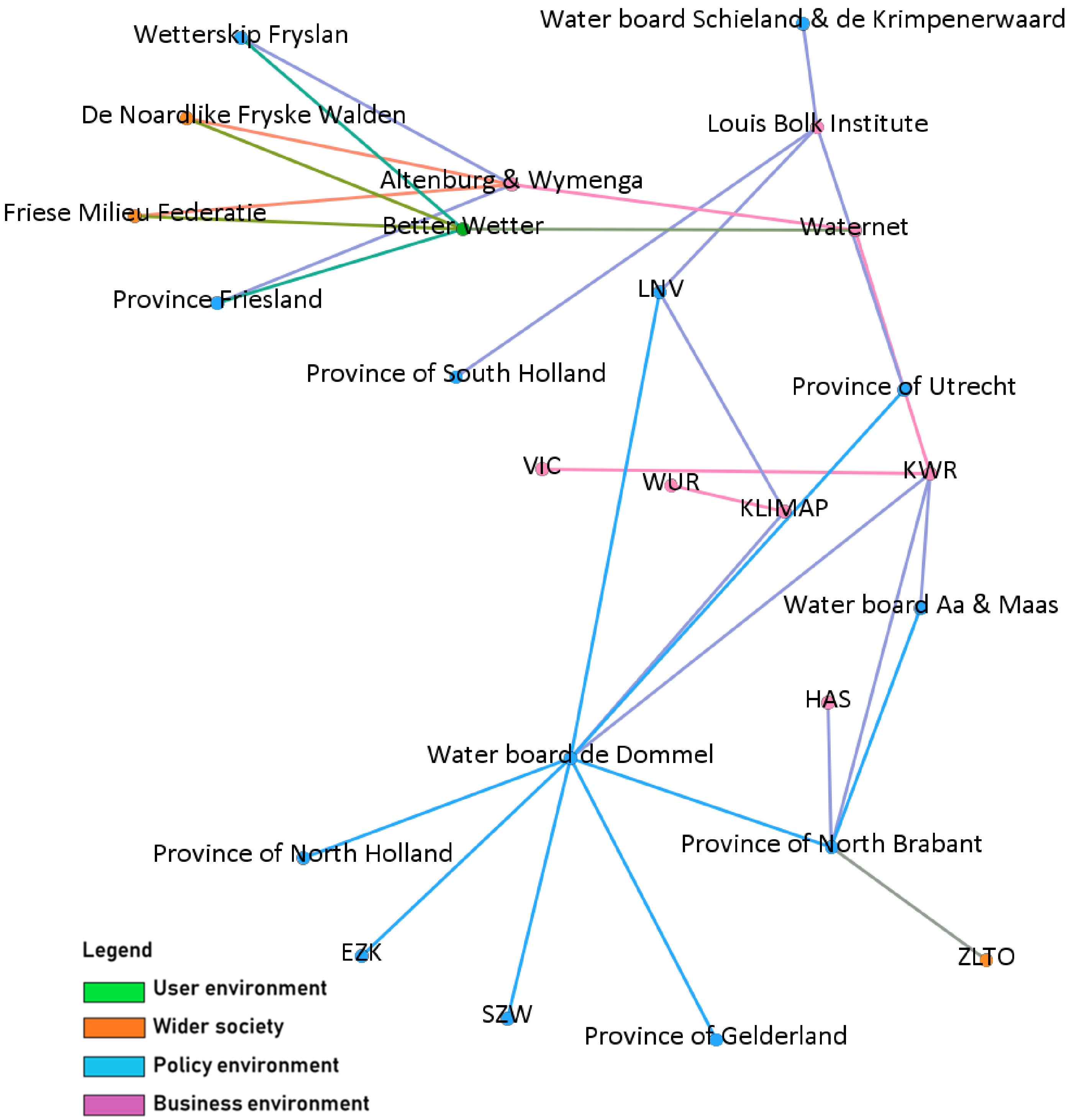

Figure 17. Policy network based on SNA results. The edges indicate 'to' which actor or organisation.

Annex N: Full results overview

Figure 21 is a compilation of the headings of the results chapter.

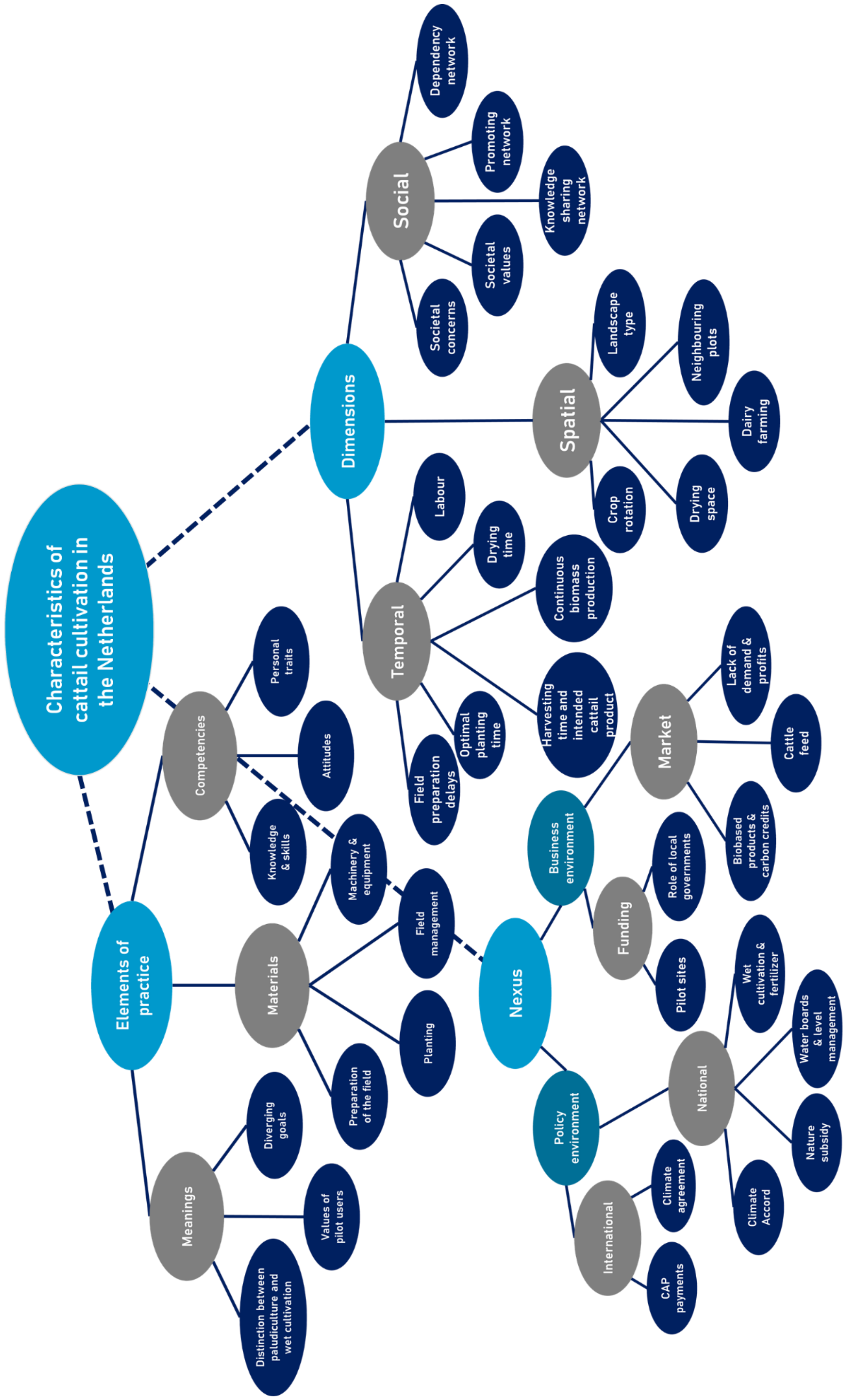

Figure 21. Results chapter overview.